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**TECHNIQUES, TACTICS AND STRATEGIES
FOR CONCEPTUAL CHANGE
IN SCHOOL SCIENCE**

by

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Thesis submitted

for the Degree of Doctor of Philosophy

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List of abbreviations and symbols

EMT	– Expert Micro-teaching (section 3.4.1)
VP	– Verbal Protocol (section 3.4.2)
RD	– Retrospective Debriefing (section 3.4.3)
In bold	– participant teacher speaking
JR:	– researcher speaking
<i>In italic</i>	– video recording being played to participant teacher during VP interview
...	– short pause
[...]	– section removed from transcript (for a full transcript please see appendix E)

Word count: 259,022 [92,399 excluding appendices]

Abstract

This study explores how experienced science teachers promote conceptual change. It examines how instructional strategies, learning methods (Darden, 1991) and conceptual change interrelate.

Three research methods (expert micro-teaching, verbal protocols and retrospective debriefing) were used. Data were video-recorded and managed using NVivo. Six groups of 11 year-old pupils took part (three girls and three boys) in each expert micro-teaching interview, led by a science specialist (Advanced Skills Teacher). A 'Concurrent Verbal Protocol and Retrospective Debriefing' interview (Taylor and Dionne, 2000) happened with the teacher approximately one month later. Six teachers participated altogether. About fifteen hours of interview data were analysed using grounded theory methods. The interpretivist theoretical perspective (symbolic interactionism) was underpinned by a social constructionist epistemology.

What can be considered evidence is inevitably affected by the researcher's methodological position. So what constitutes reliable evidence can be contentious. Appropriate criteria for evaluating the grounded theory emerging from this study were used. Interpretivist approaches for investigating conceptual change in school science are necessary to avoid dominance by positivist literature. This approach, proved successful in other fields (Pressley, 2000), is new to this context. The assumption that instructional strategy is a plan does not adequately explain the data collected here. However, abandoning attempts to unpick complicated interactions between pupils and teacher whilst learning takes place, leaves practitioners without guidance. Consensus exists among most conceptual change researchers that instructional strategies, learning methods and conceptual change must be considered together where possible. This present study proposes a grounded theory for how experienced science teachers promote conceptual change and questions how instructional strategy is understood in the literature.

Findings show that during and between sporadic periods of 'conceptual conflict' participants used eleven 'teaching and learning techniques'. The relative weight given to each technique was termed the 'strategic profile' of the teacher. 'Tactics' is the theory of the use of teaching and learning techniques in conceptual combat. 'Strategy' is the theory of the use of such conceptual combats to try to achieve an aim (here to promote conceptual change). Teachers (and pupils) demonstrated and described tactical and strategic behaviour. Techniques, tactics and strategies frequently failed. How participants managed such 'friction' was described. Teachers and researchers view classroom dynamics from different perspectives. This study argues that an interpretivist approach, which moves back and forth between the particular and the general, can help bridge the "gap" between practice and theory in this field (Duit et al., 2008, p.629).

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Chapter 1: Introduction

1.0 Research Questions

1. How do experienced science teachers interact with small groups of children, when the pupils express and discuss naïve scientific concepts?
2. How do the ways in which instructional strategy is understood within the conceptual change research community compare with the practice of experienced science teachers? Is the integrated approach to conceptual change useful for understanding relationships between instructional strategy, learners' reasoning methods and conceptual change?

The research questions arose from my concern, as an experienced secondary school science teacher, to understand how best to support children when they express naïve concepts in my lessons. This is an example of what Glaser (1992, p.25) called an emergent research problem, a characteristic of grounded theory, which is the methodology used in this study (chapter 3). Grounded theory studies always start with broad open questions, and research questions do not direct a grounded theory study in the same way as they do experiments in the natural sciences (Corbin and Strauss, 2008, p. 25). Grounded theory methodology, as will be explained in section 3.11, uses a set of procedures out of which emerges what is called a 'grounded theory' (Birks and Mills, 2011, p. 5).

The interesting aspect of qualitative research is that though a researcher begins a study with a general question, questions arise during the course of the research that are more specific and direct further data collection and analysis. (Corbin and Strauss, 2008, p. 27)

The first research question seeks to engage with primary and secondary school science teachers (chapter 4 - parts 1 and 2) and the second with the conceptual change research

community (chapter 5). As these questions are open-ended and do not involve hypothesis testing they are well-suited to exploration using grounded theory. This methodology is well established, if controversial, so is intelligible to the research community, and it provides justification for the way the data is analysed. A similar methodology has been used successfully to study other aspects of children's thinking (Pressley, 2000; Phang, 2009).

A second impetus was the desire to address, from the perspective of a teacher, the rift between practice and research acknowledged in the literature:

[There] is still a large gap between what is known about effective teaching and learning science from conceptual change perspectives and the reality of instructional practice. Finally, we argue that more research is necessary on how teachers in regular classrooms can become more familiar with the key ideas of conceptual change. (Duit *et al.*, 2008, p.629)

This thesis explores how research into instructional practice and conceptual change research can inform each other. Discoveries by conceptual change researchers, and those who explore instructional strategy, will be discussed in chapter 2. Finally researchers in this field have long called for more work on instructional strategies for conceptual change:

[There is] a danger in ... 'natural history' studies of student ideas... More classroom intervention studies [are necessary] ... studying the effectiveness of various strategies aimed at promoting conceptual change. (Driver and Erickson, 1983)

[S]tudents' prior conceptions across a broad range of science domains are extensively documented in the literature, but consideration now needs to be given as to how this literature is to inform teaching. (Scott, Asoko and Driver, 1991)

[Pintrich] called for more research examining classroom contextual factors in conceptual change (Pintrich, 1999). These studies should examine how patterns of classroom interactions and instructional contexts promote or restrict opportunities for change. (Sinatra, 2005, p. 114)

Hence this work emerged from my concerns as a science teacher, the perception by Duit *et al.* (2008) which I share of a ‘gap’ between practice and research in this field, and the call by a number of researchers over many years for studies which investigate conceptual change strategy.

Conceptual change is not the only difficulty children encounter when learning science. In a study exploring the challenges professional scientists encounter, Allchin (2002 p. 42) identified four types of problem which could equally well be applied to child scientists. Material problems refer to difficulties with the materials or the procedure, observational problems involve methods of perception and data gathering, discursive problems entail communication issues, and conceptual problems. The latter are the focus of this current study. Considerable evidence suggests children hold a wide variety of ideas about the natural world which are at odds with established scientific thinking (Driver *et al.*, 1994; Duit, 2009; Allen, 2010b). ‘Naïve concept’ (a term used by, for example, Inagaki and Hatano, 2002, and Babai and Amsterdamer, 2008, p.553) is one of many phrases used in the literature to refer to children’s ideas which differ from accepted scientific conceptions, and it proved to be useful in interpreting the data collected for this study. This terminology will be explored in more depth in section 2.1.

Teachers and researchers find that some children appear to resist changing their ideas, or relapse into previous ways of understanding, in different ways and for a variety of reasons (Illeris, 2007, p. 157). The phrase ‘conceptual change’ replaced to a large extent the word ‘misconception’ in the literature in the early 1990s (see section 2.2). Recently researchers have found evidence of several different types of conceptual change (Clement, 2008, p. 433) which again proved useful in interpreting the data collected for this study (chapter 4). Many disciplines, such as psychology, epistemology, the philosophy of science and education, contribute to the issue of how best to promote

conceptual change among children. Some aspects of conceptual change research will be described in section 2.2 in order to help position the study within this complicated, and somewhat incoherent, field.

During this study it emerged that children appear to use learning methods, and experienced teachers make use of these methods, which are sometimes similar to those which researchers have identified by investigating the methods used by professional scientists (Darden, 1991), but at times resemble the naïve learning methods which developmental psychologists have identified (Zimmerman, 2005). The issue of whether scientists, young or old, use reasoning methods in their work is controversial and will be discussed in depth in section 2.3.

Researchers do not agree as to the meaning of the word ‘strategy’ (section 2.4). The literature has countless examples of instructional ‘strategies’ based on research findings (for example Borich, 2013), and Hattie’s (2008, p. 162) “meta-meta-analysis” gives an impressive overview of the contributions from quantitative studies. However, the present study argues that understanding the interactions between pupils and teacher when naïve scientific concepts are expressed is not one where hard-and-fast rules can always apply. The thoughts, wills and feelings of participants (children and teacher) collide in unpredictable ways. At the core of this thesis is a question, addressed to both practitioners and the research community, over the meaning of the word ‘strategy’, a word which comes from a Greek word (*stratēgia*) meaning ‘generalship’ (section 2.5). Some practitioners and many researchers use the word strategy to mean ‘a plan’ (for example Scott, Asoko and Driver, 1991 p.1). A plan is a “formulated or organized method by which [some]thing is to be done” (OED). Whilst acknowledging that planning is an important aspect of strategy, what emerged from the present study is a more complicated view where teachers (and pupils) are observed using a variety of techniques in tactical

and strategic ways (chapter 4). The initial intentions of the teacher are modified continuously as a result of the interactions with the pupils. The view prevalent among teachers and conceptual change researchers that a strategy is a plan, could be replaced by the ‘Clausewitzian’ understanding of tactics and strategy that emerged from these data during this study (section 4.4). This debate echoes similar arguments among military strategists (for example Baylis, Wirtz and Gray, 2009) which will be discussed briefly in section 2.5 and business strategists (see Campbell, Edgar and Stonehouse, 2011, p. 2). This study identifies what techniques teachers appeared to use to promote conceptual change, but argues that how such techniques are used in tactical and strategic ways is a vital part of pedagogy.

The study will argue that the way participants understand what they are doing in the complicated social context of a science classroom must be taken into account when analysing behaviour (section 3.0). According to conceptual change researchers (for example Klahr, 2000), the interrelations between instructional strategy, learning methods and conceptual change mean that all these elements must be considered together when trying to understand instructional strategy (section 2.6 and chapter 5). The findings of this present study support this theory, and this thesis argues that the behaviour of teachers when working with pupils is part of the phenomenon being investigated, so participants cannot be considered as independent researchers implementing some experiment. Hence the methodology used in this study seeks to bring together the interpretations of pupils, teacher and researcher as participants, to explain and seek to understand conceptual change pedagogy.

A tension is maintained in this study between idiographic and nomothetic approaches and this study claims that interpretation inherently involves moving

backwards and forwards between the particularity of this complicated social context, and tentative general conclusions.

[Sociology] is a science which attempts the interpretive understanding of social action in order thereby to arrive at a causal explanation of its course and effects. (Weber, 1897, p. 228)

Hence, following Weber, this study adopts an interpretivist theoretical perspective to understand and explain a complicated social context in which learner, teacher and researcher interact (section 3.1). This methodological approach may be seen as a challenge to those using experimental methods to investigate conceptual change strategy (for example Smith, Blakeslee and Anderson, 1993, p.124). Researchers may have inadvertently contributed to the gap they bemoan by the way they conceptualise strategy. Teachers may be unaware of some of the sophisticated ways they already promote conceptual change in the challenging environment of the classroom. This present study holds that a typology of techniques, combined with an exploration of how such techniques can be used tactically and strategically, which emerged from what experienced teachers actually appear to do in classrooms (see Chapter 4) may be more useful for teachers, and in understanding and explaining conceptual change strategy, than one which is used because it has some ostensibly logical structure.

This study examines in considerable detail how six experienced science teachers try to help small groups of 11-year-old children who express many naïve concepts (Chapter 3). This naïve thinking emerges whilst pupils and teacher are discussing the cooling of a cup of tea and the heating of ice cubes, the concepts of ‘living’ and ‘non-living’, and how we see things. A grounded theory of what six practitioners appear to do in this context is described (Chapter 4). The study uses a snapshot of the messy classroom dynamics which many teachers may find familiar, to ask how potential relationships

between instructional strategy, learners' reasoning methods and conceptual change in school science may be interpreted (Chapter 5). This thesis challenges the objectivist epistemological assumptions of contemporary conceptual change researchers and argues for a constructionist approach (section 3.1). The interpretivist theoretical perspective used here proved fruitful in revealing some of the complicated ways experienced teachers use the techniques at their disposal. Synthesizing the interpretations of all the participants in this study has been challenging, and demands clarity as to the role of the researcher. This will be discussed briefly next, and then again in depth in Chapter 6, along with an evaluation of what claims, if any, the theory can make. The overall conclusions of the study are presented in Chapter 7.

1.1 The researcher

I have taught secondary school science (specialising in physics) for the past fifteen years in the UK. For the last four years I have been working part-time in a school for children who have learning difficulties whilst studying full-time for this doctorate. On finishing my teacher training (a Post Graduate Certificate in Education) in 1998 I remember a feeling of frustration that I still did not understand what pedagogy was. Experience in the classroom and my research have led me to conclude that, whatever it is, pedagogy is not a list of what teachers should do written by researchers. I have always enjoyed children's ideas in science and started exploring and writing about children's 'misconceptions' during a part-time taught Masters in educational studies, and the idea to pursue this current investigation emerged towards the end of those studies.

A detailed analysis of how I influenced, or may have affected, the data collection, data analysis and theory generation is given in section 6.1. As mentioned earlier, I consider myself to be a participant in this research and that my interpretation of these data

is one to be presented alongside those of other participants. However I do not think it is possible, or necessary, for me to present the interpretations of all the data of all thirty-six pupils, six teachers and myself giving equal weighting to each participant. For example my research questions led me to prioritise the interpretations of the participant teachers over those of the pupils. Though such a study would have been impossible without so many people taking part, I take responsibility for the conclusions drawn.

1.2 “What’s a stragedy [*sic*]?”

The following is a short extract from a cartoon version of *Peter Pan* (1953) which illustrates tensions between different understandings of strategy very similar to those which are discussed in this thesis.

Peter Pan: Alright men, go out and capture a few Indians.
[The lost boys salute] John, you be the leader.

John: [John salutes] I shall try to be worthy of my post.
[John points his umbrella forward] Forward march! [The lost boys and Michael follow singing a song about ‘Following the leader’] [... John sees large black footprints and stops suddenly] Indians! Ahh, Black Foot tribe. [While John examines the footprints the lost boys immediately build a round fort with a wall and a flag. Their weapons are held ready and they look out in all directions. John remains outside the fort] Belongs to the Algonquian group. Quite savage you know.

Lost boy 1: Let’s go get em! [The lost boys prepare to leave their fort to attack the Indians]

Lost boy 2: Yeh! We’ll get em!

John: Gentlemen! First we must plan our strategy.

Lost boy 1: What’s stragedy [*sic*]?

John: A plan of attack. The initial phase is an encircling movement. Thus. [John uses his umbrella to draw his plan in the sand] (*Peter Pan*, 1953, 32:32)

While John and the lost boys talk, Michael finds a feather in the forest; as he stoops to pick it up an Indian axe is thrown at him which hits the tree where his head had been. Michael takes the axe, puts the feather in his hair and plays at being an Indian. An Indian, disguised as a tree approaches. When Michael realises, he runs to warn the others, who don't listen as they are too busy discussing the strategy (or 'stragedy' [sic]). John, Michael and the lost boys are captured (using an encircling movement) and taken bound to the Indian camp where John learns that this is a game that the lost boys play with the Indians. Sometimes the boys win, sometimes the Indians.

John's theoretical ideas as regards strategy, though well informed as regards the language group the Indians belong to, prove useless in the fight. The lost boys are experienced warriors whose tacit understanding of strategy fails on this occasion possibly because they think that John knows more about this, and perhaps because he has been nominated leader. Another reason that John's 'stragedy' [sic] fails might be because he is unaware of the prior knowledge which the lost boys and the Indians share. This present study will reflect on the relationships between the ways in which the research community conceptualise strategy, the tacit knowledge of teachers as regards conceptual change strategy and the on-going conceptual 'battles' (section 4.1) between pupils and teachers in classrooms.

1.3 Summary

This study explores how experienced science teachers promote conceptual change in children. It challenges how instructional strategy is understood by teachers and in conceptual change research. How this interest emerged was discussed and a brief outline of key terms such as naïve concept, conceptual change, learning method and strategy was given. An extract from a cartoon version of *Peter Pan* (1953) was used to illustrate

competing views of the meaning of strategy. In the next chapter these terms will each be explored in more depth (sections 2.1 to 2.4) before the issues this thesis addresses are clarified in sections 2.5 and 2.6.

Chapter 2: Literature review

2.0 Introduction

This literature review will describe critically the context out of which the study emerged. The meaning of ‘concept’ and ‘naïve concept’ will be examined with a brief introduction to the ‘Active Construction of Knowledge in Science’ research program (Taber, 2006, p. 134). Research into the learning methods used by professional scientists, and the literature which has uncovered the naïve learning methods which children sometimes use, will be outlined because teachers and pupils in this study made use of these techniques (section 4.2.4). The variety of ways in which the word strategy is understood in the literature is examined, as this thesis will offer a new way of understanding instructional strategy (chapter 4) which emerged from detailed observation of six experienced science teachers at work with thirty-six pupils (chapter 3). The ways in which instructional strategy is understood within the conceptual change research community will be compared with the findings of this present study (section 2.4 and chapter 5).

Based on this literature review the thesis will then argue firstly that positivist approaches to investigating conceptual change strategies have encountered several significant problems. Interpretivist investigations of conceptual change strategies in school science like this present study have not been attempted, even though such an approach has been successful in exploring problem-solving in other fields (section 3.0). Secondly, ‘optimistic’ and ‘pessimistic’ views of conceptual change strategy will be

described. Both struggle to model adequately classroom dynamics. This study will show that teachers can and do influence conceptual change and the learning methods children use, and that instructional strategy is not a simple matter. The middle way proposed in Chapter 4 (a ‘Clausewitzian’ strategy) can guide teachers in the effective use of the teaching techniques at their disposal. Finally it is argued that an integrated approach to conceptual change research (Klahr, 2000) is necessary. Conceptual change, learning methods and instructional strategy should not ideally be treated as isolated fields of study (as in for example Smith, Blakeslee and Anderson, 1993, p.124). However, current integrated approaches appear to incorporate only positivist research and optimistic views of strategy. This literature review concludes that an interpretivist approach with a ‘Clausewitzian’ understanding of strategy can be incorporated into integrated conceptual change research. This approach has not been taken before and is the goal of this present study.

2.1 Concepts and naïve concepts

The word ‘concept’ has proved controversial for philosophers and psychologists (Margolis, 2011). There is much disagreement between different types of conceptual change theorists about the nature of the ‘mental entities’ involved in conceptual change (see for example Medin, Lynch and Solomon, 2000, p. 121). The Oxford English Dictionary defines the word concept as the “idea of a class of objects”. From the time of the ancient Greeks until very recently, Aristotle’s Defining Attribute Theory was thought to explain adequately how concepts are structured in the mind.

[A] concept can be characterised by a set of defining attributes, which are those semantic features necessary and sufficient for something to be an instance of a concept. (Eysenck and Keane, 2005, p.313)

A series of discoveries by psychologists in the 1970s undermined this theory. The most notable of these discoveries was that of ‘typicality’ by Rosch (1975). If people are asked to order exemplars of a category from typical to atypical, the order in the lists they produce is not always identical. For example, we might agree that an apple is a more typical fruit than a tomato, but disagree as regards whether an orange is more or less typical than a banana. Furthermore the threshold beyond which an object is no longer considered an exemplar of a concept differs between people. There is no consensus among psychologists about how to proceed now that the Defining Attribute Theory is discredited. The two most influential competing theories are both supported by evidence.

Prototype Theory (most notably Rosch and Mervis 1975) claims:

[C]ategories have a central description or prototype that in some way stands for the whole category... the prototype is a set of characteristic attributes... in which some attributes are weighted more than others. (Eysenck and Keane, 2005, p.297)

In contrast Exemplar Theory (for example Nosofsky, 1991 and Kruschke, 1992) argues that concepts are particular instances (exemplars) of a category that come to mind in a certain situation. Neither theory takes into account the effect of prior knowledge on the acquisition of new concepts. A comprehensive theory of concept formation is some way off according to Murphy (2002, p. 488) and will probably need to combine elements of the prototype and exemplar approaches with a recognition of the effect of prior knowledge. In this present study prior knowledge is considered to influence concept formation significantly (Chapter 4).

The problem of terminology for ‘student concepts’ which differ from those of professional scientists was examined by Abimbola (1988, p. 175). ‘Naïve concept’ is used here as some other commonly used words such as misconception (for example Tuberty, Dass and Windelspecht, 2011, p. 23), error (for example Lilienfeld, Ammirati and David,

2011), or conceptual problem (Nokes and VanLehn, 2008) overemphasise the negative effect of prior knowledge. In contrast this study does not use other words used in the literature like children's ideas (Cosgrove and Osborne 1985), mini-theories (Claxton, 1990) or preconceived notions (Smolleck, Zembal-Saul, and Yoder, 2006) as they do not adequately describe what are perceived by teachers as real pedagogical challenges. Therefore the phrase 'naïve concept', though by no means perfect, avoids some of the problems associated with other terminology. It is used frequently in the literature (for example Vosniadou and Brewer, 1990, p. 2) and is not meant in any way pejoratively. A seminal paper by Wellman and Gelman (1992, p. 338) defined 'naïve theories' as,

nonscientists' everyday understandings of certain bodies of information such as folk zoology or naïve astronomy. (Wellman and Gelman, 1992, p.338)

Science education research, alongside educational and cognitive psychologists, have catalogued a huge number of naïve scientific concepts. The enormously useful summary of a huge number of these studies by Driver (1994) was used in this present study in the research design (section 3.4) and to help interpret the data (chapter 4). I listed the 148 'misconceptions' Driver (1994) identified in the fields of heating, living things and light before analysing the data to help me identify naïve concepts which emerged. Naïve concepts were identified using the interpretations of participant teachers and the researcher as and when they occurred (see section 3.11 for a description of how these data were analysed). A more recent bibliography of research papers investigating children's naïve concepts in school science called The Students' and Teachers' Conceptions and Science Education (STCSE) database lists 8,342 entries (Duit, 2009). Hence gaining an overview of even this aspect of conceptual change research is unrealistic for busy science teachers and nigh on impossible for full-time researchers. The challenge of embedding

research-informed teaching, facing both teachers and researchers working in this field, will be discussed further in section 6.3.

2.2 Conceptual change research

The history of conceptual change research is complicated and frequently disputed, with the way that different researchers understand the field sometimes influencing how the past is interpreted. For example diSessa (2006, p. 266) presents the history of conceptual change by discussing “critical threads and fault lines”, which may be affected by his being a leading researcher from the ‘knowledge-in-pieces’ wing of conceptual change research (see below). I acknowledge that the following brief overview is influenced by my views about conceptual change. Conceptual change represents one particularly challenging type of learning:

[Learning is] any process that in living organisms leads to permanent capacity change and which is not solely due to biological maturation or aging. (Illeris, 2007, p.3)

Piaget began the interest in children’s ideas which is now known as ‘conceptual change’ research. Traditional epistemology saw knowledge as ‘justified, true belief’ (from Plato’s Theaetetus). Piaget argued that concepts evolve and that studying the growth of human understanding may be more useful than attempting to establish unchanging principles (Gruber and Vonèche, 1977, p. xxii and xxxvii). This ‘genetic epistemology’ engendered the misconceptions movement within science education, developmental psychology and experimental psychology. Started in the late 70s, this movement became prominent in the 80s and tailed off in the early 90s according to diSessa (2006, p. 272), though it still influences many teachers and researchers today (for example Peşman and Eryılmaz, 2010, p.208). In his ‘History of Conceptual Change Research – Threads and Fault Lines’ diSessa (2006) noted that a simple narrative where children have false and entrenched

ideas was permeating science teaching. These ideas interfere with their learning and therefore must be overcome. The misconception movement encouraged a qualitative approach to understanding scientific problem-solving, challenged 'blank slate' theories of a child's mind and stimulated a domain-specific approach to 'misconceptions' (see section 2.2). However studies of children's misconceptions often lacked theoretical foundations, and the question of how learning is possible was largely ignored according to diSessa. Most importantly, children's ideas were frequently viewed as having a negative influence which encouraged conflict models for their resolution (for example Scott, Asoko and Driver, 1991). A vast amount of 'conceptual change' research has now been done exploring children's ideas in science (Duit, 2009).

The name 'conceptual change' embodies a first approximation of what constitutes the primary difficulty: students must build new ideas in the context of old ones; hence, the emphasis on 'change' rather than on simple acquisition. Strong evidence exists that prior ideas constrain learning in many areas. (diSessa, 2006, p.265)

Three 'traditional' areas of research into conceptual change were identified by Sinatra (2005, p. 108): the exploration of cognitive factors (for example Vosniadou and Brewer, 1992) which included the attempt to list children's 'misconceptions' in science (for example Driver *et al.*, 1994); a developmental perspective which examined the origins of children's naïve thinking (for example Carey, 1985); and the exploration of conceptual change pedagogy (for example Posner *et al.*, 1982). This research field has been described by Taber (2006, p. 134) as the 'Active Construction of Knowledge in Science Research Program' (ACKiS RP).

Conceptual change theorists can be distinguished by two competing theoretical perspectives: knowledge-as-theory and knowledge-as-elements (Özdemir and Clark, 2007, p. 351). This debate emerged from research into the philosophy and history of

science and has had enormous significance on the history of conceptual change research, continuing both to divide current conceptual change theorists and to influence this present study (section 6.4.1). It will be described briefly now, so that the approach adopted by this current research can be understood. T. Kuhn (1962) argued that scientific change was discontinuous. Periods of ‘normal science’ (where scientists engaged in solving puzzles) were peppered with sharp ‘paradigm shifts’. The claims of new theories could not be stated in the old terms after such shifts. Concepts came to refer to different things. For example, since the discovery of Special Relativity by Einstein the concept ‘relativity’ which was first introduced by Galileo now includes, among other things, time dilation and length contraction. Furthermore paradigm shifts changed what problems were amenable to study, how theories were evaluated, what methods were reliable and even what symbolic generalizations apply. There was a sociological theme in T. Kuhn’s work which has been influential in the design of the methodology for this present study,

Scientific knowledge, like language, is intrinsically the common property of a group, or else nothing at all. To understand it we shall need to know the special characteristics of the groups that create and use it. (T. Kuhn, 1962, p.208)

Hence as pupils, teacher, researcher, etc. create scientific knowledge together the interpretations of scientific concepts, be they considered ‘naïve’ or ‘scientific’, by all these participants must each be considered when attempting to understand conceptual change. The research methods used in this present study incorporate the interpretations of participants (section 3.4). In contrast Toulmin (1972) argued against the ‘before and after’ coherent view of conceptual change, in favour of an evolutionary model. The minority ‘fragmented’, ‘knowledge-in-pieces’ or ‘knowledge-as-elements’ perspective which emerged in his wake, saw conceptual change as the collection and coordination of a large set of elements. This view sees children’s ideas as building materials to be moulded for

use. Debate between ‘theory-theorists’ (who follow T. Kuhn, 1962) and ‘fragmented theorists’ (after Toulmin, 1972) is on-going. Theorists from the knowledge-as-elements perspective argue:

[C]onceptual change involves a piecemeal evolutionary process rather than a broad theory replacement process. (Özdemir and Clark, 2007, p.355)

In addition some argue that conceptual change involves both evolution and revolution (for example Wisner and Amin, 2001, p.332). Though different researchers adopt a range of positions within each of the two main approaches, this divide influences what each community propose practitioners should do to promote conceptual change. For example, a hugely influential, though now dated, theory by Posner *et al.* (1982) from the knowledge-as-theory perspective encouraged the view that conceptual change followed from a combination of dissatisfaction with naïve concepts, together with the perceived intelligibility and plausibility of the scientific concept at issue, and ‘fruitfulness’ (the new idea must appear useful to the pupil in solving problems).

This study argues that there can be no stable relationship between conceptual change and instructional techniques, and that the ways in which the conceptual ecologies of different pupils in a classroom will interact will always be too complicated to predict. Hence the inductive approach (taken in this present study) of identifying the techniques used by experienced teachers which did lead to conceptual change in a complicated context, may be all that is possible. The term ‘conceptual ecology’ was coined by Toulmin (1972) and introduced into conceptual change research by Posner *et al.* (1982, p. 213). The idea that a learner’s conceptual ecology (concepts, ontological categories and epistemological beliefs) influences learning and problem-solving is still influential with both types of theorist and in this present study. Ontological commitments can constrain a learner’s ability to restructure their thinking (Vosniadou, 1994, p.55). Incorrect

ontological classification of concepts by students, and the lack of a category to which a concept could be assigned, are both barriers to conceptual change (Chi, 1992, p. 129). Considerable evidence suggests that epistemological beliefs influence conceptual change (Deniz, 2011) and different types of epistemological belief were proposed by Perry (1968), but different researchers disagree about how these beliefs should be understood and assessed (Smith and Wenk, 2006, p. 748). Motivation and affect were largely ignored within conceptual change research until a seminal article by Pintrich, Marx and Boyle (1993) prompted interest in ‘hot’ conceptual change. They criticised the ecosystem metaphor:

Ecosystems are not purposeful, but individuals learners and communities of scholars can and do have goals, purposes, and intentions, thereby suggesting a role for an individual’s motivational beliefs. (Pintrich, Marx and Boyle, 1993, p. 172)

A consensus has emerged among conceptual change researchers that thinking,

...may differ substantially in different areas or domains (Chomsky 1975; Fodor 1983; Gallistel 1990). (Wellman and Gelman, 1992, p.338)

For example there is now considerable evidence that reasoning in ‘naïve physics’ is often very different from thought in a framework like ‘naïve biology’ (see Vosniadou, Vamvakoussi and Skopeliti, 2008, p. 15). This present study acknowledges this discovery in the research methods by examining a topic taken from each of biology, chemistry and physics. In addition the six participant teachers were selected to represent specialists in all three sciences.

This brief overview of some of the major areas of conceptual change research demonstrates that there is no consensus among conceptual change researchers about what conceptual change involves (Vosniadou, 2008, p. xv). In consequence the approach proposed by Clement (2008, p. 433) will be adopted. He saw the results of a range of

researchers in the field as evidence that (at least) ten different types of conceptual change exist. Clement's approach is used in this present study because it is an inclusive position within the conceptual change research community, which attempts to reconcile theory-theorist and fragmented approaches by acknowledging a range of types of conceptual change, from fine grained movement through to paradigm shifts. It allows the analysis (chapter 4) to make use of discoveries from both sides of this divide. To illustrate Clement's (2008) typology of conceptual change, one type of conceptual change (integration) will now be described before the others are outlined. The principle goal of school science, according to Clement (2008), is often to build 'explanatory models'. Explanatory models are complex structures formed in the mind when concepts are combined:

[An explanatory model is a] hypothesized, theoretical, qualitative model... such as molecules, waves, and fields [which are] a kind of hypothesis separate from empirical patterns or observational descriptions of behaviour. As a special kind of scientific model, an explanatory model is not simply a condensed summary of empirical observations, but is rather an invention that contributes new theoretical terms and images that are part of the scientist's view of the world, and which is neither given in, nor implied by, the data. (Clement, 2008, p.419)

Adopting a new 'explanatory model' without relinquishing an old one, is one type of conceptual change (Clement 2008 p. 434). This will be called 'integration' and is listed as type 8 in Table 1 below, where ten types of conceptual change are described briefly, ranging from relatively minor cognitive shifts at the bottom of the table to extremely challenging changes at the top:

No.	Name	Description
10	Paradigm Shift	A theory that differs significantly from the original in many ways.
9	Branch jumping or tree switching	A concept is replaced with an ontologically different type of concept.
8	Differentiation or integration	An explanatory model is divided or joined.
7	New model creation	A new explanatory model is created which has not developed from a previous one.
6	Synthesis or combination	'Overlapping' explanatory models are separated or separate models are integrated.
5	Major model modification	An element of an explanatory model is added, removed or changed.
4	Abstraction from exemplars	A concept (or schema) is formed from exemplars.
3	Applicability change	The conditions indicating when an explanatory model can be used are changed.
2	Minor model adjustment (also called 'tuning')	Small changes are made within an explanatory model.
1	Concept change	One concept is changed for another.

Table 1: Types of conceptual change in science (adapted from Clement, 2008, p. 433)

This typology proved useful in interpreting the 602 examples of naïve concepts which emerged during this study.

Alternatives to the conceptual change perspective exist. For example there has been dialogue between conceptual change researchers and socio-cultural theorists. Roth (2008), arguing from what Smardon (2008, p. 364) describes as an “extreme postmodern, radical culturalist position” concludes that these viewpoints are different paradigms:

I am certain that conceptual change does not describe our experience of learning and therefore is an essentially wrong theory. (Roth, 2008, p. 381)

In contrast several other researchers in the same special edition of *Cultural Studies of Science Education*, coming from both socio-cultural and conceptual change traditions, argue that a multiple perspective approach is of value (for example Treagust and Duit, 2008b, p. 394; and Mercer, 2008). Sociocultural theory emphasises the importance of discourse in teaching and learning (Mercer and Howe, 2012), the influence of subtle

differences in the way we speak (Tiberghien, 2008, p. 287), how non-verbal communication like gesture, proxemics, gaze direction and rhythm must be included in analysis (Smardon, 2008, p. 364), and also gives insight into the pitfalls of misinterpretation.

Interpretive errors enter the analysis precisely then when gestures and indexicals are translated into words, literally carried from imagery and body motion into words, thereby necessarily articulating different dimensions of sense; a different sense is articulated even if the re-articulation occurs in the same modality (Italians say, “Traduttore, traditore!”), all translation is treason), such as when something already said is said differently subsequently. Saying something differently clearly is non-identical with what has been said before and therefore already constitutes an interpretation - allowing us to understand that everything is untranslatable although nothing really is untranslatable; translation is the name of the impossible (Derrida 1998). (Roth *et al.*, 2008, p. 251; cf. Treagust and Duit, 2008a, p. 323)

This thesis will explore misinterpretation and misunderstanding later (sections 4.2.6, 6.6, 6.2.1. and 6.3). However, Mercer, writing from a socio-cultural perspective, notes that:

Research on teacher-student dialogue ... has generated little hard evidence about how, and the extent to which, teacher-student dialogue affects conceptual change. That work is still to be done. (Mercer, 2008, p. 361)

This present study offers detailed exploration of the exchanges surrounding and underpinning scientific teacher-student discourse from a conceptual change perspective, so supports this multiple perspective approach.

2.3 Learning method research

In this section philosophical arguments for and against the idea of ‘learning methods’ will be examined, then some of the research in this field by educational psychologists, in particular the discovery of ‘naïve learning methods’ (Zimmerman, 2005), is described. This present study argues that children use ‘learning methods’ and

‘naïve learning methods’ when discussing scientific ideas and that experienced teachers make use of both when attempting to promote conceptual change. In addition some educational psychologists argue that instructional strategy, learning methods and conceptual change are interconnected and must be considered together (Klahr, 2000). This thesis, whilst agreeing with this integrated approach to conceptual change, challenges the understanding of ‘strategy’ that researchers like Klahr incorporate into their research (section 2.4).

Twentieth century philosophy distinguished between the ‘context of discovery’ and the ‘context of justification’ (Hans Reichenbach, 1938, p. 7). The former refers to how people formulate hypotheses and deal with anomalies; the latter to the way we determine whether or not a hypothesis should be accepted. Philosophers have been largely sceptical about the possibility of producing a logic of discovery.

Some literature in the philosophy of science exists that discusses strategies for producing new ideas, but most work on this subject has been done outside twentieth-century philosophy of science. Such lack of attention is a consequence of philosophers’ scepticism about the possibility of producing a logic of discovery. ... On a Popperian view, a falsifying instance (an anomaly) requires that the theory be discarded and that a new trial and error process be started to find a replacement (Popper, 1965). This procedure of ‘conjectures and refutations’ neglects the information that the prior refutation can play in guiding the construction of the next conjecture. (Darden 1991, p. 9)

One reason the Logical Empiricists came to the conclusion that a logic of discovery was inaccessible or even impossible, was because many important steps in the history of science appear to be imaginative leaps (for example, Kekulé’s discovery of the structure of Benzene by ‘seeing’ a snake eating its tail in the fire) or lucky accidents (for example, Becquerel’s discovery of radioactivity). Even philosophers of science who explore

scientific change (Lakatos 1970, Kuhn 1962 and Laudan 1977) have ignored or even cautioned against the analysis of reasoning in discovery according to Darden (1991):

[N]one of these philosophers concerned with conceptual change has proposed methods for the development of new ideas for the next stage. Nor have they indicated how anomalies at one stage can guide refinements. Laudan (1980) even argued that a search for such methods should not be the concern of philosophers. (Darden, 1991, p. 10)

However T. Kuhn's work implied that,

[T]he likelihood of future discoveries of particular kinds are sometimes entangled with judgments of evidence, so discovery can be dismissed as an irrational process only if one is prepared to concede that the irrationality also infects the context of justification itself. (Kitcher, 2010, p. 4)

Some philosophers have attempted to analyse the logic of discovery (for example Darden, 1991; and Hanson, 1961). Reasoning methods for conceptual change used by professional scientists were explored in a study by the philosopher Darden (1991). Darden divided her findings into three groups: learning methods for producing new ideas, for theory assessment and for anomaly resolution. She undertook an empirical study into the learning methods used by professional scientists in the development of Mendelian genetics. The study spanned a period from when Mendel's work was rediscovered around 1900, until a consensus emerged in the study of genetics in the 1930s. Darden makes no suggestion that the taxonomy she proposes is complete or even that she has correctly identified what learning method a scientist used in a particular instance.

A ... strategy [called a learning method in this present study] is a plausible hypothesis for a reasoning method that could have contributed to the change that did occur. (Darden, 1991 p.15)

To prevent confusion between the way Darden uses the word strategy and the definition which emerged in this present study, Darden's strategies will be called 'learning methods' from now on. The published papers, notebooks and other sources Darden examined,

contained evidence of twenty-eight learning methods which this group of scientists appeared to use: seven for developing new ideas, eleven for evaluating them and ten for dealing with anomalies (appendix D describes these briefly). These learning methods provide a background against which children's immature reasoning can be situated. It might be expected that children will use some, but not all, of the methods that professional scientists would use.

It may be the case that the issue of learning methods in the natural sciences does not lend itself to philosophical analysis. Psychologists who investigate problem-solving processes have found considerable evidence of the use of learning methods (Heppner and Krauskopf 1987; Schoenfeld 1983; Silver and Marshall 1990). Within that community there has been much discussion as to whether, or in what circumstances, covert cognitive processes can be uncovered and reliably described (Taylor and Dionne 2000; Ericsson and Simon 1993; Nisbett and Wilson 1977; Pressley and Afflerbach 1995; Van Someran, Barnard and Sandberg 1994). Furthermore:

Research on strategy instruction has demonstrated that knowledge of how to implement a specific strategy, although necessary, is not sufficient for spontaneous and effective strategy use. Other essential forms of strategy knowledge include the conditions under which a particular strategy is useful; how strategy knowledge is learned; and general beliefs about the problem-solving process, strategy use, and one's problem-solving abilities (Borkowski, Carr, Rellinger and Pressley, 1990; Pressley, Borkowski and O'Sullivan, 1985). (Taylor and Dionne, 2000, p. 414)

In this present study I will argue that participants were seen using both learning methods that professional scientists appear to use (Darden, 1991) and naïve learning methods. Children's scientific reasoning methods have been found by psychologists to evolve (Zimmerman, 2005, p. 17). For example, the familiarity of a phenomenon being investigated has been found to influence the choice of reasoning method by children

(Zimmerman and Glaser, 2001). So the hypothesis ‘tap water is good for plants’ (one children are familiar with) is not investigated by children in the same way as ‘coffee grounds are good for plants’ (an unfamiliar idea). The study by psychologists and educationalists of domain-general reasoning and problem-solving skills in children emerged from Piaget’s work. ‘Domain’ refers to a child’s thinking in, for example, biology or physics. Hence ‘domain-general’ denotes science. The evidence for children’s naïve thinking in various scientific domains being significantly different was reviewed by Vosniadou, Vamvakoussi and Skopeliti (2008, p. 15). Early studies investigated the child’s skills in constructing hypotheses, controlling some variables in order to find relationships between others and making observations (for example Inhelder and Piaget, 1958). The role of domain-specific knowledge was deliberately reduced or removed so that domain-general learning methods could be observed (for example Siegler and Liebert, 1975). More recent work within this research tradition recognises the importance of the content, whilst maintaining the interest in domain-general learning methods (for example Koslowski, 1996). Finally an ‘integrated approach’ has emerged where the way children revise their scientific concepts is monitored, as they generate and evaluate evidence during an investigation.

This recent line of research involves simulated-discovery tasks that allow researchers to investigate the dynamic interaction between domain-general [learning methods] (i.e., experimentation and evidence evaluation skills) and conceptual knowledge in moderately complex domains. (Zimmerman, 2005, p.12)

One type of study is carried out independently by the child or children involved (self-directed experimentation) and the other involves the teacher having some control over how the investigation proceeds (partially-guided experimentation). Multivariable systems have been explored by actual exploration of a real system (for example Chen and Klahr,

1999; Masnich and Klahr, 2003; Gleason and Schauble, 2000, Kuhn, D. *et al.* 1992) and through use of computer simulations (Schauble, 1990; Echevarria, 2003; Keselman, 2003; Hast and Howe 2010). Therefore contemporary research by educational psychologists into the learning methods children use in science involves many strands. These different types of research into scientific reasoning were described by Zimmerman using Klahr’s (2000) Scientific Discovery as Dual Search framework (Table 2 below which was adapted from Zimmerman 2005 p. 11):

		Type of cognitive process		
		Hypothesis space	Experiment space	Evidence evaluation
Knowledge type	Domain-specific	A	B	C
	Domain-general	D	E	F

Table 2: Scientific Discovery as Dual Search (SDDS) framework by Klahr, 2000 (adapted from table 1 in Zimmerman, 2005, p. 11)

This framework provides a useful way of understanding the different types of research in this field and seeing the context of this present study. For example research into conceptual change in science, from a domain-specific perspective, occupies cell ‘A’ in Table 2. Another example, which inhabits cell ‘F’ in Table 2, is work exploring scientific reasoning methods concerning how children evaluate evidence from a domain-general (or ‘general science’) perspective. Research of type A was reviewed by Wellman and Gelman (1992), Driver *et al.* (1994) or Confrey (1990). Studies of type D are uncommon according to Zimmerman (2005, p. 10) but she cites Bruner, Goodenough and Austin

(1956) as one example. This current study belongs to conceptual change research traditions A and D. Zimmerman (2005) reviews studies of types 'B', 'C', 'E' and 'F'. She also examines studies called self-directed experimentation and partially-guided experimentation, where children or adults follow all (in SDE) or most (in PGE) aspects of scientific discovery. These types of integrated research monitor the development of conceptual knowledge and learning methods in more realistic contexts so can be seen as spanning types A through to F or other combinations of cells in Table 2. The key point is that 'state of the art' research recognises the interrelations between hypothesis generation, experimental design learning methods and evidence-evaluation learning methods. In addition both domain-general and domain-specific perspectives have brought useful insights into the dynamics of conceptual change. These discoveries by educational psychologists about the domain-general and domain-specific learning methods that children use when thinking about science proved useful in interpreting the data for this present study.

2.4 Instructional strategy research

This study questions the understanding of 'instructional strategy' which psychologists investigating conceptual change have incorporated into their integrated approach to conceptual change. In addition the way that many teachers conceptualise strategy is challenged. A different way of understanding strategy, interpreted with the help of military theory, emerged during this study and will be discussed in section 4.4. To help situate this study within the literature, after a brief discussion of the difficulties inherent in writing such a history, the variety of ways in which instructional strategy is understood by conceptual change researchers will be reviewed.

Care must be taken when situating this present study within the field of research into instructional strategies for conceptual change. The field of conceptual change has itself changed so much since the misconceptions movement (which began in the 70s and developed into the conceptual change research of the 90s) that approaches to instruction must be considered in the context from which they emerged. For example Scott, Asoko and Driver's (1991) early review of instructional strategies for conceptual change in science comes from an era when it was believed that various aspects of scientific investigation could be investigated independently (i.e. before the seminal work of Wellman and Gelman, 1992 - see section 2.2). Similarly Pressley and Woloshyn (1995) approach instructional strategy from an Information Processing perspective. Hence the way teachers and researchers use the word strategy is sometimes influenced by the theoretical perspective they adopt (for a discussion of my own position see section 3.1).

The word 'strategy' is not used in a consistent way within the instructional strategy literature as a result of the different perspectives we have when exploring the social world, but also because this concept is a challenging one. This present study will argue that what some researchers call 'strategy' may be understood as simple teaching techniques, and that words like 'tactic' and 'strategy' might be best reserved for describing more sophisticated behaviours. Some research appears to see strategy as something decided before the lesson, which does not change during teaching:

We see strategies in terms of overall plans which guide the sequencing of teaching within a particular topic. (Scott, Asoko and Driver, 1991 p.1)

This view may be contrasted with approaches emerging from more recent research where instructional strategies interact with learner's reasoning methods during lessons, in dynamic and often unpredictable ways (section 2.6). Some researchers understand instructional strategy in very limited terms. For example, Forsyth, Jolliffe and Stevens

(1999, p. 84) speak of there being “only” three types of strategy: teaching the entire class together, group work and individual tuition. Such grouping techniques will be discussed in section 4.2.10. In contrast Molenda (2005, p. 4) identified ten instructional strategies by classifying according to the type of interaction between teacher and pupil. For example, a tutorial is a two-way interaction between learner and teacher, whereas a lecture involves the dissemination of information from teacher to learner. There exists an on-line database of instructional strategies in alphabetical order which currently lists 1271 entries (Rowan 2010). These techniques were described in this present study as ‘Use an activity’ (section 4.2.7).

‘Instructional Design’ has roots in behaviourist psychology and constitutes yet another approach (for example Reiser and Dempsey, 2006). The classic empirical study of emotional and behavioural management in classrooms by Kounin (1970) identified five instructional strategies and has been influential in this present study both because of the discoveries made and with the methodology used. For example ‘withitness’ describes how well a teacher understands complicated dynamics in the classroom and ‘overlapping’ involves a teacher multitasking. This approach to strategy has been developed in more recent research (Kyriacou and McKelvey, 1985, and Kyriacou, 2009 p.82).

A distinction was drawn by Scott, Asoko and Driver (1991) between what they saw as ‘conflict and resolution’ strategies from a Piagetian tradition (Nussbaum and Novick 1982, Stavy and Berkovitz 1980, Cosgrove and Osborne 1985, Champagne, Gunstone and Knopfer 1985 and Rowell and Dawson 1979) and strategies “which build on learners’ existing ideas and extend them”, which can be seen as Vygotskian in origin (Brown and Clement 1989, Stavy 1991 and Niedderer 1987). This divide is still evident among contemporary researchers from a ‘coherent’ or ‘fragmented’ tradition. What

precisely conflicts are and how useful conflict is in bringing about conceptual change received much discussion:

[E]ven meaningful conflicts are not always successful. (Dreyfus *et al.*, 1990, p.567)

In this present study the grounded theory in Chapter 4 can be seen as embracing both these Piagetian and Vygotskian traditions within instructional strategy research in order to model what happens during ‘conceptual conflicts’ (section 4.1).

There are teaching programmes offering,

targeted teaching strategies which concentrate on improving student understanding by eradicating ... identified misconceptions. (Sharma *et al.*, 2010, p. 1).

Examples of such ‘interactive engagement’ strategies include ‘Cooperative Group Problem Solving’ (Cummings *et al.*, 1999), ‘Tutorials in Physics’ (TIP) which involve questions and exercises for students working in small groups (McDermott, 2001) and ‘Interactive Lecture Demonstrations’ (ILD) (Sokoloff and Thornton, 2004). Such programmes can produce significant learning gains (Sharma *et al.*, 2010). Cognitive acceleration (for example Cognitive Acceleration through Science Education or CASE) was designed to develop thinking skills, rather than as a specific programme to address scientific misconceptions, but offers learners opportunities to discuss and change concepts while undertaking interesting activities and experiments. The programme is underpinned by both Piaget's schemata of formal operations (Inhelder and Piaget, 1958) and Vygotsky's Zone of Proximal Development according to Shayer and Adey (2002). Intellectual challenges are introduced, with support, to encourage 'cognitive conflict' among learners, with alternating cycles of small group and whole class work. Teachers using cognitive acceleration encourage metacognition and transfer to other contexts. There is evidence that CASE enhances the cognitive development of children and

academic achievement (Shayer, 1999a and Shayer 1999b) with an effect size ranging from 0.3 to 1 (Adey and Shayer, 1994). The teachers were asked directly during the RD interviews if they consciously applied specific teaching practices (for example 1c:36, 2c:13 and 4c:25), but ‘strategic plans’ like Cooperative Group Problem Solving, TIP, ILD and CASE were not mentioned once. Of course some may have used such plans, or have been influenced by them, but did not think of them in this particular context. No claims about the impact of such strategic plans can be made here, as this was not the focus of the present study and the sample size is too small (see section 7.2).

In contrast to the ‘strategic plans’ and programmes described above, where educational researchers invite practitioners to implement certain techniques, this present study attempts to build a theory of instructional strategy from the bottom up. Grounded theory methods are used to attempt to understand what a group of experienced teachers actually do whilst working with small groups of children who express naïve concepts. There is obviously much to be learnt by classroom teachers like myself from the extensive literature on instructional strategies for conceptual change summarized earlier. However,

As research accumulates from laboratory studies on the conditions which support scientific thinking and conceptual change, continued research will need to explore the best ways to teach such skills. (Zimmerman, 2005, p.89)

The assumption implicit in this quotation, that there are ‘best ways’ to promote conceptual change which can be identified by researchers and communicated to teachers, does not match the findings of this present study. The messy dialogues between pupils and teacher, examined in detail here, suggest that even the most well informed practitioner cannot predict the consequences of the interactions of complicated conceptual ecologies which teachers encounter in the classroom.

2.5 Optimistic, pessimistic and Clausewitzian strategies

There is no agreed definition of the word ‘strategy’ among teachers or educational researchers (section 2.4). For example some see strategy as something relatively straightforward (for example Clement 2008, p. 445 or Scott, Asoko and Driver, 1991), whereas others see it as something hidden in the mind which can often only be seen by its effects (Taylor and Dionne, 2000, p.413). An adapted understanding of tactics and strategy from the military proved useful in interpreting these data for this present study. The word ‘tactic’ comes from the Greek word (*taktike*) meaning ‘arrangement’. The word ‘strategy’ comes from the Greek word (*stratēgia*) meaning ‘generalship’.

[T]actics is the theory of the use of military forces in combat.
Strategy is the theory of the use of combats for the object of
the War. (Clausewitz, 1832, p.172).

The following definitions are used for this present study. Tactics is the theory of the use of teaching and learning methods in ‘conceptual combat’. Strategy is the theory of the use of such ‘conceptual combats’ to try to meet an objective (here conceptual change). The idea of ‘conceptual combat’ will be discussed in section 4.1. This military analogy must not, of course, be taken too far (Saltman and Gabbard, 2010). Pupils are not soldiers, teachers are not generals and a classroom is not a battlefield. More modern military definitions of the word strategy continue to support the idea of this being about how to achieve aims:

[A strategy is a] prudent idea or set of ideas for employing the instruments of ... power in a synchronized and integrated fashion to achieve ... objectives. (United States Department of Defence - Source: JP 3-0)

This ‘Clausewitzian’ understanding of the nature of strategy can be contrasted with the views of those I will call optimistic and pessimistic strategists. Optimists appear to understand strategy as a set of instructions employed to solve educational problems

definitively. This viewpoint can be identified in educational research and among psychologists who explore conceptual change. For example, a review by educationalists of teaching strategies for conceptual change, defined strategy as:

[Overall] plans which guide the sequencing of teaching within a particular topic. (Scott, Asoko and Driver (1991, p. 1)

The work of the psychologist Clement (2008) has been used in this present study in recognising the variety of types of conceptual change present in the data. However, his work reveals a view of strategy which could be interpreted as optimistic:

[In] future research, we may be able to map ... teaching strategies to different types of conceptual change. One can then imagine a form of top down curriculum planning that could occur, starting from research on students' preconceptions and a learning pathway specifying the type of conceptual change that needs to happen at each juncture. (Clement, 2008, p. 445)

As a science teacher interested in conceptual change strategies, I recognise a desire within myself to 'know the answer' of how best to promote conceptual change among pupils, which may reveal optimistic assumptions about what teachers can do to promote learning.

Pessimistic strategists see no hope. In discussing military strategy during the Napoleonic War with Russia, one of Tolstoy's characters makes a remark which some might see as helpful in describing classroom dynamics:

What science can there be in a matter in which, as in all practical matters, nothing can be defined, and everything depends on innumerable conditions the significance of which is determined at a particular moment which no one knows when? (Tolstoy, 1869, p. 521)

Pessimism as regards the possibility of articulating and influencing reasoning methods can be seen in the work of many twentieth century philosophers of science (section 2.3). Some educators are pessimistic as regards the possibility of teaching or influencing learning methods. Nineteen of thirty-six participants (university lecturers and 3rd Year

undergraduates) in Taylor and Dionne's (2000) study reported an inattention to the explicit learning of problem-solving methods during their own academic careers. One of the university lecturers noted:

I have never sat down with someone and discussed problem solving per se... it is something that you pick up as you go along. (Taylor and Dionne, 2000, p. 421)

Assuming that pupils will acquire problem-solving methods en route could indicate a lack of awareness of the naïve learning methods psychologists have found some children using (section 2.3), and might be influenced by pessimism as regards the possibility of a logic of discovery.

Research can be pessimistic about the possibility of identifying learning methods and/or pessimistic about the strategic knowledge of teachers. Studies investigating the strategies secondary school science teachers use to promote conceptual change are rare. One example concluded that participants did not have much strategic knowledge:

Almost all the teachers in this study did not employ any specific teaching for conceptual change strategies as articulated in the literature such as cognitive conflict, bridging analogy or metacognitive strategies. (Abd Rahman, 2004, p. 1).

However, Abd Rahman's research may not have accessed what experienced science teachers actually know about strategies for conceptual change because of the methodology the researcher used. For example, the use of classroom observations followed by structured interviews allows only limited access to the ways participants may have understood their own practice. This methodological weaknesses in the study by Abd Rahman (2004, p. 1) undermines her claim that science teachers are strategically naïve. Indeed the findings of this present study (Chapter 4) indicate that at least some experienced science teachers are accomplished tacticians and strategists. However, the experienced science teachers involved in this present study may sometimes need help to

articulate their ‘covert’ strategic knowledge in ways that make sense to the research community (Chapter 5). In addition, researchers should not underestimate the difficulties involved in incorporating the interpretations of participants into research (see Chapter 6).

The Clausewitzian view that strategy is neither a simple plan which will bring about conceptual change, nor a doomed endeavour, has been helpful in developing the grounded theory expressed in Chapter 4. According to Baylis, Wirtz and Gray (2009 p. 68), the military strategist Clausewitz saw the purpose of strategy to be the education of the mind rather than the discovery of fixed laws or principles:

Earlier theorists aimed to equip the conduct of war with principles, rules, or even systems, and thus considered only factors that could be mathematically calculated (e.g., numerical superiority; supply; the base; interior lines). All these attempts are objectionable, however, because they aim at fixed values. In war everything is uncertain and variable, intertwined with psychological forces and effects, and the product of a continuous interaction of opposites. (Clausewitz, 1832, p. 127-147)

It is unfair to release trainee teachers onto the battlefield of conceptual change in the science classroom without sharing with them something of how experienced science teachers work in this environment. Nor is it fair to expect even advanced skills science teachers to be able to articulate complicated educational strategy without the support of educational research. Describing these strategies for others is not their responsibility. Many teachers become expert educational tacticians and strategists in spite of vague and continuously shifting guidelines which demand “a clear understanding of appropriate teaching strategies” (DfE, 2012) without explaining what this means.

2.6 Integrated approaches

In a study by Klahr and Dunbar (1988) which explored the scientific reasoning of twenty university undergraduates, successful scientific work was found to involve two interrelated skills: the design of experiments, and the formation and evaluation of theory.

the implicit research strategy in most psychological studies of scientific reasoning has been to investigate each skill in isolation and in semantically lean contexts. This strategy has yielded many important findings about distinct stages of the scientific reasoning process, but much remains to be learned about how the stages interact and about how the interaction is influenced by prior knowledge. (Klahr and Dunbar, 1988, p. 2)

This early work introduced the integrated approach (also called ‘Scientific Discovery as Dual Search’ or SDDS). It built upon laboratory studies by Bruner, Goodnow and Austin (1956) and Wason (1960) who described how subjects construct a hypothesis, and then gather evidence in order to confirm this idea (rather than try and disprove it), and the historical analysis of the work of real scientists (for example a study exploring the work of Apollo moon landing scientists by Mitroff, 1974).

In modern conceptual change research the integrated approach continues to be influential. Four current approaches used by psychologists who research scientific reasoning were identified by Zimmerman (2005). These will now be outlined in order to understand the integrated approach (Klahr, 2000), how it relates to other branches of conceptual change research, how investigating instruction has become part of this approach and why it has been adopted in this present study. Firstly, ‘conceptual change research’ explores various concepts that children and adults use in scientific content domains (i.e. in physics, chemistry or biology). Children’s scientific ideas may or may not match explanations currently accepted by the scientific community (for example Vosniadou and Brewer, 1992). In this present study such thoughts are referred to as naïve concepts. Consensus has emerged among conceptual change theorists that cognition may be substantially different in various domains like biology, physics or psychology (Wellman and Gelman, 1992). This conceptual change research typically focuses on an

individual's grasp of a particular phenomenon. Instructional strategies and reasoning methods used to bring about this change are not investigated.

[C]ognitive developmental research . . . aspires to model the emergence of the children's competence apart from any instructional intervention (Metz, 2004, p. 222).

Secondly, domain-general strategies have been investigated by reducing or eliminating domain-specific knowledge from the studies (for example Siegler and Liebert, 1972).

Thirdly some researchers combine the first two approaches (for example Metz 2004).

Scientific reasoning, by definition, involves both conceptual understanding and inquiry skills. Sufficient research has been compiled to corroborate the claim that in the context of investigation, domain-specific knowledge [i.e. within a subject like biology or physics] and domain-general strategies [i.e. across several scientific subjects] "bootstrap" one another, such that there is an interdependent relationship between these two types of knowledge. (Zimmerman, 2005, p. 4).

In those self-directed experimentation (SDE) and partially-guided experimentation (PGE) studies, child or adult scientists follow all (in SDE) or most (in PGE) aspects of scientific discovery, whilst researchers monitor the development of conceptual knowledge and reasoning strategies in more realistic contexts. Such research examines,

[R]eciprocal influences of strategy on knowledge and knowledge on strategy. (Schauble, Glaser, Raghavan and Reiner, 1991, p. 203).

Finally, a few studies (for example Metz, 2004) seek to bring together research into conceptual change, learning methods and instructional strategy research whilst acknowledging the influence, and the domain specificity, of prior knowledge. This is called the integrated approach (Klahr, 2000).

Children's scientific reasoning can be studied for what it informs us about the development of inductive, deductive and causal reasoning, problem solving, knowledge acquisition and change, and metacognitive and metastrategic competence. However, such studies can and should be informative with

respect to the kinds of practice and instruction that may facilitate the development of knowledge and skills and the ages at which such interventions are likely to be most effective. In more recent ... studies, there has been a shift to include instructional components to address such concerns. (Zimmerman, 2005, p. 78).

This present study contends that conceptual change, learning methods and instructional strategy should not ideally be treated as isolated fields of study. In chapter 5 the extent to which the data collected for this study might provide evidence for this integrated approach is considered (this is the Grounded Theory Method of theoretical integration - see section 3.11).

Some conceptual change researchers already acknowledge that instructional strategy is not straightforward:

[The] question about the relative efficacy of different interventions – whether they be prompts, scaffolds, didactic instruction or opportunities for particular types of practice – is a far trickier endeavor than would appear on the surface. (Zimmerman, 2005, p. 90).

Indeed evidence shows that scientific reasoning cannot be relied on to emerge without intervention (D. Kuhn and Franklin, 2006, p. 47). The exploration of how experienced science teachers promote conceptual change (one aspect of strategy) by using instructional techniques in tactical ways is indeed ‘tricky’ (see chapter 4). The typology of interventions (called techniques here) used by experienced science teachers in tactical and strategic ways could guide those wishing to explore the efficacy of what teachers do (section 7.1). One way in which military strategists learn their trade is by exploring the behaviour of generals during real historical conflicts. This thesis argues that educational strategists can also learn from detailed qualitative investigations of the behaviour of experienced teachers and children whilst conceptual change is taking place.

Hence this thesis will argue, based on the literature review, that an integrated approach to conceptual change is necessary where conceptual change, learning methods and instructional strategy interact. However within this integrated approach, the Clausewitzian understanding of instructional strategy which emerged during this present study may be more useful than optimistic or pessimistic approaches to strategy in understanding conceptual change pedagogy.

2.7 Summary

This literature review has shown how this present study fits into, and builds upon, research into conceptual change in school science. The word ‘concept’ means a class of objects, but there is no consensus among either philosophers or psychologists as to how concepts are formed, hence a theoretical ‘solution’ to how conceptual change should be promoted is not possible currently. The conceptual change literature (Duit, 2009) describes an enormous number of children’s naïve concepts in science. Different types of conceptual change have been identified (Clement, 2008, p.433). Children sometimes use the same reasoning methods as professional scientists (Darden, 1991), but also employ naïve reasoning methods (Zimmerman, 2005). Researchers have long noted the need for effective strategies for conceptual change (Driver and Erickson, 1983; Scott, Asoko and Driver, 1991), but a number of different meanings are assigned to the word ‘strategy’ within this literature. The findings in chapter 4 arose from this complicated context.

Optimistically assuming that instructional strategy is a simple matter of ‘picking the right tool’ (for example Miller, 2000, p. 21), does not adequately explain the data collected in this study (see Chapter 4). However, the pessimistic extreme of abandoning the attempt to articulate the complicated interactions between pupils and their teacher

whilst learning is taking place, leaves practitioners without guidance. In Chapter 4 the ‘Clausewitzian’ strategy which emerged during this research is described.

The literature review shows that a consensus exists among most conceptual change researchers that conceptual change, learning methods and instructional strategies must be considered together where possible. This present study attempts to use this integrated approach, yet argues that the overwhelmingly positivist research in this field should be balanced by interpretivist studies. Hence the need for the new approach in this present study which offers an integrated approach to conceptual change pedagogy, an interpretivist methodology and a ‘Clausewitzian’ understanding of strategy.

Chapter 3: Research methodology

3.0 Introduction

The research questions, considered in the context of current conceptual change research, led to the following research design. The methodology is Grounded Theory which involves using:

a systematic set of procedures to develop an inductively derived grounded theory about a phenomenon. (Strauss & Corbin, 1990, p.24)

The research methods used in this study are a combination of ‘expert micro-teaching’ (EMT), ‘concurrent verbal protocols’ (CVP) and ‘retrospective debriefing’ (RD). Expert micro-teaching has been adapted from micro-teaching (Allen, 1966) for this present study as a way to learn from experienced teachers rather than for use in training. The combined use of verbal protocols and retrospective debriefing was proposed by Taylor and Dionne (2000). Underpinning the research methods and methodology are the theoretical perspective (interpretivism) and epistemology (social constructionism). In this work the

distinction between qualitative and quantitative research is seen to arise at the level of research methods (an approach recommended by Crotty, 1998, p. 15).

Numerous quantitative studies which use a positivist theoretical perspective have tried to assess the ‘impact’ of various instructional strategies on conceptual change (for example Lorch *et al.*, 2010). Indeed many of the papers in the Students’ and Teachers’ Conceptions and Science Education (STCSE) database (Duit, 2009) are concerned with learning and/or teaching strategies. However some of this research into instructional strategies for conceptual change has encountered problems. For example, a quantitative study by Smith, Blakeslee, & Anderson (1993), which used a positivist theoretical perspective, concluded:

The measures we used were at once too complicated for use in a study with a large sample size and not sophisticated enough to capture many of the important patterns of teaching and learning in the classrooms that we observed. In particular, these failed to capture the structure and sequencing of tasks and information, including, for example use of combinations of strategies. (Smith, Blakeslee and Anderson, 1993 p. 124)

This present study attempts to capture and analyse some of these “important patterns” by using an interpretivist theoretical perspective (section 3.1) and a microgenetic grounded theory methodology (section 3.2). Recording interactions between groups of pupils and their teacher on video, and managing these data using NVivo software, has meant that many examples of different teaching techniques being used simultaneously have been documented for this present study. Using teaching techniques in a sophisticated way like this is interpreted as tactical behaviour in this present study (section 4.4). The quantitative study just mentioned noted that:

[It] may be that an understanding of causal relationships between teaching strategies and student learning can best be advanced by studies relying on rich qualitative data from small

numbers of classrooms. (Smith, Blakeslee and Anderson (1993, p. 124).

It is precisely this sort of rich qualitative data which this study explores. Some positivist approaches to conceptual change teaching strategies may have encountered problems because they attempt to control variables which cannot be isolated. This present research contends that in this field, no methodology can ignore the interrelations between conceptual change, learning methods and instructional strategy (section 2.6).

As far as I am aware, interpretivist approaches have not been used in the field of integrated conceptual change research in school science. This claim is hard to verify as this area of research is now so large. Out of 8,342 papers in the Students' and Teachers' Conceptions and Science Education (STCSE) database (Duit, 2009), 176 mention strategy or strategies in the title. Of these, 36 also mention conceptual change or misconception. Almost all of these papers use positivist quantitative methodologies. One reason school science conceptual change researchers tend to use positivist theoretical perspectives could be that many of us are natural scientists. For people with this background, adopting qualitative methods from the social sciences can be challenging.

Interpretivist methodologies which combine grounded theory and the use of Verbal Protocols (Ericsson and Simon, 1993) have been used successfully to study aspects of children's thinking. For example, Pressley (2000) investigated consciously regulated reading and noted that,

Qualitative analysis of complex cognitive and metacognitive processes makes a great deal of sense before even attempting quantitative analysis of those processes. ... I believe, as do others (Ericsson and Simon, 1993), that the most telling analyses of complex, conscious, self-regulated cognitive processes have been produced using verbal protocol procedures – that is, when people have thought aloud as they performed complex tasks. (Pressley, 2000, p. 261)

Though Pressley (2000, p. 262) describes his experiences of some success using quantitative experimental approaches to investigating skilled reading, he notes “important frustrations” with this type of approach. He describes an early experience:

I started inviting people to my office, asking them to think-aloud for me as they read. What I heard was a bit overwhelming. Reader after reader provided extremely rich think-alouds, ones filled with strategies, attempts to make inferences, and great intellectual activity in general, including reflection on and evaluation of what was read. As I reviewed the quantitative, experimental studies of text processing conducted in the 1980s, what was surprising to me was that none of these studies seemed to be capturing the richness of the processing that I heard readers describing. ... Most of the think-aloud studies were designed to test particular hypotheses – to determine if particular types of processing were occurring. That is, many of the investigators believed some particular type of processing was occurring in reading and conducted their think-aloud analysis to confirm such a possibility or elucidate the processing further. I realized what was needed was think-aloud studies in which the researchers were as open-minded as possible about the processes that might be reported. (Pressley, 2000, p. 264)

Verbal protocols, when used as part of a grounded theory methodology, generate ‘high definition’ categories which are determined more by the thoughts of participants than by the methodological decisions of researchers. The trustworthiness of such data will be discussed in Chapter 3. In another interpretivist grounded theory study which used verbal protocols, Phang (2009) explored physics problem-solving and noted:

[Throughout a] symposium on metacognitive assessment in Buos, Lincoln, the method used by Pressley and Afflerbach (as cited in Pressley, 2000) – a grounded theory study using thinking-aloud – to develop the metacognitive aspect of reading and comprehension received the most praise from the contributors to this symposium (Pintrich et al.; Baker & Cerro; Schraw et al.; Schraw, 2000). Schraw et al. (2000) recognised that thinking-aloud is the only way to study control processes because it allows the students “to demonstrate overtly in a directly observable manner” (p.232). Nevertheless, the foremost reason for many researchers to avoid using thinking-aloud is

because it is extremely “labour intensive” (Tobias & Everson, 2000). (Phang, 2009, p. 39)

This present study maintains that one reason for the gap between research and practice in conceptual change strategies in school science (Duit *et al.*, 2008) could be that the methodologies used by researchers do not capture the rich dynamics in the relationships between pupils and their teacher, and between pupils, whilst learning is taking place. Nor do current methodologies acknowledge just how complicated the thinking of teachers may be as they attempt to promote conceptual change. Based on the literature review I argue that interpretivist approaches to investigating conceptual change in school science are necessary to avoid conceptual change research becoming dominated by a positivist stance.

How should research within this integrated framework be conducted? The literature review observed that researchers have favoured positivist, and largely quantitative, approaches when interpretivist qualitative research is equally significant. The approach to instructional strategy in some research involves telling practitioners to use a particular technique and then exploring how this affects learning. As a physicist, I have no problem with the suggestion that some aspects of the universe, even aspects of teacher and pupil behaviour in classrooms, can be explored using the methods of the natural sciences (whilst retaining a sceptical attitude to uncritical positivism). However, this present study considers that, at least initially, instructional techniques which teachers are already using should be explored in a similar way to the way we investigate children’s ideas and learning methods. Positivist research needs this qualitative approach to outline how the field may fit together. Instructional strategies are part of a whole which also includes conceptual change and learning methods. The actions of the teacher should be

considered as part of the phenomenon to be investigated, rather than assuming that the teacher is a bystander or researcher who can be removed from the equation.

3.1 What are the theoretical and epistemological perspectives underpinning this study?

I will look at why and in what ways this study reflects the interpretivist theoretical perspective called symbolic interactionism. Interpretivism is often associated with the work of Max Weber who understood the social sciences to be concerned with understanding (*Verstehen*). Though some (for example Dilthey, 1976, p. 104) have sought to suggest the social sciences seek understanding, whilst the natural sciences pursue explanation (*Erklären*), Weber wished to explain as well as understand (Weber, 1897, p. 228). This present study is interpretivist in that it attempts to understand and explain the variety of ways teachers promote conceptual change and to model possible relationships between conceptual change, teaching strategy and learning methods.

[Interpretivism] looks for culturally derived and historically situated interpretations of the social life-world. (Crotty, 1998, p.66)

Does knowledge of science classroom culture help or hinder this task of understanding and explaining complicated classroom dynamics? The interpretivist theoretical perspectives of symbolic interactionism and of phenomenology respond in opposing ways to this question. Symbolic interactionism explores the inherited meaning-system which is culture. Phenomenology reacts cautiously to culture and calls researchers to lay aside, as best they can, prevalent understandings so that new meanings may be revealed (Lewis and Staehler, 2010, p. 14). An assumption behind this present study is that some understanding of the meaning participants ascribe to incidents in these data is necessary, in order to explain what experienced teachers do when supporting students who express

naïve concepts. Communication in classrooms might not always be underpinned with hidden meaning, but the analysis of these complicated data demonstrates that understanding what pupils and teachers say frequently requires the use of methods which allow participants the opportunity to explain both what was said or done, and what was not said or done (for example see section 4.2.6). Hence the theoretical perspective (the philosophical stance underlying the methodology) is symbolic interactionism.

Assumptions behind symbolic interactionism are:

That human beings act toward things on the basis of the meanings that these things have for them

That the meaning of such things is derived from, and arises out of, the social interaction that one has with one's fellows

That these meanings are handled in, and modified through, an interpretive process used by the person in dealing with the things encountered

(Adapted from Blumer, 1969, p.2)

Corbin and Strauss (2008, p. 2) acknowledge symbolic interactionism and pragmatism as the philosophies which underpin their version of grounded theory. In contrast Glaser (2005) rejected the idea that grounded theory has a specific philosophical position (in particular symbolic interactionism) because he thought this would restrict the potential of the theory. The approach taken in this present study is similar to that of Corbin and Strauss. This influence can be seen in the research methods used (section 3.4), which encourage participants to explain how they understand incidents from the data. Symbolic interactionism is also evident in the way grounded theory methods are implemented (section 3.11), in the data analysis (Chapters 4 and 5) and in the discussion of the researcher effect on these data (section 6.1).

The peculiarity consists in the fact that human beings interpret or 'define' each other's actions instead of merely reacting to each other's actions. Their 'response' is not made directly to the

actions of one another but instead is based on the meaning which they attach to such actions. (Blumer, 1969, p.19)

As the theoretical perspective is a way of looking at, and making sense of, the world, it inevitably involves knowledge. The epistemology behind this theoretical perspective is social constructionism (Gergen, 2009). Epistemology encompasses:

[The] nature of knowledge, its possibility, scope, and general basis. (Hamlyn, 1995, p.242)

I see meaning in this study as coming into existence in and out of an engagement between participants (including myself) within this educational context. This engagement influences the methodology used (section 3.2), the research methods selected (section 3.4) and the theoretical perspective described above. The epistemology behind this study is therefore constructivist. But as the word constructivism is used in such a wide variety of ways, it is necessary to consider how it influences this work.

Constructivism refers to a family of theories that share the assertion that human knowledge and experience entail the (pro)active participation of the individual. (Mahoney, 1988, p.2)

‘Constructivism’, according to Ernest (1996), can refer to an epistemology, an ontology, a methodology or a pedagogy. I refer to constructivism as an epistemology in this study. The main types of constructivism (according to Raskin, 2002) are personal construct psychology (also known as constructive alternativism) (Kelly, 1955), radical constructivism (von Glasersfeld, 1995) and social constructionism (Gergen, 1985). Constructivism explores the cognitive basis of language, whereas constructionism examines language and social interchange. I am interested in understanding how individual science teachers use teaching techniques to promote and influence conceptual change within groups of pupils both directly, and through guiding the use of reasoning methods. Therefore social constructionism underpins this work. Some other researchers share the understanding of grounded theory used in this present study:

With deep roots in symbolic interactionist sociology and pragmatist philosophy, the grounded theory method can be viewed as a theory/methods package with an interpretive, constructionist epistemology. (Clarke, 2003, p.559)

The constructivist and interpretivist approach adopted here could have led to either a qualitative, quantitative or mixed methods study. Educational researchers into conceptual change teaching strategies have already used a variety of quantitative methodologies to test theories (see section 2.4). For example Smith, Blakeslee and Anderson (1993, p. 115) trained teachers in the use of specific teaching strategies, then compared pre- and post-test results for what they called “treatment” groups of pupils with control groups. Such studies can be valuable for practitioners, but need to be balanced by the qualitative approach taken here, which seeks to construct a grounded theory from what experienced science teachers appear to do to promote conceptual change in a messy context which models, to some extent, what happens in science classrooms. Here it is argued that rich qualitative data from whole classrooms are best interpreted once a grounded theory for conceptual change is in place, and that the methodology presented in this chapter can provide such a foundation.

An assumption behind this present study is that small scale, and often subtle, actions of the teacher and pupils are highly significant in how conceptual change is promoted in science classrooms. Collecting and analysing data as detailed as those explored in this present study from a teacher working with a whole class, during a single lesson in the course of a normal school day, whilst incorporating the interpretations of all participants (pupils, teacher, researcher) into the study, would be an enormous undertaking. This is especially the case, because many lessons would need to be studied, as the expression of naïve concepts and experiences of conceptual change are probably infrequent during real science lessons. Nevertheless, the context of conceptual change

being investigated needs to be similar enough to that experienced by teachers in the science classroom, that the grounded theory developed might eventually be used to interpret whole class interactions. Hence the research methods (section 3.4) are a necessary compromise between naturalistic observation, where the detail needed to address the research questions could be masked by whole class effects, and observing a teacher at work with a pupil in laboratory conditions.

This study's research methods prioritise collecting detailed data, at a fine scale, in a move to put a satisfactory theory in place which would enable whole class dynamics to be interpreted. This is similar to the way a biologist who chooses to explore a pond using a microscope, necessarily sacrifices (at least temporarily) the view of the whole pond in favour of the detailed view. This present study can be seen as microgenetic (Siegler and Crowley, 1991) in that it uses observation of individual participants (teacher and pupils) throughout the period of conceptual change, offers a high density of observations over this period, and employs an intensive analysis to attempt to infer the processes used to promote conceptual change. In consequence it should be viewed as a first step, and the theory which emerges will eventually need to be tested using whole classes. Whole class effects probably do have significant influence on the strategies for conceptual change used by teachers. However, to construct the grounded theory necessary to understand these whole class dynamics, we need the fine-scale observations made possible using the selected research methods.

[The Microgenetic] approach can illuminate both qualitative and quantitative aspects of change, indicate the conditions under which changes occur, and yield otherwise unobtainable information about short-lived transition strategies. (Siegler and Crowley, 1991, p.606)

3.2 Why analyse these data using grounded theory methods?

[The methodology called ‘grounded theory’ is a] systematic set of procedures to develop an inductively derived grounded theory about a phenomenon. (Strauss and Corbin, 1990, p.24)

The detail of what these procedures are, and how data are analysed using these ‘grounded theory methods’, will be discussed in section 3.11. This section will explain why grounded theory methods were used to analyse these data before answering various criticisms of grounded theory as a methodology. The study is an exploration of how experienced science teachers promote and support conceptual change. In the research questions can be seen attempts to address the needs of practitioners and open a dialogue with educational researchers in this field.

Symbolic interactionism has ... spawned the research methodology known as grounded theory. Grounded theory can be viewed as a specific form of ethnographic inquiry that, through a series of carefully planned steps, develops theoretical ideas. Throughout the process, it seeks to ensure that the theory emerging arises from the data and not from some other source. It is a process of inductive theory building based squarely on observation of the data themselves. (Crotty, 1998, p.78)

Why use grounded theory methods to analyse the rich qualitative data collected? Firstly, the research questions are open-ended, and do not involve testing hypotheses, so can be seen as well suited to grounded theory. Secondly, grounded theory methods (which Crotty above calls “carefully planned steps”) offer an approach to these qualitative data which is intelligible to the research community. Thus the methodology (grounded theory) provides a justification for the data analysis procedures used (grounded theory methods). Indeed a similar methodology (combined grounded theory and the use of Verbal Protocols) has been used successfully to study aspects of children’s thinking (Pressley, 2000; Phang, 2009 - see section 3.0). Thirdly, it has been argued by Corbin and Strauss (2008, p. 2) and Bryant and Charmaz (2010, p. 31), that grounded theory is underpinned by an

interpretivist theoretical perspective (symbolic interactionism). The use of the participants' interpretations of data in this study, indicate that meaning is here seen to arise out of the engagement of participants (including teachers, pupils and researcher) with each other in this social context. The practice of experienced teachers can be observed in considerable detail, and practitioners offer and discuss their own interpretations of incidents, using this combination of methods. In contrast, the traditional 'quasi-scientific' methodologies mentioned earlier do not investigate the variety of meanings which incidents in these data may hold for participants. Fourthly, grounded theory is action or interaction orientated, according to Strauss and Corbin (1990, p. 104). In this present research, theory is derived from observations and views of participants, to explain complicated interactions between pupil and teacher, as well as pupil and pupil. At the heart of this study is an exploration of the relationships between conceptual change, learning methods and teaching strategy and grounded theory was designed to aid the exploration of such complicated associations. Finally, from the very beginning, grounded theory was seen as a challenge to "theoretical capitalists" and a defence of the "proletariat testers" (Glaser and Strauss, 1967, p. 11).

The researcher can use his or her own concepts generated from the data instead of using, and probably forcing, the received concepts of others, especially those concepts of unduly respected theoretical capitalists. (Glaser, 2002, p. 23)

Whilst recognising the slightly 'dated' sound of these claims, research into strategies for conceptual change has got bogged down in trying to test the effectiveness of various instructional strategies (for a review see Chapter 2). The grounded approach in this present study aims to offer a way through this impasse. Hence grounded theory was considered a suitable methodology for the exploration of the rich qualitative data which emerged from the research methods (see section 3.4).

Some of the criticisms of grounded theory will now be discussed along with the ways in which they have been accommodated or rejected. Some critics of grounded theory would modify it (for example Emerson, 1983, Katz, 1983, Lofland and Lofland, 1984, Burawoy 1991, Haig, 1995, Robrecht,1995, Dey, 1999, Silverman, 2001, Bryant and Charmaz, 2010), whereas others would reject it completely (for example Layder 1998, Spalter-Roth, 2005, and Thomas and James, 2006). ‘Modification’ criticisms are centred on three issues according to Thomas and James, each of which will be discussed next:

[First], that grounded theory oversimplifies complex meanings and interrelationships in data; second, that it constrains analysis, putting the cart (procedure) before the horse (interpretation); and third that it depends upon inappropriate models of induction and asserts from them equally inappropriate claims to explanation and prediction. (Thomas and James, 2006, p.768)

In response to the first point, the methodology for this present study has been specifically designed to capture something of the complex meanings which participants ascribe to these data. Layder (1998) maintained that grounded theory cannot,

[Take] into account the layered and textured nature of social reality (its ontological ‘depth’) (Layder, 1998, p.27).

Some grounded theory studies may oversimplify complex meaning, but I would argue that the findings of the present study are anything but simplistic. The whole project can be seen as a challenge to those who propose simple models of strategies for conceptual change (for example Clement, 2008, p.445).

The interpretivist theoretical perspective led to the choice of grounded theory, and guides the way grounded theory methods are used. So I would also reject the second point by Thomas and James that this particular grounded theory study is dominated by the use of procedures and neglects the importance of interpretation.

The third point by Thomas and James (2006, p.768 - quoted above) is the charge of naive inductionism, which has also been made by others against grounded theory (for example Haig, 1995, and Layder, 1998):

Devotees of grounded theory have yet to make a case that their kind of theory possesses characteristics of induction in the way that natural scientists' theories may. (Thomas and James, 2006, p.774)

There are two purposes of experiments in the natural sciences: to test a hypothesis (deduction) and to create a pattern of findings with which to make a hypothesis (induction). By induction Thomas and James make clear that they mean:

“For all x and some y if x has property ϕ , then y has property ψ ”
MacIntyre (1981, p. 91)

So as bananas (x) have the property of being yellow (ϕ), we can say that some fruit (y) are bent (ψ). Their point about a grounded theory is that it cannot be said, in any precise way, under what conditions it is true. This is a fundamental challenge to the social sciences, but the final point made by Thomas and James (2006, p.768 - quoted above), that it is inappropriate to claim that a grounded theory ‘explains’, makes clear that underneath the charge of naïve inductionism they are making an assumption about the social sciences which is hotly contested by sociologists. Thomas and James think interpretivism is only concerned with understanding:

[To] the question of Miller and Fredericks (1999), ‘How does grounded theory explain?’, we would answer, ‘It doesn’t,’ because grounded theory procedures are a scion of qualitative inquiry, and qualitative inquiry is about interpretation. It is about—using Ricoeur’s (1970, p. 33) well-known distinction—understanding before explanation. (ibid. p.772)

I would argue, following Weber, that the methodology used can lead to both understanding and explanation. Indeed Weber defined sociology as:

[A] science which attempts the interpretive understanding of social action in order thereby to arrive at a causal explanation of its course and effects. (Weber, 1897, p. 228)

In this study we follow Weber (see section 3.1) in attempting to develop something (here called a theory - see below) which will both aid understanding and explain, to some extent, some of the ways experienced science teachers promote conceptual change. The position Thomas and James (2006) criticise was seen by Crotty (1998) as an aberration:

In more recent times, interpretivism seems to have largely cut itself loose from these traditional moorings [i.e. Weber's interpretivism]. (Crotty, 1998, p.71)

Though the link between understanding and explaining envisioned by Weber was lost to interpretivism for a time, the undermining of claims to objectivity in the natural sciences has led to a rapprochement between hard science and the social sciences according to Crotty (1998). Indeed this present study is an investigation by someone trained as a physicist, using social science methods, to explore science teaching within a social context.

As another criticism of grounded theory, Thomas and James (2006, p. 772) follow the philosophical tradition of dividing science into logic of discovery and justification, and rejecting the idea of a logic of discovery (Hans Reichenbach, 1938). Whilst acknowledging the point that:

One must be careful ... that in creating something called 'theory' (together with a set of procedural accompaniments for finding it) one does not inhibit rather than liberate discovery. (Thomas and James, 2006, p.773)

some philosophers of science (Hanson 1961; Darden, 1991), have argued that a logic of discovery can be justified, and this is the position adopted by this present study as was argued in section 2.3. The use of the word 'theory' by grounded theorists is sometimes

criticised and the point made above by Thomas and James (2006, p.773), that the labelling of something as a theory requires some justification, will be discussed next.

A whole range of meanings of the word ‘theory’ used within qualitative research have been identified:

[Systems] of evolving explanation, personal reflection, orienting principle, epistemological presupposition, developed argument, craft knowledge, and more. (Thomas and James, 2006, p.771)

This diversity of meaning led Fish (1989, p. 14) to reject such ‘theory talk’ as meaningless. In this present study, the grounded theory, the evidence supporting this and the criteria used to establish the trustworthiness of the conclusions are presented. It was argued by Lincoln and Guba (1985, p. 316) that it is for those who use grounded theories to establish the extent to which they transfer to other contexts. I think the grounded theory developed here can be transferred and used to explain and understand the ways in which teachers promote conceptual change in science lessons (see section 6.2.2), but further research would be necessary to confirm this. The criticism by Fish (1989, p. 14) and others, that qualitative research only calls what it produces a theory in order to be taken seriously, invites analysis of the motivations and methodological posturing of those who use this attack.

Other points by ‘modification’ critics have been useful in designing the methodology. For example, the detailed discussion in section 3.1 is a response to the charge of epistemological naivety made against some grounded theory studies (Emerson, 1983, Katz, 1983). The grounded theory used was open to constructivist grounded theory (Bryant and Charmaz, 2010, p. 10) as the methods used would have been adapted if necessary as the study progressed (chapter 4). The charge has been made by Lofland and Lofland (1984) that grounded theory methods are sometimes used in a slipshod way, so great care was taken in the ways these methods were implemented (section 3.11). I do not

think that the categories in these data identified are trite, as Silverman suggested is often the case with the results of grounded theory studies (2001, p. 71), but perhaps this is for the reader to judge. Qualitative studies such as this are sometimes criticised for using a small sample size (Bryant and Charmaz, 2010, p. 177), and a justification for this has been given in section 3.6.

It is of course possible to use other research methodologies to investigate conceptual change strategy. However, earlier (section 3.0) I argued that quantitative studies have not narrowed the gap between research and practice in this field, and may even have widened it inadvertently. Other qualitative methods, from what Biddle and Anderson (1986) call the ‘discovery perspective’ (for example, phenomenology), do not provide a rigorous mechanism to ‘verify’ theory generated according to Lichtman (2006, p. 65 and 73). The verification criteria for “naturalistic studies” proposed by Lincoln and Guba (1985, p. 328) are all used in this grounded theory research. These verification criteria, and how they are applied in this study, will be discussed in section 3.10. Some critics who would reject grounded theory, have adopted different epistemological foundations to the one used in this present study, or use alternative theoretical perspectives. For example, Spalter-Roth (2005, p. 6) criticises grounded theory as being ‘un-scientific’. I would argue that grounded theory is not trying to be scientific, in the sense of using an objectivist epistemology with a positivist theoretical perspective. In this present study I use a constructionist epistemology with an interpretivist theoretical perspective.

3.3 What potential difficulties are there with this methodology?

There are several types of grounded theory, and any lack of clarity in the epistemology and theoretical perspective underlying a grounded theory study could result

in methodological confusion. For example a division occurred between some ‘first generation’ grounded theory-theorists in the 1990s. Glaser (1992) thought that theory only emerges from data through the ‘Constant Comparative Method’ (described in section 3.11). He claimed that Strauss and Corbin (1990) allowed theory to be ‘forced’ because of preconceptions, analytical questions, hypotheses and methodological techniques. Strauss and Corbin (1998) claimed their earlier work was simply an introduction for researchers new to grounded theory, and that Glaser’s critique was unfair. However, Bryant and Charmaz (2010) argue that these disagreements were caused by differences in the theoretical perspectives underpinning the approaches of these researchers. The interpretivist theoretical perspective underpinning the grounded theory used for this present study is similar to that of Strauss and Corbin (1998), so the way they implement the grounded theory procedures is appropriated here.

We know that we never can be completely free of our biases [so we must] ... acknowledge that these influence our thinking and then look for ways in which to break through or move beyond them. (Strauss and Corbin, 1998, p.99)

Grounded theory studies take time, and grounded theory methods are “painstaking” (Glaser, 1978, p. 16). Time was a particular challenge in this PhD study. The focus has been restricted in several ways in order that the project is manageable. For example, the teachers work with a small group of children rather than the whole class. A questioning route and resources are provided to help the teacher during the expert micro-teaching interview (appendix B). This focuses discussion on particular scientific topics. In more open-ended research such restrictions may not be necessary.

I am conscious that experienced grounded theory researchers note that ‘theoretical sensitivity’ is difficult to acquire, and that grounded theory data analysis is extremely rigorous (Glaser, 1978). In grounded theory, substantive theory explains phenomena in

one particular context. If substantive theory achieves ‘theoretical saturation’ (see section 3.11), a formal theory is possible which explains a phenomenon in a wider context (Glaser and Strauss, 1967, p. 31). This will be discussed further in Chapter 6.

3.4 Research methods

The research methods (instruments) used in this study are a combination of ‘expert micro-teaching’ (EMT), ‘concurrent verbal protocols’ (CVP) and ‘retrospective debriefing’ (RD). Using a combination of concurrent verbal protocols and retrospective debriefing was proposed as a research method by Taylor and Dionne (2000). They compared how lecturers and university students solve problems in biology. Their “research based guidelines” for CVP-RD (Taylor and Dionne 2000, p. 413) were used in this study.

The complementary use of CVP and RD data has the potential to access [a broad] range of strategy knowledge, generating a more comprehensive account of problem-solving strategy knowledge than either method used alone. Despite apparent advantages, the complementary use of CVP and RD data is uncommon in the research literature. (Taylor and Dionne, 2000, p.413).

Each of these research methods will now be described and the reasons why they were chosen and combined for this present study will be examined. Concurrent Verbal Protocols will hereafter be called verbal protocols (VP).

3.4.1 Expert micro-teaching

Micro-teaching (Allen, 1966), a method designed to train new teachers, is here adapted into an instrument for learning from experienced teachers. The reasons for using this method, and why it is used in combination with verbal protocols and retrospective debriefing, will be discussed in section 3.5. Six science teachers, who have qualified as Advanced Skills Teachers, were recruited for the study (see section 3.6 for more on participant selection). Every expert micro-teaching session is recorded on video and lasts

approximately one hour. Each involves six pupils (three girls and three boys) from Year 7 (aged 11 or 12), with one teacher, sitting around a table. Therefore in total 6 teachers and 36 students took part in this study. Discussion ranged over topics in chemistry (heating and cooling), biology (living things) and physics (light). A questioning route, following the advice of experts in the running of group interviews (Krueger and Casey 2000), was developed to help direct the attention of these groups into discussion around each of the three topics (see appendix B for the questioning routes).

The topics were identified from a review of the ‘science misconceptions’ literature, popular among science teachers, by Driver *et al.* (1994 - see section 2.1). They were chosen as ones where students are likely to have a variety of naïve ideas. Three resources were provided to support these discussions. The ‘heating and cooling’ topic focused on a cup of tea and a bowl of ice cubes (Figure 1 below). A ‘card sort’ activity was designed for the ‘living things’ topic. A teddy bear and torch was used by participants during the ‘light’ topic and pupils were given access to small whiteboards and pens (later paper and pencil). Figure 2, Figure 3 and Figure 4 below illustrate firstly how I would sort the cards on these mats, secondly how one pupil from the first EMT interview sorted the cards (see Appendix E - interview 1a for the transcript) and finally the card sort activity in use during the second EMT interview. When comparing Figure 2 and Figure 3, this pupil and I do not appear to agree about whether the sun, seeds, and the bicycle are living or not.



Figure 1: The cup of tea, bowl of ice cubes, teddy bear and torch used in the EMT interviews

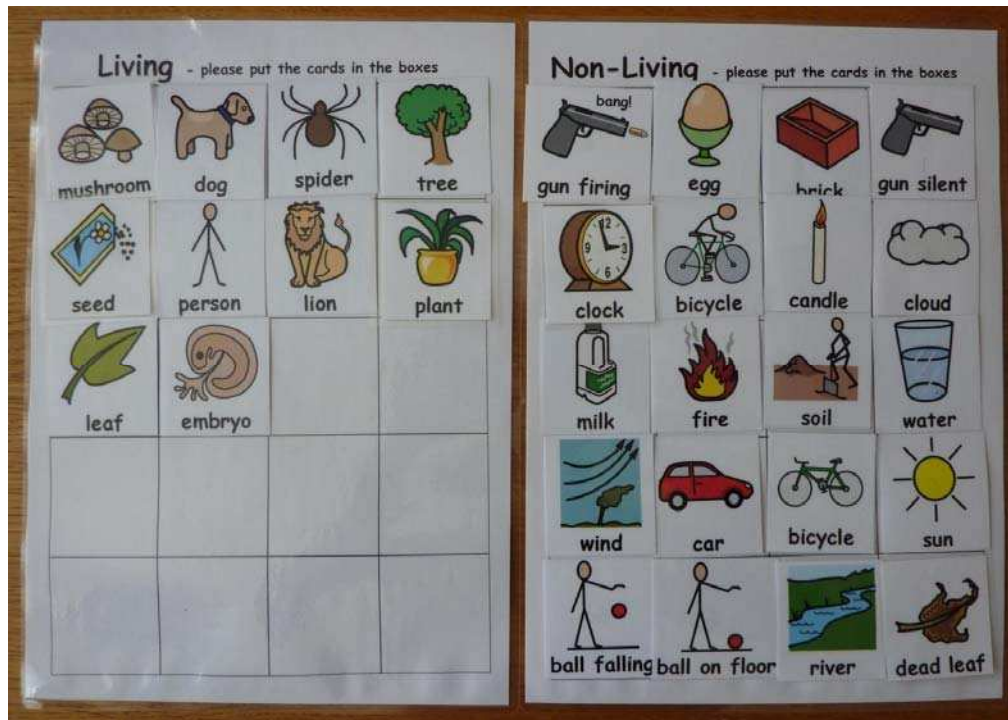


Figure 2: The card sort activity used in the EMT interview completed by me (© Widgit Software 2013 - used with permission)

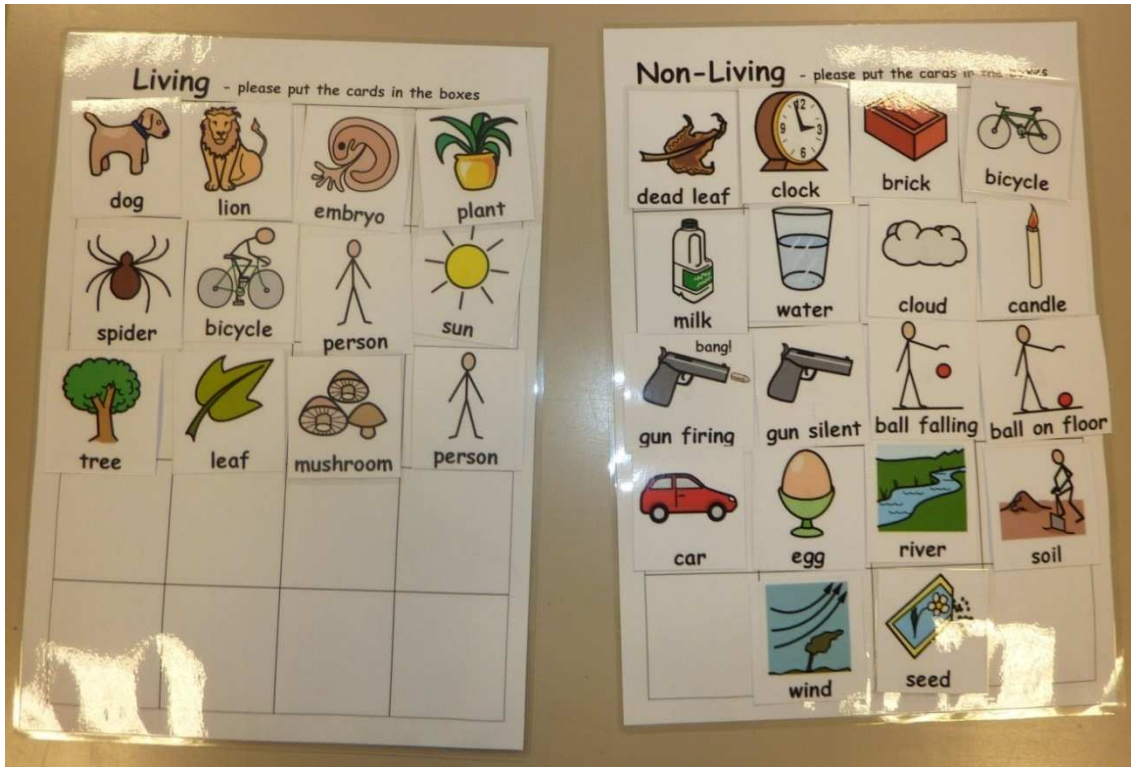


Figure 3: The card sort activity used in the first EMT interview completed by a student (© Widgit Software 2013 - used with permission)

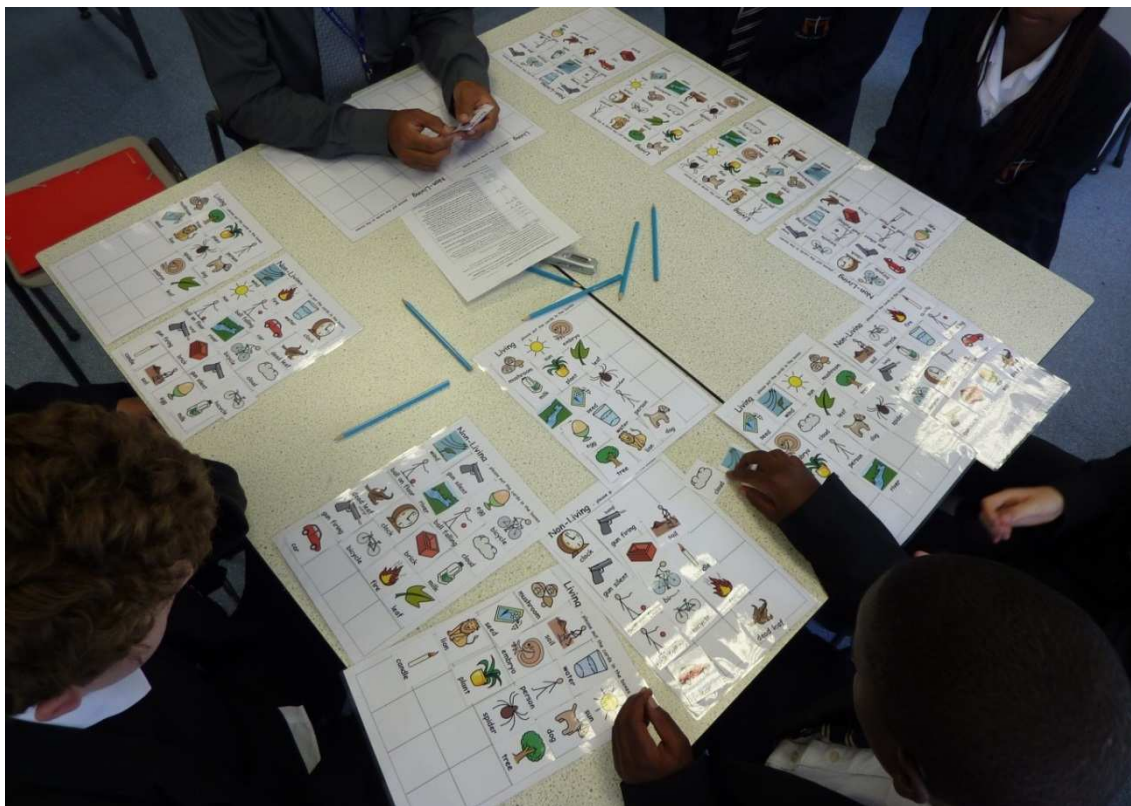


Figure 4: The card sort activity used in the second EMT interview completed by a group of students (© Widgit Software 2013 - used with permission)

The same resources were used in all the EMT sessions. The key questions from the EMT questioning route (see appendix B, questions 4a, 4b and 4c) were, respectively:

Please tell me what is happening to the hot tea and the cold ice cube in as much detail as you can.

Please sort these cards onto the spaces on the two mats quickly: one for living things and the other for non-living things. Try not to look at what your neighbours do as the idea is to explore the different ways in which we might understand the word 'living'. It is OK to have your own ideas on this and you can change your mind later if you want.

Please imagine you walk into a completely dark room with that torch on and you see teddy. Please make a quick sketch showing the torch, teddy and your eye which explains how you can see the bear. Stick people are fine. We'll talk about our ideas afterwards.

Participating teachers were asked to choose three boys and three girls at random from their Year 7 class. Sessions contain equal numbers of girls and boys where possible. The selection of participants will be discussed in more depth in section 3.6.

3.4.2 Verbal Protocols

Verbal protocols (VPs) involve the participating teacher watching, and commenting on, short video clips from the EMT video where a pupil expresses a naïve concept (Van Someren, Bamard and Sandberg, 1994). VPs have been used before by Pressley (2000) and Phang (2009) to explore children's thinking. Each participating teacher 'thinks aloud' as they watch these video clips while being recorded on video. This allowed the teacher's reasoning to be explored as they explained how they 'solved', or would solve, some of the issues which were raised in the EMT session. This VP interview lasted 30 minutes. It would not have been possible within a small scale study like this to show all six and a half hours of EMT video to participants and record and analyse their verbal protocols. Only 1 hour 48 minutes of EMT video were shown to the six participant

teachers in total, yet the verbal protocol interviews alone lasted 5 hours 34 and minutes in total. Even if it had been possible to show each teacher their entire EMT video, this may have meant the focus from the research questions on how experienced teachers promote conceptual change being lost. Grounded Theory Methods involve theoretical sampling (see section 3.11) where cases are selected in order to better understand aspects of complicated phenomena.

Video clips were selected using the following criteria: where a pupil had expressed what appeared to be a naïve concept or used a learning method; where I wished to compare my interpretation with that of a participating teacher; and/or where I was not sure how to understand an exchange during an interview. As findings emerged these influenced the selection of clips used in subsequent VP interviews (a process called ‘theoretical sampling’ within grounded theory (Corbin and Strauss, 2008, p. 146)).

The rationale for the selection of the clips evolved during the study (another Grounded Theory Method called ‘constant comparative analysis’ discussed in section 3.11). The methods used in this study do pre-empt each participant’s own choice of which sections are important. Many things are important during lessons and this study explores only one aspect of what occurred during these EMT interviews. Using the selection of clips to maintain the focus of this study on the complicated interactions between participants which occurred whilst pupils expressed naïve concepts was considered a necessary compromise. Clearly the selection of clips represents one of many significant influences of the researcher on data collection and analysis, which will be evaluated in section 6.1.1.

3.4.3 Retrospective Debriefing

Immediately after the VP interview, the teacher was interviewed for a further 30 minutes in what is called ‘retrospective debriefing’ (RD). This used open-ended questions

and a questioning route. The questioning route was adapted in the light of previous interviews while the study progressed (theoretical sampling). Two versions of the RD questioning route can be found in appendix B.

3.4.4 General points about the research methods

All three types of interview were recorded using two video cameras filming from different angles (with an audio backup on the table). For EMT this allowed the faces and gestures of participants to be seen whilst they sat in a circle around a table. This seating arrangement helps encourage discussion between participants. The different filming angles meant that events necessary for understanding the EMT interview can be seen from one camera, even if they are obscured in another.

There was a delay of approximately one month between the EMT session and the other interviews (VP and RD). This allowed time firstly for the EMT video to be analysed using the grounded theory techniques described in sections 3.2 and 3.11, secondly for video excerpts from the EMT to be edited for use as prompts in the VP interview, and finally for questions based on the analysis to be prepared for the RD interview. The time delay between EMT and the VP/RD interview was therefore unavoidable given the research design, but does represent a limiting factor on the trustworthiness of these data. For example participant teachers may have forgotten how they understood some event which occurred during the EMT interview when they came to do the verbal protocol some weeks later. However, the additional time for reflection may also be seen as a potential advantage (Schön, 1983). The implications of this interruption will be discussed in section 6.1.1. The combination of EMT, VP and RD interviews with six participating teachers accumulated a rich data set (approximately 15 hours of video).

3.5 Rationale for research methods

Five arguments were made in section 3.2 for why grounded theory was a suitable methodology for the exploration of the rich qualitative data which these research methods unearthed. The research methods proposed (combined EMT, VP and RD) are a suitable way of gathering data for the open-ended research questions guiding this study. In this section several other reasons why it was decided to develop expert micro-teaching (EMT) as a research method, and to use this in combination with verbal protocols (VPs) and retrospective debriefing (RD), will be discussed. Firstly, as was argued in the introduction (Chapter 1), most research into teaching strategies for conceptual change uses quantitative methods to test theories in order to try and establish the effectiveness of various ‘strategies’ (instructional techniques). Although it has its merits, this cannot capture the subtlety of what experienced teachers do. Combined EMT, VP and RD allow the messy interactions between a teacher and students to be examined while learning is happening. Furthermore it gives practitioners the opportunity to watch this process on video and express how they understand these complicated dynamics.

Secondly, in my experience observable ‘evidence’ of conceptual change is rare in busy science classrooms. Collecting evidence from science classrooms going about their normal business would have greater ‘ecological validity’, but would take more time than is available and require a team of researchers like Kounin (1970) used to explore classroom management. Such an approach is not possible within a PhD. The EMT context gives six pupils and a teacher ample time to discuss in depth complicated scientific ideas. Video recordings, and the use of NVivo software (section 3.8), meant these data could be revisited over and over as the analysis proceeded (called ‘concurrent data collection and analysis’ by grounded theorists - Elliot and Lazenbatt, 2005). EMT as

a research method concentrates opportunities for expressing naïve concepts, for collecting evidence of teachers (and pupils) using a variety of strategies to address such thinking, and for allowing evidence of conceptual change to emerge.

Thirdly, the teacher is not distracted by the need to manage a large group of children. The focus of the research questions is on conceptual change. Normal lessons involve many disturbances like the taking of registers, behaviour management issues, bees flying in the window etc. The pupils in the EMT sessions, though interacting in realistic ways with the others in the group, do not have to compete with 29 other children for the teacher's attention. The 'transferability' of conclusions emerging from EMT, VP and RD data to normal classroom context will be discussed later (see section 6.2). Finally, using a 'questioning route' during the EMT sessions allowed the discussions to focus on topics about which pupils are known to have a huge range of 'naïve concepts'. It would be much harder to gather evidence on the interactions between 30 children and their teacher in a normal classroom and to keep track of all the issues being discussed (often simultaneously). Using a questioning route meant that the way the six teachers dealt with similar pedagogical challenges could be compared.

3.6 How were participants selected?

Six Advanced Skills Teachers (two biologists, two chemists and two physicists) were involved in this study. Teachers were recruited from among 211 secondary school science Advanced Skills Teachers in the UK, and those who worked closer to my home were invited first. Hence a convenience sample was used. Such teachers pass a national assessment to show they meet certain standards (DfE, 2009) and are appointed to an Advanced Skills Teacher post. The title of Advanced Skills Teacher indicates that the participant is an experienced teacher with recognised aptitudes in the classroom, which

was why this type of teacher was recruited for this research. However, one of the Advanced Skills Teachers in this study had just been awarded this status, whilst others had had this role for years. The participating Advanced Skills Teachers were selected as they represent an expert group, but it is recognised that this title hides huge variations in experience and skill between these people. The size of the sample needed to be balanced against the depth of analysis. As the theoretical perspective is interpretive, it was decided to use a small sample size so that these data could be examined in considerable detail. The extent to which such a study can provide trustworthy evidence is discussed next in section 3.10. All these teachers will have experience teaching science subjects outside their specialism, since the evidence of domain-specific issues as regards conceptual change (Wellman and Gelman, 1992; Vosniadou, Vamvakoussi and Skopeliti, 2008, p. 15) indicates that listening to science teachers teaching within and outside their specialist areas could be significant.

Participant teachers were chosen from a list of all the Advanced Skills Teachers in the UK. Selection criteria were that they were specialist science teachers and working in the South East of the UK in non-selective state schools. The choice to work with Advanced Skills Teachers in science subjects was influenced by my background as an experienced science teacher and the wish to work with an expert group (see section 3.6). The geographical focus was for my convenience. Non-selective state schools (comprehensive or secondary modern) were used to try and ensure participants were representative of the vast majority of teachers in the UK, but I am conscious that my views on selection in education may have influenced this decision. I contacted participants by email (see appendix A) and using the telephone, with the latter technique being more successful in recruitment. Over the telephone I tried to use a similar invitation to the email message, but the nature of such a conversation means that I may have given

more information about the study than was contained in the email. Sixty-four teachers were contacted in total, and eventually six agreed to participate. Several asked about how or why they had been selected, and the criteria mentioned earlier were always explained in these circumstances. Hence some teachers knew the criteria I used to select participants and others did not, and this could influence the data collected for this study. The criteria could have been given in the email sent to participants, but I felt that it was important to keep this as short as possible as busy teachers were unlikely to read or appreciate a lengthy correspondence, and so might have been put off from taking part in the study at all.

There were many reasons given by teachers who chose not to take part, the most common being that they were too busy, permission was not given by their line-manager, or that they did not wish to take part. Clearly the reasons given by teachers for not taking part may not be their real reasons (see section 4.2.6). With such a small sample size I felt that it was not possible to interpret non-participation as being more significant than the obvious conclusion that teachers in schools are busy. Several teachers had moved from the school since the list had been made, or did not reply to the email and could not be contacted by email and telephone.

Each participating teacher (and one teacher who eventually did not take part) was visited at their school a few weeks before the EMT interview in order for me to explain more about the project and to answer their questions. Undoubtedly this preliminary meeting influenced the data collected for this study. Teachers in the UK are now very familiar with people from inside the school and outside coming into lessons and observing for a variety of reasons (for example for teacher training, Continuous Professional Development, inspections etc.). During the initial visit I stressed the way all data would be anonymous for this study, in order to allay fears by participants that a

different performance from their normal work was expected (a significant problem with inspections in the UK). I also presented myself as a colleague with experience in science teaching. Clearly my status as a colleague from another school may influence the data collected. Potential benefits include participant teachers being more willing to discuss challenging aspects of their work with a colleague who may have some understanding of the particular difficulties associated with science teaching. However participants may assume that some aspects of their work do not need to be described to a researcher familiar with secondary school science teaching, or might mean that they would be more likely to feel that they had something to prove. Researcher effects on these data will be discussed later in the light of the findings in section 6.1.

Demographic differences between pupils are minimised as much as possible, by choosing participant teachers from the same type of school (non-selective comprehensive or secondary modern schools in the south of the UK). Teachers were asked to pick three girls and three boys at random from their own Year 7 class. In order not to disrupt the teacher any more than necessary, it was decided not to ask the teacher for any more details of this selection. Thus convenience sampling was used in the selection of pupils. I am aware that selection of pupils by some participating teachers may be far from random. The decision to ask participating teachers to select pupils 'randomly' for the EMT interview, discussed in section 3.6, has significant implications for the quality of the data collected. This convenience sampling meant the teacher could use their judgement to select pupils who were likely to have the confidence to speak with others in a group. Had I made a random selection of three girls and three boys from the class list, it is possible that a combination of students who worked badly together as a group would result. I am conscious of a wish to cause as little inconvenience to participating teachers as possible and the need to ensure that the group will talk with each other. English was an additional

language for two pupils (VH and LM) and one teacher (TV) and this will be discussed in section 6.1.2.

Asking the teacher about how they selected pupils after they have selected the pupils, but before the EMT, VP and RD data was collected, was possible, but risked having an effect on the interview. For example, the teacher might feel that their judgement in forming the group was being questioned, and this might affect how the teacher answered subsequent questions. I am aware of taking a decision to allow the teacher to make the actual selection of pupils and the consequences of this will be discussed in section 6.2. Teachers were also encouraged to pick students who would be comfortable talking in an EMT session, as pupils who say nothing provide minimal data for this work. The pupils selected are therefore more likely to be people who are confident speaking in this particular group, which could be caused by any number of factors. Researcher influence on these data will be discussed in sections 3.9 (ethical considerations) and section 6.2.

3.7 Research phases

3.7.1 Phase one: scoping of the field

Several practical issues which occurred during the data collection and analysis will be discussed briefly now. Some will be considered in more detail during the data analysis (Chapters 4 and 5). The expert micro-teaching research method was trialled with a group of fifteen year-old students. I took the role of the science teacher. This interview was videoed and analysed to trial the research methods, test the recording equipment and experiment with NVivo software. Lively discussion of science topics within the group, the expression of a host of 'naïve concepts', and evidence of conceptual change, showed that this was a viable way of exploring conceptual change, learning methods and teaching

strategy. A wider range of topics were discussed during this interview than in the main study and more resources were used. It became clear that a much narrower focus would help when it came to comparing the practice of a range of teachers. As a result, questioning routes for the research methods were written and only three topics are used (heating and cooling, living and non-living, and light) with one resource to support each area of discussion.

The decision, following the scoping of the field, to work with Year 7 students (aged 11 or 12) rather than Year 10 students in the scoping of the field was for convenience. Year 10 students have many exams and teachers and schools are less likely to allow them to have time away from their studies than Year 7 students. Pupils in Year 7 are likely to express more naïve scientific concepts than older pupils, hence EMT interviews with this younger cohort might be expected to provide more opportunities to see what participant teachers do to promote conceptual change. Challenging behaviour might be more prevalent with adolescent participants than with younger pupils, which could lead to more irrelevant exchanges as regards the focus of this present study. Older pupils may be more adept at hiding their embarrassment about naïve scientific concepts than younger pupils, so may be a harder age group to explore.

3.7.2 Phase two: the investigation

Noise from adjoining rooms and corridors might have disturbed participants during interviews but this did not appear to cause significant problems. Noise from outside the interview rooms, and within, sometimes made it hard to hear parts of the audio recording (even though two video cameras recorded audio and a back-up audio recorder was placed in the middle of the table). Where it was not possible to determine what was said, 'unclear' was written in the transcript.

Emotional and behavioural management tactics were coded, even though this was not the focus of this research, because I think the conduct of participants can influence conceptual change and the tactics used. For example, one participating student was sent outside to calm down for 1½ minutes by a teacher during the EMT interview 1a (see 1a:209-216). Clearly this event, and the discussion he missed during this time, could influence his understanding of the topic and the way he and others subsequently spoke and acted. Some teachers may be better than others, because of the tactical and strategic way they use the techniques at their disposal, at cultivating an environment in the classroom where hidden and embarrassing thoughts are more likely to be expressed and discussed. How sensitivity to the emotions of children infuses tactical and strategic behaviour by teachers could be further investigated within this data set (for example see 1c:1-2 and 37; 3a:258 and 4c:32 and 46 in appendix E).

Participating teachers did not always use the exact wording from the EMT questioning route (even though they were all asked to use the exact wording when introducing each topic). This variation did not appear to have a significant effect on participants. The exact words used by participants were used in the transcripts. Participating teachers were asked not to prepare for the interviews. It was felt that busy practitioners were more likely to take part in this study if there were assured that no preparation was necessary. However, for various reasons, some might have prepared for these interviews anyway. One participant made a PowerPoint resource to use during one of the interviews (this person was asked not to use it).

3.7.3 Phase three: data analysis

I attended training in the use of NVivo before beginning data analysis. I am aware that I learnt more about using the software during the data analysis, and that this impacts

on the analysis. This can be seen as ‘theoretical sensitivity’ developing during the research process, which is a feature of grounded theory (section 3.11).

Inter-rater reliability checks for grounded theory studies at the level of ‘initial coding’ (see section 3.11) are desirable according to Thompson *et al.* (2004) so as to try and mitigate subjective bias. However the grounded theory method of ‘intermediate coding’ (see section 3.11) is not suitable for inter-rater reliability checks as this identification of themes goes well beyond simply describing incidents in the data (Miles and Huberman, 1994). Such intermediate coding would require researchers to discuss and compare their interpretations of what emerged during initial coding. NVivo software used in this present study (see section 3.8 below) can check coding consistency using a ‘coding comparison query’ to measure ‘inter-rater reliability’. This gives a percentage agreement and a Kappa coefficient (i.e. a statistical measure which takes into account the amount of agreement between two users which could be expected to occur through chance). Though inter-rater reliability checks offer self-evident benefits to quantitative researchers,

It would be wrong to assume that such advantages are transferred automatically to qualitative research. Whilst there is nothing in the process of calculating Kappa per se that prevents its use in qualitative research, several epistemological and ontological differences need addressing if it is to be used sensitively and with respect for qualitative methods’ theoretical roots. These differences are reflected most vociferously in the debate surrounding the relative merits and demerits surrounding the nature of reliability in qualitative research. Inter-rater reliability is a feature of some qualitative research (Armstrong, 1997; Carey et al., 2000; Roebuck et al., 2001). However, few papers make use of formal Kappa. Where they do, discussion of the place of quantitative measurement of agreement in qualitative studies is rare and cursory (Carey et al., 2000). We have found no other examples of the use of the multi-rater version of Kappa. (Thompson *et al.*, 2004, p. 16)

Hence using inter-rater reliability checks within the present study, with sensitivity to the methodology, would not automatically make the study better. The transferability of the research findings will be discussed in section 6.2.2 and the dependability and confirmability of the grounded theory in section 6.2.3. The main reason such checks were not used is that within the practical limitations of such a small scale study, it is simply not possible to get volunteers to recode all 14 hours and 49 minutes of video data, which would involve months of work. With such large amounts of data, some variation within coding ‘reliability’ should be expected due to operator error, and from the difficulty inherent in interpreting such a rich data set.

3.8 Why use NVivo software?

The use of Computer Assisted Qualitative Data Analysis Software (CAQDAS) is now so widespread that the United Kingdom Economic and Social Research Council (2009, p. 18) call for “direct practical experience” as part of postgraduate training and development. The way CAQDAS is used depends upon the methodology, so Bringer, Johnston and Brackenridge (2004, p. 247) recommend that research using NVivo to support a grounded theory study should include a discussion of how the software is used (for this see below and section 3.11). The careful consideration of how software can support analysis should help resist what Coffey, Holbrook and Atkinson (1996) call the ‘homogenisation of methodology’ by CAQDAS. NVivo was selected for this study, rather than one of many alternatives (for example MAXQDA, Qualrus, Atlas, Transana, HyperRESEARCH and QDA miner) because in a recent expert review (Lewins and Silver, 2007) NVivo was seen as the most suitable software for a grounded theory study. Although NVivo 9 accommodates a wide range of qualitative research methods, it is particularly well suited to this grounded theory research. For example, findings can be

rigorously justified by links to the original video evidence. Large collections of each type of teaching technique can be compared, and subdivided easily, so that subtle actions of the teacher (and pupils) can be identified. As the grounded theory develops, data that has been coded in one way can be renamed and reclassified easily so that different relationships between codes can be trialled.

Interview videos were imported into NVivo software and transcripts were made which included the duration of each phrase (hereafter called time-spans). This allows statements by participants on the video to be re-examined very quickly and easily in context. NVivo was used in the data analysis procedures required by grounded theory (section 3.11) to explore these data. All 14 hours and 49 minutes of video were imported into the software and transcripts made (with accompanying time-spans). The software allowed a hierarchical coding grid to be constructed and modified as these data were coded. Each word or line in the transcript can be coded in several different ways simultaneously. Data which has been given the same code can be easily retrieved so that variation among these data within a code can be reviewed and discussed. The software keeps a complete record of changes to the coding system and ‘memos’ (section 3.11), so that both are available for auditing, as part of the ‘verification’ procedure (see section 3.10). Diagrams (called models) showing possible relationships between the different codes were generated and saved, so that the evolution of these models could be traced (see for example Figure 5 and Figure 7 on page 94). Several powerful search tools (for example ‘queries’) allowed these data to be explored in detail.

Potential problems with the use of NVivo to support a grounded theory study have been debated in the literature (Bringer, Johnston and Brackenridge, 2004, p. 248). For example, is it appropriate to use computers to analyse qualitative data? Does using NVivo change the way analysis is conducted? Does using CAQDAS increase or reduce the

quality of qualitative research? Care has been taken in this present study to show that NVivo was used in accordance with grounded theory methods. The danger of qualitative research being transformed into inflexible and automated text analysis (Kelle, 1995) is addressed through the importance given to human interpretation in the methodology. Automatic coding and text frequency searches were not used in this study. NVivo was used in this study to organise a huge body of rich data. Integrating a description of how CAQDAS is used within the iterative grounded theory processes into a linear written document is challenging, and the experience of Bringer, Johnston and Brackenridge (2004, p. 252) has been used in this regard.

3.9 Ethical considerations

Pupils and teachers participate in this study, so the guidelines from the British Educational Research Association (BERA, 2004) were followed. Advanced Skills Teachers were invited to participate by email or telephone. Formal permission to do this research was then requested by letter to the Head Teacher. Pupils were first informally invited to take part by the participating teacher. Those interested were given letters with reply slips for their parents. Pupils were also written to, and asked to fill in a consent form, so as to ensure informed consent. Copies of all the letters used are available in appendix A. As a practicing secondary school teacher, I have a criminal background check from the Criminal Records Bureau.

As regards confidentiality, the names of the schools were not used. Teachers and pupils were referred to using only initials. Each teacher was sent a full transcript of their interviews. General feedback was offered to each participating teacher on the results of the analysis and participants were sent this thesis before publication and invited to comment.

Some of the actions and interpretations of the researcher, which undoubtedly have a significant effect on the data collected and conclusions drawn, will now be outlined. My reasons for doing this work are influenced by my experience as a secondary school science teacher and my studies for an MA in education. As a practitioner I wish to understand better how to promote conceptual change. As one interested in educational theory, I feel frustrated by the gap between research and practice in this field (section 1.1). This prior experience brings advantages and disadvantages. For example, a broad understanding of the role of a science teacher in a school, and my interest in children's naïve scientific concepts, is helpful in interpreting classroom dynamics. However, someone without such experience may see aspects of these data I might miss through over-familiarity. The reasons why symbolic interactionism emerged as the interpretivist theoretical perspective underpinning this study over phenomenology were discussed in sections 3.1 and 3.2, but a phenomenological approach to conceptual change clearly has merit (Marton and Pang, 2008, p. 533).

The way participating teachers were recruited may well have caused some people to be less likely to be included than others. The methodology for this study necessitates a small sample size and no statistics are possible. Nevertheless, I am conscious that the wording of this invitation, and the method of delivery, could influence the data. For example, teachers who don't check their email inevitably exclude themselves from this study. The invitation to participate, which was sent by email, is included in appendix A. The sample size was determined in part by reaching what grounded theorists call 'theoretical saturation'. This has been defined as:

The continuation of sampling and data collection until no new conceptual insights are generated. At this point the researcher has provided repeated evidence for his or her conceptual categories. (Bloor and Wood, 2006, p. 164)

This will be discussed further in section 3.11. In addition the size of the sample was influenced by practical considerations of what was possible within a full-time PhD time-frame. My judgement about how much data I needed, and how much I could analyse in the time available, influenced this decision about how many teachers to work with. The methodology fully acknowledges the place of interpretation within this study, so my interpretations of the data, and those of the participating teachers, will be fully described in the data analysis sections (Chapters 4 and 5). Finally, though the theory generated in this study is fully grounded and arose by using grounded theory methods, I think this does not prevent my ideas and prejudices affecting it significantly. Where I am aware of such effects influencing the data, I will discuss them in section 6.1.

3.10 Can this grounded theory study provide trustworthy evidence?

What can be considered evidence is a function of the methodological position taken by the researcher (Pearson, 2004, p. 47). So what constitutes reliable evidence can be a contentious issue. For example, some argue that only conclusions from traditional scientific methodologies can provide an evidence base for practitioners (for example Watson, 2003). Such an approach proclaims a hierarchy of evidence, where the ‘gold standard’ is sometimes seen as the systematic review of randomized control trials. This implicitly undermines interpretative studies like this present research as evidence for practice, irrespective of the quality of the work. In contrast, this present work takes the position that,

[E]pistemologically, daily practice is much closer to the interpretive or postmodern paradigms and ... the validity and value of evidence ought to be considered by the criteria of these paradigms. (Mantzoukas, 2008, p.219)

Appropriate criteria for the evaluation of the grounded theory emerging from this present study, were defined by Lincoln and Guba (1985, p. 294).

The four terms ‘credibility’, ‘transferability’, ‘dependability’ and ‘confirmability’ are... the naturalist’s equivalents for the conventional terms ‘internal validity’, ‘external validity’, ‘reliability’ and ‘objectivity’. (Lincoln and Guba, 1985, p.300)

Do the research findings represent a credible interpretation of the data? To what extent can the findings be transferred beyond this present study? How well were the integrated processes of data collection, data analysis and generation of theory carried out (dependability)? To what extent are the findings supported by the data (confirmability)? The following “operational techniques” (Lincoln and Guba, 1985, p. 219), will be used in this study to establish credibility, transferability, dependability and confirmability:

Criterion area		Technique
Credibility	1	Activities in the field that increase the probability of high credibility: prolonged engagement persistent observation triangulation (sources, methods, and investigators)
	2	peer debriefing
	3	negative case analysis
	4	referential adequacy
	5	member checks (in process and terminal)
Transferability	6	thick description
Dependability	7a	the dependability audit, including the audit trail
Confirmability	7b	the confirmability audit, including the audit trail
All the above	8	the reflexive journal

Table 3: Summary of techniques for establishing trustworthiness from Lincoln and Guba (1985, p. 328)

The meaning of these techniques, and how they were used to establish the trustworthiness of the data collected for this study, will be discussed in depth in section 6.2. This thesis acknowledges the on-going debate among researchers about the nature of reliability in qualitative research (Armstrong, 1997; Morse *et al.*, 2002), yet argues that the techniques proposed by Lincoln and Guba (1985) used in conjunction with grounded theory methods (section 3.11), can lead to trustworthy evidence.

3.11 How are these data analysed?

In order to generate a grounded theory of how experienced science teachers promote conceptual change, and to explore potential relationships between conceptual change, teaching tactics and learning tactics, the rich qualitative data collected were analysed using grounded theory methods. An assumption behind this study is that there are indispensable techniques (grounded theory methods) which must be used for any research to be a ‘grounded theory’ study (Birks and Mills, 2011, p. 5 and Bryant and Charmaz, 2010, p. 12 and 51). These grounded theory methods are:

[Initial] coding and categorization of data; concurrent data generation or collection and analysis; writing memos; theoretical sampling; constant comparative analysis using inductive and abductive logic; theoretical sensitivity; intermediate coding; selecting a core category; theoretical saturation; and theoretical integration. (Birks and Mills, 2011, p.9).

It is these methods used in combination, within the theoretical and epistemological frameworks described in section 3.1, which characterises grounded theory, and I acknowledge similarities to other methodologies (Aldiabat and Le Navenecm, 2011, p. 1). How each of these essential methods is applied in this present study will now be explained. These procedures were used in the analysis of EMT, VP and RD interviews (section 3.4). The extent to which grounded theory techniques are prescriptive or heuristic is hotly debated among grounded theorists. ‘Constructivist grounded theory’ (Bryant and Charmaz, 2010, p. 10) contends that data, analysis and methodological strategies are constructed. During this study I was conscious that grounded theory methods, and the way they were used, might have needed to be adapted. On finishing I decided that the grounded theory methods mentioned above had adequately described the processes employed in this research.

Initial coding involves identifying words, and groups of words, which appear to be important and then labelling them. A word, or group of words, can be described as an incident. For example in 1a:159 a student (EM) suggests that plants are living things because they have leaves that can move in the wind (Interviews 1 to 6 refer to the six participant teachers. EMT interviews are labelled as 'a', VP as 'b' and RD as 'c'. Hence the transcript line 159 in the EMT interview with the first teacher is written as 1a:159):

1a:159 EM: [...] I just think that a plant and a mushroom is a living thing because when you think of a plant it moves because it grows and can sway in the wind...

Experience as a science teacher, and the literature, help identify this idea as naïve. Some children appear to think that anything that moves is living (Piaget, 1929). Children sometimes do not use the same criteria as scientists in establishing whether something is living (Lucas, Linke and Sedgwick, 1980). The coding of any transcript is a matter of interpretation, and the approach taken in this study is pragmatic. The response:

1a:160 **TU (teacher): But isn't that the wind moving it? It is not the plant moving it.**

indicates that EM's teacher also thinks this pupil has said something which is not correct. Later EM continues to refer to leaves flapping in the wind which, from the context, could suggest that she continues to hold this as evidence of them being alive even after this intervention from her teacher:

1a:161 EM: [...] The plant has leaves and its leaves will grow. Its leaves can move [indicating leaves shaking in the wind using her hands]. [...]

The fact that she mimes this motion, rather than describes it in words, could suggest she is now aware that this idea is disputed, but it might not. Where possible, interpretations were triangulated like this. Links were made between different parts of the same transcript and between different types of interview. This Grounded Theory Method of

‘constant comparative analysis’ led to VP and RD data being integrated into the grounded theory (chapter 4). In the VP and RD interviews teachers were asked if an interpretation of what they said is correct, or to explain how they understood a student during the EMT interview. It is possible that the interpretations of such evidence by any or all participants (including myself) are mistaken. Teachers make judgements quickly in the classroom about what children mean, and it was decided not to interview the pupils about what they meant because of the limitations inherent in such a small scale study and the focus of the research questions on the role of teachers in promoting conceptual change. Frequently teachers in the VP and RD settings revise the interpretations they made at speed during the EMT interview. For example:

1b:10 **TU (teacher): [...] But she is talking about feelings not actual temperatures. So she is muddling up two things, two concepts and I didn't notice it at all the first time I watched that clip. Interesting isn't it.**

The discussion above reflects a straightforward pragmatic approach to coding, one supported by Bryant and Charmaz (2010, p. 16-18) who are ‘second generation’ grounded theorists. Early work on grounded theory by ‘first generation’ theorists (for example Glaser, Strauss and Corbin) took coding for granted and generally did not specify coding techniques. An intricate coding system was proposed by Strauss and Corbin (1990), but is rarely used by modern grounded theorists as it is too complicated to be of use in practice. In vivo coding involves using the actual words of participants as codes. This was not found to be useful during the analysis of the interviews.

As more incidents were coded, particular labels became ‘theoretically saturated’ (Corbin and Strauss, 2008, p. 143) and were then called substantive codes. Saturation here implies that there is some evidence to suggest the code represents more than an isolated event. For example, in the expert micro-teaching interviews (1a, 2a, 3a, 4a, 5a

and 6a) 436 ‘naïve concepts’ were identified (see Table 4). ‘Naïve concept’ can therefore be described as a substantive code. Incidents within a substantive code are renamed ‘indicators’ by grounded theorists. Interrelations between codes are identified and groups of related codes are called categories. For example, a teacher telling a pupil something (a category called ‘tell’), and confirming what a pupil has said as correct (the category ‘confirm’), can both be identified as ‘transfer’ (a type of teaching and learning technique). When new analysis continues to return codes which fit existing categories, the category is described in grounded theory as ‘theoretically saturated’. The sample size necessary to achieve theoretical saturation is unpredictable in grounded theory according to Denscombe (2010, p. 19), so the initial difficulty in predicting the number of participants for this study was to be expected. Grounded theory is open-ended and extendable according to Lincoln and Guba (1985, p. 206). It should continue until theoretical saturation is reached (Glaser, 1998, p. 162 - 165). It is recognised that categorization is, once again, a matter of interpretation. The names of codes and categories, and the contents of categories, continued to be adapted as new data was analysed. I recognise that my theoretical sensitivity (i.e. the ability to identify instances and relations) deepened as the study progressed.

[Theoretical sensitivity is the] ability to pick up on subtle nuances and cues in the data that infer or point to meaning.
(Corbin and Strauss, 2008, p.19)

Written records of my thinking as the data analysis proceeds were recorded as memos in the NVivo software.

The core stage in the process of generating theory, the bedrock of theory generation, its true product is the writing of theoretical memos... Memos are the theorizing write-up of ideas about codes and their relationships as they strike the analyst while coding. (Glaser, 1978, p.83)

The way the software keeps track of what part of the transcript each memo is linked with, was one reason for using NVivo. This record has been used in the construction of the grounded theory and as part of the ‘verification procedures’ discussed later (section 3.10).

Concurrent data collection and analysis was used in this study. Firstly, video data was collected from an EMT session and then analysed using grounded theory methods. Secondly, video clips from the EMT group interview were selected. Initially clips were selected if they showed a pupil expressing a naïve concept. These clips were used as prompts in the VP interview. Thirdly, VP and RD data were collected and analysed before the next EMT session was done. During this research, the reasons for selecting clips for the VP evolved. For example a clip might be shown to a teacher to compare their interpretation of an incident with my own understanding. Another reason for selecting clips for the VP interview was in order to exploit this information-rich source of data so that a category could be saturated (a process called theoretical sampling). An example of this is when the questioning route for the next set of interviews was adapted in order to gather information needed to saturate a category (appendix B).

Intermediate coding involved grouping categories, relabeling them as a single category, and linking categories together. This can be seen happening in this study through the evolution of the diagrams used to describe the coding grid (models were named using the letters A to Q - the first, an intermediate model and last one made are shown below as Figure 5, Figure 6 and Figure 7:

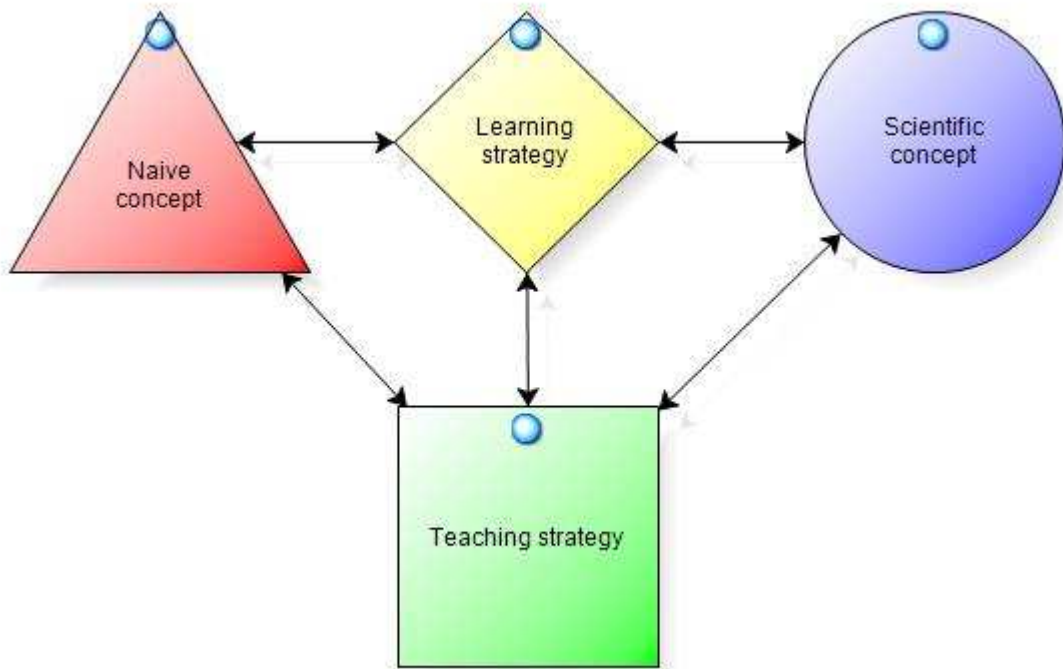


Figure 5: The first NVivo model (A) from 6/1/11

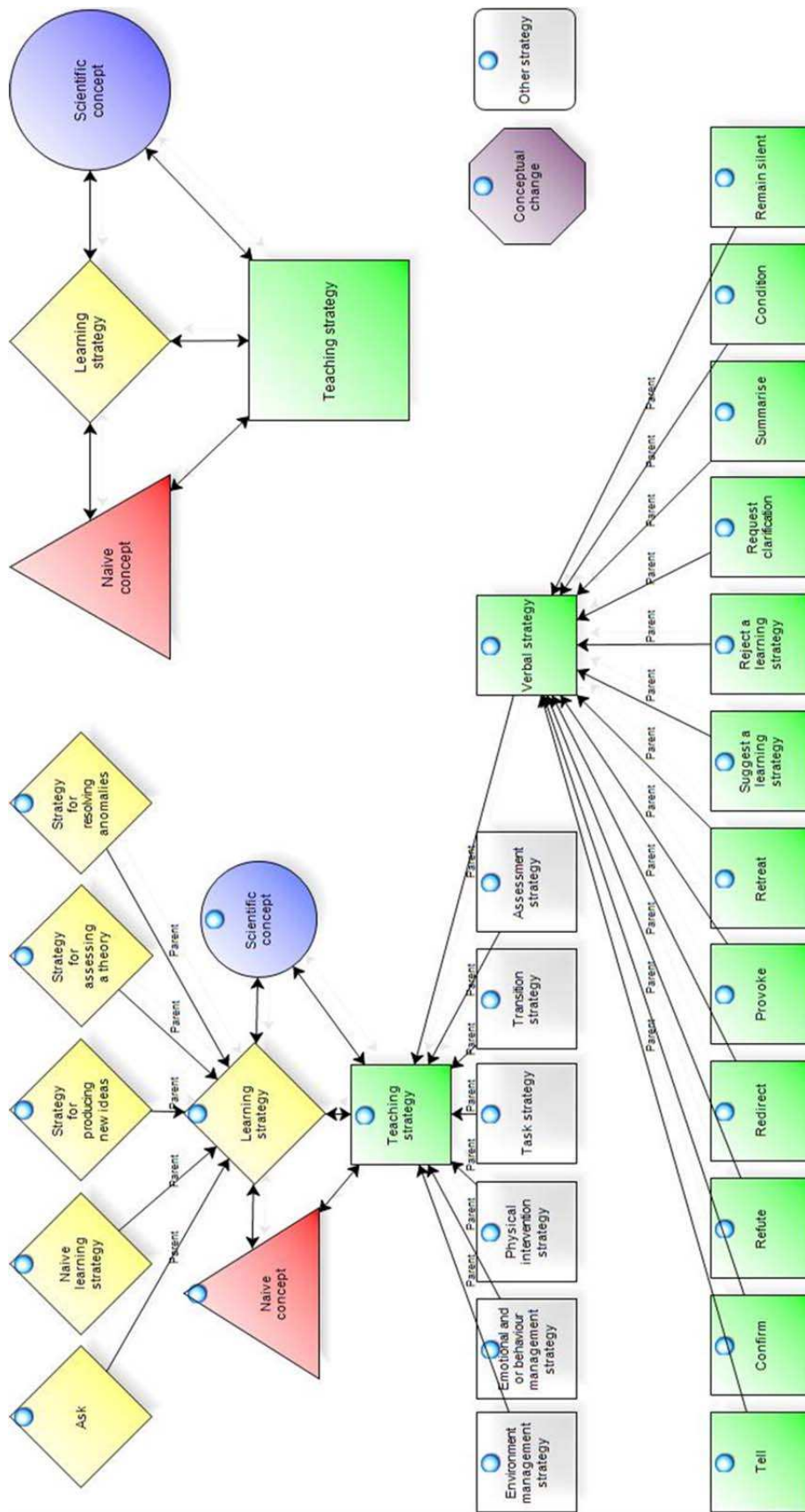


Figure 6: An intermediate NVivo model (L) from 31/3/11

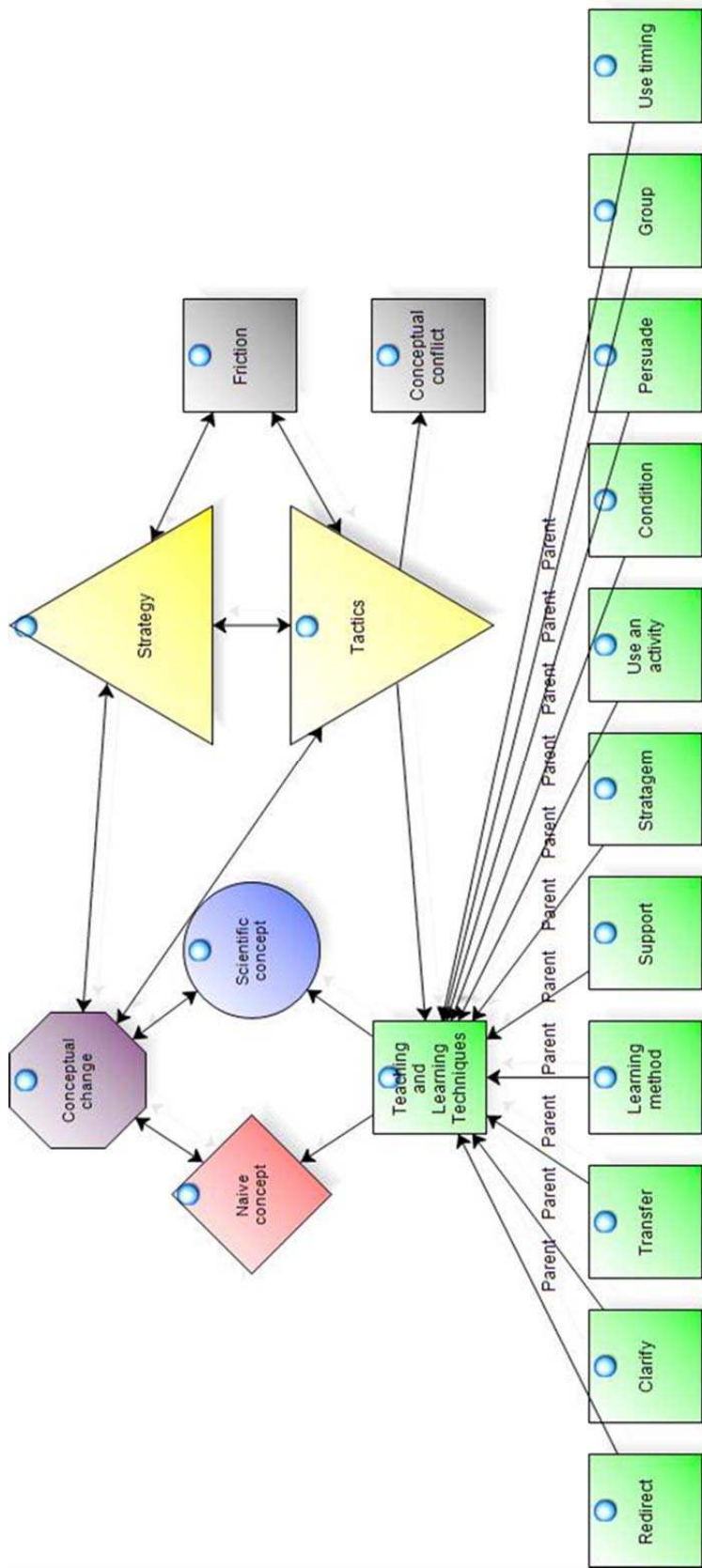


Figure 7: The last NVivo model (Q) from 8/3/13

Model A was a first attempt to visualise the relationships between conceptual change (from naïve concepts to scientific concepts), learning ‘strategy’ and teaching ‘strategy’. During the study a different understanding of strategy emerged (section 4.4) and, as can be seen in Figure 7, the grounded theory presented in Chapter 4 shows a variety of teaching and learning techniques (shown as green squares) used tactically or strategically (represented by yellow triangles). As some sections of transcript were coded as conceptual change, this was included in Figure 7 as a purple octagon. Strategic friction and conceptual conflict emerged as significant factors and are shown as grey squares in Figure 7. The lines with arrows in Figure 5 and Figure 7 try to describe relationships between elements of the theory. For example when Figure 5 was drawn I understood naïve concepts to influence teaching strategies and vice versa. So I drew the relationship as a line with arrow heads at each end. In contrast I now think tactics and strategy influence each other (so are linked with an arrow with two heads), but that it is tactics rather than strategy which effects teaching and learning techniques (hence the line with a single arrow head in Figure 7). In Figure 5 the yellow diamond representing ‘learning strategy’ was placed in-between naïve concept and scientific concept and ‘teaching strategy’ was positioned below. This suggested, at least in my mind at the time, the idea that learning strategy was essential for learning, but that someone could learn without teaching strategies being used. The placement of elements within Figure 7 was largely dominated by the need to fit so many pieces into one diagram.

Selective coding involves the identification of a core category which expresses everything in a single ‘storyline’. The constant comparison of incident with incident, incident with code, code with code, code with category and category with category, continues until theory emerges from these successive comparative analyses. When a

grounded theory is complete, it consists of a core category which has been theoretically integrated. This means:

Linking categories around a central or core category and refining the resulting theoretical formulation. (Corbin and Strauss, 2008, p.87)

The purpose is to,

[P]ull all of the research threads together to construct a plausible explanatory framework about the experience of [participants]. (Corbin and Strauss, 2008, p.264)

3.12 Summary

The interpretivist theoretical perspective (symbolic interactionism) was underpinned by a social constructionist epistemology. Three research methods (expert micro-teaching, verbal protocols and retrospective debriefing) were used. Data were recorded on video and managed using NVivo 9. Six Advanced Skills Teachers participated in this study. Six Year 7 pupils (11 or 12 years old) took part (three girls and three boys) in each expert micro-teaching interview, which was led by one of the Advanced Skills Teachers specialising in a science subject. A second ‘Concurrent Verbal Protocol and Retrospective Debriefing’ interview (Taylor and Dionne, 2000) took place approximately one month after the expert micro-teaching session. Grounded theory methods were used to analyse the data. In the next two chapters the findings of this study will be presented (Chapters 4 and 5).

Chapter 4 - part 1: Techniques

4.0 Introduction

This chapter describes the findings of this study as regards the first research question. How do experienced science teachers promote conceptual change in school

science? There were eight findings and together they constitute the grounded theory which has emerged from this study:

1. Sporadic episodes of ‘conceptual conflict’, and the intervening periods of ‘peace’, were both used by teachers (and pupils) to promote conceptual change.
2. Eleven ‘teaching and learning techniques’ were used by participants.
3. Participant teachers used some techniques more than others. The relative weighting participant teachers gave to each of the teaching and learning techniques was called their ‘strategic profile’. Each of the six teachers had a different profile, and there were similarities between profiles.
4. ‘Tactics’ is the theory of the use of teaching and learning techniques in conceptual combat. ‘Strategy’ is the theory of the use of such conceptual combats to try to promote conceptual change. Teachers (and pupils) demonstrated and described tactical and strategic behaviour.
5. Six ‘levels’ of direct and indirect intervention were seen.
6. Tactics and strategies frequently failed. Participants sometimes took advantage of such ‘strategic friction’. Six stages when strategic friction could occur were identified and four reasons for such failure can be recognized in these data.
7. Teachers demonstrated considerable logistical skill during the interviews and on occasion logistical problems occurred. How logistics may have influenced the techniques, tactics and strategies employed by participants will be discussed.
8. Prior knowledge influenced techniques, tactics and strategies used by participants.

Each of these findings will be discussed in detail below.

The intention of this study has never been to investigate the naïve concepts themselves (section 2.1), but to explore how conceptual change is promoted and the nature of instructional strategy. However, before discussing the findings of this study in

sections 4.1 to 4.8, a few points about the coding of these data will be made, as it was necessary to identify naïve concepts, scientific concepts and moments when concepts appeared to change, so that the context which may have contributed to these changes could be investigated. Table 4 below shows the number of times in each type of interview that ‘naïve concept’, ‘scientific concept’ and ‘conceptual change’ were coded:

Type of interview	Naïve Concepts	Scientific concepts	Conceptual change
Expert Micro-teaching (EMT)	436	620	127
Verbal Protocol (VP)	117	23	21
Retrospective Debriefing (RD)	49	3	9
Total (All interviews)	602	646	157

Table 4: Naïve concepts, scientific concepts and conceptual change

The ubiquity of these categories in initial coding lead them to be identified as substantial codes (section 3.11). Interpretation of meaning in this complicated context can never be an exact science. For example participants sometimes quoted each other’s naïve concepts (for example 1a:196) and these were still coded as ‘naïve’, even if the speaker did not agree with the concept they are quoting. If this meaning was not evident from the context, then an annotation was attached to the transcript to explain the interpretation. Where there was significant doubt about an interpretation the passage was not coded, but a note was made explaining this thinking as an annotation in the transcript (for an example see section 6.2.3). Many of the naïve concepts expressed were familiar from the literature. For example, the ideas that particles themselves melt (Driver, 1994, p.142; and 4a:211), that fire is living (Bell and Barker, 1982, p.197; and 6a:311) and that light bouncing off objects has no relevance to seeing (Anderson and Smith, 1983; and 5a:578-581).

The following example illustrates the synthesis of a ‘scientific’ concept with a well-known naïve concept and shows how some of the findings of the conceptual change

research community (here Clement, 2008, p.433) were helpful in interpreting these data. The teacher and pupils were discussing why we see a teddy bear. One student (UA) expressed very clearly the science explanation of how we can see an object (for the full transcript of all the interviews please see Appendix E):

3a:335 UA: But when you turn on the torch, because it generates a light source, if you point it at a specific area the the thing or object or area that has been hit with the light you'll be able to see that because the light bounces back into your eye. So you're able to see - so you're able to see where it is.

The teacher later asked what happened inside the eye. It became clear from a later interview (3b:90-93) that this was asked in order to extend the answer, and there was no indication that what came next was expected by the teacher. The same pupil (UA) went on to explain that after the light has gone into the eye, it then bounces out so that we can see objects (a naïve concept identified by Fetherstonhaugh and Treagust, 1992, p. 653).

3a:357 UA: I think - I think there's. I'm not sure what it is called but I think there is something in your eye that allows the light to sort of - yes. As I say - bounce back. But when it bounces back to the original space so you're able to see where it was.

Some light does bounce off the surface of our eyes (one can sometimes see objects reflected in the eyes of another person) and the retina can reflect light (causing 'red-eye' in photography), but this pupil is not referring to either of these ideas. This pupil may think simultaneously that light goes into our eyes so that we can see (a scientific concept), and that light comes out of our eyes so that we can see (a naïve concept).

Participants frequently expressed 'scientific concepts' (see Table 4 above). For example:

5a:75 MG: The cup is conducting the heat.

A pragmatic approach was taken in this study to the complicated issue of distinguishing between 'naïve concepts' and 'scientific concepts' as the reason for coding both these terms was to help identify conceptual change, and the focus of the study is on what teachers do to promote this. When a student expressed an idea which either the participating teacher or I recognised as similar to that of a professional scientist, this concept was coded as 'scientific'. Interpretation of children's thinking in this complicated context is not perfect and it is recognised that some ideas may appear to be scientific when in reality they mask naïve ideas and vice versa.

'Conceptual change' was coded when there was some indication that a pupil had changed their thinking. On occasion this was clear. For example:

2a:356 SF: I thought it [a cloud] was living.

Sometimes this could be deduced from a transcript entry. For example:

1a:72 **TU: You keep talking about the heat each time don't you. So on this one [indicating the cup of tea] the heat is going where?**

1a:73 BN: Into the cup.

CS: Out. [shows movement with her hands of 'out of the cup']

BN: Oh, out, out of the cup. Yes, out.

As will become clear in the following discussion (in particular in sections 4.2 where stratagems are discussed and section 4.6 on strategic friction), what participants say which appears to be conceptual change may be deception (section 4.2.6), and conceptual change can unfortunately be from scientific to naïve thinking.

In the following sections each of the themes which emerged during the analysis will be illustrated with one section of transcript, which will then be discussed in detail. Many of these findings were coded hundreds of times in the transcript (for example

‘redirect’ in section 4.2.1 was coded 953 times) and choosing a single example was challenging. In contrast some of the findings describe techniques which appeared to be used extremely rarely (for example ‘use timing’ was only coded 56 times). The relative frequency with which participants used teaching techniques is one of the findings (termed the ‘strategic profile’ of a teacher) which will be discussed in section 4.3. The chapter continues by attempting to describe how techniques were sometimes used in tactical and strategic ways, which represents another way in which the same data can be interpreted. The need for different levels of analysis for the complicated social interactions studied here is analogous to the way a table tennis player may know how to hit forehand and backhand strokes (that is to know the techniques necessary to play the game), but may also be capable of combining these shots such as to win a point (tactics). In addition a good player might notice frailty in the backhand of an opponent, and deliberately target this weakness (strategy).

4.1 Conceptual conflict

In the following extract from an EMT interview, during the ‘living or non-living’ card-sort activity, a heated discussion arose around whether eggs were living or non-living. The picture on the card showed a chicken’s egg in an egg cup (see Figure 8 below) and, as far as I can tell, all the pupils in this group had placed the card on the ‘non-living’ mat.

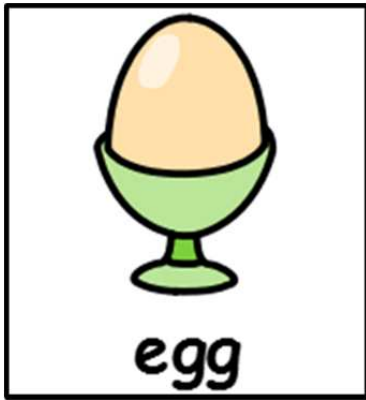


Figure 8: Symbol for 'egg' on a card for the EMT card sort activity (© Widgit Software 2013 - used with permission)

Many children and adults are confused about whether eggs and embryos are living (Tamir *et al.*, 1981, p.241). Biologists would argue that a fertilised egg which has been laid by a chicken is a living thing. In addition the image used indicates that the egg has been boiled, so for some children who consider an egg to be a living thing, placing the card raises the issue of death. Numerous studies (reviewed by Carey, 1985) have shown this to be a deeply challenging concept for children. The egg and this image were deliberately chosen for the card sort activity because it was likely to raise a number of naïve concepts which the teachers in this study might attempt to address. The following passage illustrates a complicated conceptual conflict which emerged during one EMT interview:

2a:255 **TV: [...] Now an egg. Living or non-living?**

2a:256 Several students: Non-living.

2a:257 **TV: Non-living? Why non-living?**

2a:258 AC: It doesn't reproduce.

2a:259 **TV: It doesn't reproduce. Didn't we agree...**

2a:260 SF: It doesn't really grow.

BB: It does...

AC: It could be a boiled egg.

LD: If we didn't have the picture of it, it could [be alive]. Because it could be a different kind of egg.

AC: That is an eating egg. That is an egg ready to eat. [points at the picture TV is holding up].

2a:261 **TV: Right. OK. You think - when it is... OK. Therefore it is boiled, yes?**

2a:262 **TV: When you boil it it becomes living or non-living?**

2a:263 Several students: Non-living.

2a:264 **TV: Non-living. But before that? Was it living?**

2a:265 ES: It depends whether the chicken has...

SF: Don't people like inject stuff into the egg to make it like...

2a:266 **TV: Freshly laid from the...**

ES: If the chicken hasn't been around a male - a cockerel, if there hasn't been sexual intercourse [SF looks at LD and starts to laugh. LD doesn't laugh but smiles] then because they're basically - that's like... It is like a woman's egg so it is just like a woman's periods.

2a:267 **TV: OK. Now you say a woman's egg. Is that living or non-living?**

2a:268 ES: It is non-living.

2a:269 **TV: Non-living?**

2a:270 SF: Yet. Not living yet because it hasn't been fertilised by...

LD: Male sperm.

SF: Yes, male sperm.

2a:271 **TV: OK. I'm going to put that to you. An egg. Is it a cell or not?**

2a:272 SF: Not sure. [The expression on her face matches this]

BB: Erm. Well. [pause]

- AC: The shell is kind of like the cell wall.
- 2a:273 LD: And the yolk is kind of like the nucleus.
- 2a:274 **TV: If I said to you now, OK, that this is a cell that you're looking at. This is one of the largest cells that you can see. Right. Now by definition, is a cell living or non-living?**
- 2a:275 SF and LD: Depends.
- BB: Living.
- 2a:276 **TV: Living? Why?**
- 2a:277 AC: [After a short pause] Because it... when they join they reproduce other cells.
- 2a:278 **TV: Cells can multiply?**
- AC: Yes.
- 2a:279 **TV: So they take nutrients from outside? They can move can they?**
- BB and AC: Yes.
- 2a:280 **TV: Yes. They can move. Are they sensitive?**
- 2a:281 Everyone: Yes.
- 2a:282 **TV: Yes? So they can produce wastes, can they?**
- 2a:283 Everyone: Yes.
- 2a:284 **TV: Yes. OK. So if a cell can do all these, would an egg be a living thing then?**
- 2a:285 SF: We don't know if it is a cell or not. [Head is leaning on her hand - tone and facial expression may indicate she is not happy about something].
- 2a:286 BB: Yes it is a cell.
- SF: Oh.
- BB: But we don't know if it is cooked or not.
- 2a:287 **TV: OK, freshly laid. Living or non-living?**

- 2a:288 AC: Living.
- 2a:289 **TV: Living. Alright. So it can produce - you can get a chicken out of it can't you?**
- 2a:290 Everyone: Yes.
- 2a:291 **TV: So therefore it can grow into a chicken. So therefore it is living. When you boil it...**
- 2a:292 AC: It is killed.
- BB: That is when it is non-living.
- 2a:293 **TV: OK, so what makes it different then when you boil it?**
- 2a:294 LD: It turns into food. [Said very quietly]
- TV: Sorry?**
- LD: [Louder] It turns into food cooked. [TV smiles]
- 2a:295 **TV: It turns into food. So it destroys when you're cooking. It destroys its ability to...**
- 2a:296 SF: Live.
- LD: Grow.
- 2a:297 **TV: To grow. It changes it. [...]**

Using an analogy is a learning method for producing new ideas according to Darden (1991, p. 245) which will be discussed further in section 4.2.4. The teacher (**TV**) attempts a bridging analogy (Brown and Clement, 1989, Scott, Asoko and Driver, 1991) in line 2a:297 above by suggesting that an egg is a cell, and that cells are living. The pupil (**AC**) evaluated this anomaly by using his knowledge that (plant) cells have a cell wall. Even though he is mistaken in using a plant cell analogy rather than an animal one, it is none-the-less interesting that he tries to resolve the anomaly of the status of the egg by using a feature of a cell. Many of the techniques that the teacher and pupils have been using here will be discussed in section 4.2. One of the challenges in coding this rich data set was that

a single word or sentence sometimes appeared to be being used for several different purposes. Having watched the whole of this video clip as part of a VP interview, the teacher commented:

2b:45 **TV (teacher): [...] at the end when I was asking them, living or non-living, and they still thought, 'Not sure'. Because that shell was blocking their mind because they're thinking it is a hard shell. If you leave it in the supermarket - just they can't see it growing, can't see it developing. I think that was a - it was quite a hard battle to fight.**

Hence the battle analogy, called 'conceptual conflict' in this study, came from participants. On occasion the interpretation that an exchange involves conceptual conflict can be corroborated using triangulation. So evidence from VP or RD interviews sometimes supports the 'cognitive conflict' interpretation as in the example above.

Different words were used by participants to describe what I interpret as conceptual conflict. For example another teacher (TX) mentions 'challenging' someone's thinking eleven times during interview 4b. Here are three examples:

4b:6 **TX (teacher): [...] you get the student ideas and then you challenge it, you break the ideas, and then you reform.**

4b:35 **TX: [...] you then challenge and regroup accordingly depending on what feedback you get from the students.**

4b:41 **TX: So all I'm doing there is just challenging - they've got their - they've got that kind of rubric of MRS GREN [a mnemonic for the seven characteristics of life] [...]. It is what is on the national curriculum. So really it is just challenging the criteria on each one of those components. And I think movement for plants is a classic - because**

students' interpretation of movement in animals is much different to interpretation in plants.

Yet another teacher (**TY**), who had been watching himself talking with a pupil about the naïve concept that condensation involves air turning into water when it hits a cold surface (see 5a:63), described this as 'fencing':

5b:15 **TY (teacher): [...] I don't think that they had any better idea of what was going on so they were interested to see how he would cope with the the the fencing [TY laughs] [...] I think they're enjoying it as a spectator sport rather than actually taking part in the model building or the model deconstructing.**

So the use of conflict within sport is used by this teacher as an analogy for the interaction between a pupil and a teacher over a naïve concept. In these data pupils often give as good as they get during the exchanges, and frequently appear unconvinced when the conversation moves on as was evident in line 2a:285 quoted above when a pupil (**SF**) points out that she has not yet accepted the argument from the teacher that an egg is a cell. One teacher (**TY**) used the metaphors of "shatter" (5b:55), "dent" (5b:55) and "drop the bomb and run" (5b:64) when talking about interactions with and between pupils when naïve concepts are mentioned. Hence teachers may be deliberately trying to 'break' or 'damage' naïve thinking. In the following example a teacher (**TW**) describes "just messing with him" (3b:79) which I have interpreted as conceptual conflict. The text in italic (*3a:209-211*) in the extract which follows is what the teacher hears from the video recording of the EMT interview playing on the laptop during the VP interview. The text in normal script (3b:79) is what the teacher said during the VP interview. This convention has been used throughout this study:

3a:209 UA: As GS said about the brain, as I said about the nucleus, that could be considered considering the number of cells that make up a single tree the amount

of nucleuses could [TW smiles] be considered the brain of it - of the tree.

3a:210 **TW (teacher):** *So would you say that a tree would be cleverer than a daffodil, because it is bigger?* [TW laughs whilst watching this bit]

3a:211 **UA:** *Um.*

3b:79 **TW:** **I think at that point I was just having fun!** [TW and JR laugh]. **I was just messing with him there [laughing].**

This illustrates the playful nature of many of the conflicts over ideas between pupils and teachers. The teacher did not laugh at the time during line 3a:210, even though this is funny (in my opinion) and they did laugh when watching this back. This ‘hiding’ will be described as a stratagem and is discussed in section 4.2.6. This might be considered necessary by the teacher so as not to embarrass the pupil and to allow this line of argument to continue.

The interpretation of these data that teachers and pupils frequently engage in conceptual conflict is supported by the regret several participants expressed when watching themselves on video during an EMT interview where they had missed a naïve concept which a pupil expressed. In the following clip from a VP interview the teacher (TV) is listening at 2b:21 to his own EMT interview. TV notes that he missed the naïve concept at the time, but would have challenged this:

2b:21 *CLIP 6: organs [2a:102-107] 2a:102 TV (teacher): is there anything that you already had in mind about living things and non-living things before you put those pictures on those matts? Yes SF?*

2a:103 *SF: I was going to say that living could be something that... [BB interrupts]*

BB: Moving around

SF: Yes, is moving. Like a person has organs that keep us alive and stuff like that.

- 2a:104 **TV: Anything that moves about you would consider as living. [Slight question in the voice perhaps] Yes. Any other feature about the living things... [...]**
- 2b:24 JR: And the student here [SF] mentioning about organs. I thought that was interesting.
- 2b:25 **TV: I didn't pick that up.**
- 2b:26 JR: Shall we just replay that one?
- 2b:27 **TV: OK, so. [Replays clip 6] [...]**
- 2b:28 **TV (teacher): ... that is something that I didn't pick up. [...] But then I would have challenged her about certain machines that have subsystems. Like in a car or something like that. I could have challenged her and it would have been interesting to see what she would have said. But it was an interesting thought there, living things made up of organs. [...]**

The teacher (TV) appears to be suggesting that SF's 'theory' (that living things have organs) could be challenged by suggesting that cars have subsystems (like an engine, or windscreen wipers) in a similar way to people having a heart or lungs, but that does not make cars living. This technique will be discussed in section 4.2.3. The important point at this stage in this thesis, is that the teacher expresses that if they had heard what the pupil had said at the time they would have challenged this thinking. Such a challenge is termed 'conceptual conflict' in this study. The following is another example where a teacher (TX) expresses regret for not challenging a pupil (DM) over a naïve concept:

- 4b:27 **TX: So what I'm doing there ... is I'm - 'heat is particles' - Is that what DM said?**
- JR: I think so.*
- 4b:28 **TX: Yes. ... So I'm really now - I should have challenged him more on that. [...]**

The naïve concept that heat is a 'thing' (rather than a process) is well known in the literature (for example Driver, 1994, p. 138). With hundreds of naïve concepts being

expressed at speed in these data it was not uncommon for teachers to miss naïve concepts like this, which they often picked up when watching the video back in the less challenging environment of a VP interview.

Pupils sometimes engage in conceptual conflict with each other. In the following extract **TX** (the teacher) challenges AJ (a pupil) and AJ responds vigorously. Commenting on this during the VP interview **TX** also notes that another pupil (DM) challenges AJ. By the tone that AJ uses in 4a:443 it is clear that she is well aware she is being challenged:

4a:437 **TX (teacher):** *So you've all changed. AJ you haven't changed.*

4a:438 **AJ:** *I haven't.*

4a:439 **TX:** *Why haven't you changed?*

4a:440 **AJ:** *Because it [fire] is not living. Because ... it spreads, but that is by adding more wood. If it didn't have anything to spread to - [DM interrupts here]*

4a:441 **DM:** *It spreads like I was adding more food.*

4b:60 **TX:** **[TX smiles] So DM is challenging.**

4a:443 **AJ:** *But we don't spread and grow. But you don't grow by putting out a [unclear - DM and JS joking about something - unclear what] It will grow constantly.*

In line 4a:440 and 441 the pupils AJ and DM appear to be using the MRS GREN mnemonic for the theory that all living things exhibit seven characteristics. Two of these are 'growth' and 'nutrition' (the others being movement, reproduction, sensitivity, respiration and excretion). AJ appears to be arguing in 4a:440 that the spread of fire is not the same as the growth of a living thing, as the fire only grows if more wood is added. DM counters this argument by suggesting that wood is food for the fire. It is unclear in 4a:443 how AJ responds, but she has clearly not given up this conflict yet.

During one RD interview (6c:2) I asked a participant directly about conceptual conflict:

6c:1 *JR: [...] In classrooms, do you sometimes get almost conflict building up between - over ideas, I don't mean sort of nasty conflict - I mean -*

6c:2 **TZ: Yes. Yes. I think so, and I think if there is a really difficult concept to understand. If they hold one, then you come with another, and it doesn't match - you get it when it doesn't match what they hold. Um. But I thought [TZ shrugs] blady bla bla, and if you present them with some evidence - that's when you have to argue your point [JR nods] to try and convince them, maybe what they're thinking is not entirely correct.**

So **TZ** suggests that within a dispute the teacher has a role in convincing pupils of an argument. In section 4.2.9 below, evidence that teachers use seven different ways of persuading pupils will be presented.

There appears to be overwhelming evidence in these interviews that periods of conceptual conflict occur. During all fifteen hours of interview there were 269 times when 'conceptual conflict' was identified. This included 225 instances during the six Expert Micro-teaching interviews, 32 instances during Verbal Protocol interviews (this occurred in all VP interviews except 3b) and 12 times during Retrospective Debriefing interviews (only during interviews 4c, 5c and 6c). Those with secondary school classroom experience may feel that this point hardly needs to be made, but conceptual change research literature sometimes appears to imply that there are simple solutions to how to promote conceptual change (see section 2.5). The cognitive conflicts which flared up during these interviews were rarely resolvable through the use of a single simple technique. In addition, while acknowledging that consensus-building has a place within conceptual change strategy (Meyer & Woodruff, 1997, p. 173), this did not emerge as a

significant theme in this present study during initial coding. The following extract, where pupils at the end of the EMT session have been invited by the teacher (**TU**) to evaluate the experience, illustrates how some pupils relish conceptual conflict:

1a:421 LN: Yes, because I didn't know that it would be that hard to explain [how we see] because it sounds really easy but I learnt that it is quite hard.

1a:422 **TU: I agree.**

1a:423 JB: The same as we found out on Friday with [Mr W].

TU: OK, go on.

JB: He said we had to put how to put a jumper on.

TU: How to put a jumper on? [amused]

JB: Yes, how to put a jumper on and I went, "Pick the jumper from the chair, pick the jumper up from the chair, then put your head through, and then put your arms through and then..."

1a:424 **TU: And it didn't work.**

1a:425 JB: He put his head through. And then he put his arms, you know the ends of them, he went - he didn't go through like that [as one would put on a jumper normally] he went like that [miming putting his hands through the sleeves from the outside of the jumper]. So his arms were like that... [JK and CS both talk for a second - unclear]

1a:426 **TU: So what you're learning from that is that when you're trying to explain things it is difficult.**

1a:427 JK: [JB] said put your head though your sleeves.

JB: No I didn't.

JK: Who said that?

TU: I think you're distracted [to JK]. Let him say what he learnt from today.

1a:428 JB: Yes, I really enjoyed it as well. And it was quite fun arguing and stuff. [LN smiles - can't see other faces from this angle]

1a:429 **TU: You liked the arguing about the ideas.**

1a:430 BN: Debate.

TU: Called debate. [smiles at BN] I prefer debate too.

JB: And I just like watching people arg... debating and all that.

TU: Interesting isn't it.

JB: Yes, and when you finally get the answer you might start another argument.

1a:431 **TU: [Unclear - but probably 'What about you JK?'] You like the debating side of things too?**

JK: [Nods]

TU: Do you think that you like arguing just for the sake of arguing and you'll ask the awkward question even if you believe it.

JK: It is funny arguing. [Looks at JB then laughs]

TU: Do you like to win an argument?

JB: Yes, definitely.

JK: I like an argument to carry on.

JB: I can never win an argument with my mum or step dad.

JK: I can!

1a:432 **TU: But that is different. We're talking about an argument or a discussion aren't we [JK and JB are talking together - unclear] [JK with a short pause after]. We're talking about an argument or a discussion about some information not about an argument because we've fallen out with somebody.**

This discussion began with a comment about how hard it is to explain how we see (1a:421), but ends with two pupils expressing how much they enjoy conceptual conflict (1a:431).

Several types of conceptual conflict were observed in the data. In military strategy (Baylis, Wirtz and Gray, 2009) skirmishes are when neither ‘combatant’ intends to enter into conflict but it happens anyway; one force can attack whilst the other defends themselves (a siege); a ‘pitch battle’ can occur over an issue where both parties are aware of disagreement and turn on each other; and finally the Fabian strategy involves avoiding conflict yet winning by attrition (so one participant attempts to attack another, but the opponent avoids confrontation deliberately until the attacker desists). All four of these types of conflict are discernible in the EMT data. For example, the teacher appears to deliberately establish a pitch battle between students in 1a:129-136 which will be discussed in detail in section 4.4. Conceptual conflict was sporadic. The intervals between these events will be described as conceptual peace and there were forty-six references to ‘disengaging’ from conceptual conflict. For example:

3a:258 **TW (teacher): [...] Shall we leave that bit there and carry on with our cards, because I'm not sure science can answer that question. Certainly not at the moment. UA, [who has his hand up] do you want to tell us about another card?**

This example, which marked the end of a period of conceptual conflict during an EMT interview, also demonstrates the teacher changing the direction of the conversation. This technique has been interpreted as ‘redirection’ in this study and it will be discussed next.

4.2 Teaching and learning techniques

The following teaching and learning techniques were identified in these data (Table 5 below). The frequency with which each technique was used will be discussed in

section 4.3. Techniques are procedures participants were observed using repeatedly in what appeared to be attempts to influence others (including trying to effect conceptual change):

Number	Type of teaching and learning technique	Definition
1	Redirect	Deliberately influence the direction of a discussion.
2	Clarify	Summarize what has been said or request clarification.
3	Transfer	Tell another participant something, confirm what someone has said or refute what has been claimed.
4	Use a learning method	Use a method for producing new ideas, for assessing a theory or for resolving an anomaly. Naïve learning methods were also used.
5	Support	Assist either directly or indirectly. May involve emotional and/or behavioural management, ‘scaffolding’, organizing resources, controlling the physical environment or physical intervention.
6	Use a stratagem	Deliberately distort the perception of other participants.
7	Use an activity	Use (or suggest the use of) an experiment, demonstration, worksheet, etc. in order to influence thinking.
8	Condition	Attempt to modify behaviour by making an association between what a participant does and a consequence (reward or punishment).
9	Persuade	Try to convince another participant of something
10	Group	Use whole class, group, individual tuition (or a combination of these) to influence thinking
11	Use timing	Choose to act now, later or never. Acting later sometimes involved deliberately changing the order of actions. The pace the teacher or pupils worked at was adjusted on occasion.

Table 5: Types of teaching and learning technique

Each of these techniques will now be illustrated with examples.

4.2.1 Redirect

In the following transcript excerpt pupils argue, in effect, over what physicists call the second law of thermodynamics. This famous scientific idea was first expressed by Clausius in 1850 as ‘heat energy does not flow spontaneously from colder things to hotter things’. This theory contradicted the established caloric theory which claimed that heat was a self-repellent liquid which flowed from hot things to cold things. The teacher (TU),

who was not a physics specialist, presses the pupils on how cold a cup of tea left in a room will get. One pupil (BN in line 1a:53) claims that the tea will reach a similar temperature to the room (which was interpreted as a 'scientific concept' in this study). Other pupils (first LN and then EM in 1a:57) claim that the tea will become colder than the room in direct contradiction to the second law of thermodynamics. Hence this passage was interpreted as involving conceptual conflict (section 4.1). However, the passage is used here to illustrate 'redirection', a technique which the six experienced teachers in this study used extremely frequently, which involved changing the direction of a conversation:

1a:48 **TU: So I think we're talking about two things. One we're talking about the room and the cup of tea and then we're talking about putting the ice with the cup of tea. You need to stick with one idea to make sure we know what we're talking about. So can we just stick with that [putting the mug into the middle of the table and bringing the bowl of ice closer to TU] for the moment. Just the cup of tea, ignore the ice cubes and talk about this [the mug].**

1a:49 CS: I..

TU: So you're [looking at LN] still of the opinion... can you just say what you said again?

1a:50 CS: If the room is freezing [BN] is saying that it would get colder faster.

BN: No. It would go down slowly but it would eventually drop to the temperature in the room.

1a:51 **TU: So whatever the temperature of the room is that is going to be the temperature of the cup of tea?**

1a:52 BN: Not precisely but...

TU: But close.

1a:53 BN: Yes.

TU: OK. What did you [LN] say?

1a:54 LN: I don't think that it goes to the temperature of the room.

JB: Because...

TU: Do you [LN] think this is going to get colder?

LN: Eventually.

TU: How cold will it get?

LN: [Not sure]

TU: You're not sure. [indicating with finger for BN to come in]

1a:55 **TU: What do you [BN] think?**

BN: If you wait about an hour it will get really cold [laughs and smiles with LN].

JB: [Starts to say something - unclear]

TU: What about you [JK]? You're being very quiet amongst all this. [EM tries to speak] Hang on [to EM - TU keeps facing JK].

1a:56 LN: You're keeping... You're [BN - but looking at TU] changing your mind.

EM: Yes but... because [BN] earlier you said if when...

TU: It is OK to change your mind though isn't it after listening to other people's arguments?

1a:57 EM: When the tea gets colder it gets to room temperature but when I have a cup of tea, my Mum always makes me a cup of tea in the morning, I drink quite a lot of it, but there is always a bit left - by the time I go it [the tea] is freezing cold even though my living room is quite hot. So the difference is...

1a:58 **TU: So you feel that it [the tea] is getting even colder than the room?**

EM: Yes.

- 1a:59 JB: Because I've had a cup of tea before that was burning hot, and I left it for... I drank half of it and then I had left it for a long time like one and a half hours and then when I went back to drink some of it it was quite, it was mepid [sic]. It was mepid, but it was quite cold.
- 1a:60 **TU: When you say 'mepid', do you mean 'tepid'? [JK laughs then other students laugh] Tepid is the word you mean. Not too hot and not too cold. [JB seems to be embarrassed - puts his head on his arms on the table then sits up and covers his face with his hands]. Come on then [JK], I haven't heard from you. You tell us about the ice cubes. What is going on there? [JB turns to him] We've heard about the cup of tea.**

This teacher deliberately influenced the direction of this conversation eight times in the passage above (1a:48, 49, 53, end of 54, three times in 55, and 60). Line 1a:55 illustrates redirection very clearly as a pupil (LN) has just been speaking in 1a:54 and the teacher asks another pupil (BN) what she thinks, thereby stopping a discussion with LN and starting one with BN. Many other things are happening in this short passage as will become clear in the rest of this chapter. For example, I interpreted the way the teacher (TU) redirected the conversation in line 1a:60 as also involving the use of a stratagem (see section 4.2.6). I think TU deliberately hides JB's embarrassment over using the incorrect word 'mepid', by getting JK to explain how he understands ice-cubes. This again illustrates how a single word or sentence was sometimes used for a whole range of different purposes. Redirection was coded 953 times during all the interviews and was the teaching technique used most frequently by the teachers in this study (in section 4.3 the frequency with which each technique was used is compared) and was identified in all 18 sources (i.e. 6 EMT, 6 VP and 6 RD interviews).

Pupils sometimes redirected the conversation. For example, in the following passage a pupil (AC) offers a mischievous redirection in line 5a:591 to resolve the issue of who should go next (and perhaps in order to avoid having to speak himself).

5a:590 [...] **[TY indicates with his hand that AC should speak next. MG has her hand up] Hang on [MG]. Who is first? DF or AC?**

5a:591 AC: Let's go for a vote. Who votes it should be DF?
[MG and AC are the only ones to put up their hands]
[Everyone laughs including TY]

5a:592 **TY: Democracy in action. Go for it [DF].**

Once again, the line 5a:591 was interpreted as redirection and the use of a stratagem which will be discussed in detail later in section 4.2.6 (I think the smile AC has when saying this line indicates that he is hiding his real intention, and that the fact that everyone laughs shows that the rest of the group are quite aware of what he is doing).

Redirection of the conversation was often used for mundane reasons. For example participant teachers indicated in a variety of ways who should speak next. For example:

1a:23 **TU: Do you [indicating with eyes and hand EM] think something different then?**

2a:416 **TV: OK. [Indicates to BB that it is his turn by pointing]**

3a:26 **TW: [...] Anyone else got any experience that they've thought of? [Slight pause] It could be in a science lesson you did back at primary school. [Pause] That is a difficult one isn't it. Well maybe, as we go [GS indicates he wishes to come in]... Go on GS.**

Hence verbal and non-verbal cues were both interpreted as redirection. The direction of a conversation might be influenced to ensure that pupils are allowed to speak without being shouted down:

1a:136 **TU: [To EM] Let him [JB] have his say and then you can argue with him. Like a good scientists we**

have to also listen to the other person's point of view.

However, redirection was sometimes used in more sophisticated ways in these data which indicated tactical and/or strategic awareness (section 4.4). For example, the teacher (TV) in the following extract changed the direction of a conversation when the discussion didn't appear to be helping the students' understanding in line 2a:161. I interpreted this as the teacher deciding that the use of the MRS GREN mnemonic, which includes the idea that all living things are sensitive to their environment, was not achieving his strategic aim (which here was conceptual change from the naïve concept that the sun is living to the idea that it is non-living). The teacher redirects the conversation in 2a:161 to a discussion about another feature of all living things which appears in the MRS GREN theory, namely whether the sun actively seeks nutrition. There is considerable evidence that many children think that the sun is a living thing (Driver, 1994, p.17):

2a:153 **TV (teacher): ...Do you think the sun is sensitive. You [SF] put it on the living? Do you think that the sun is sensitive to its environment?**

2a:154 BB: Well it is a star.

2a:155 LD: The sun is part of the environment that we're talking about. It is sensitive to it.

2a:156 **TV: Because it is part of the environment, does that make it sensitive?**

2a:157 **TV: For example that table, it is part of the environment, does that make it sensitive to the environment?**

2a:158 BB: No. [Shakes his head]

2a:159 **TV: [Pause] OK? What do you [LD] think?**

2a:160 LD: It could [speaking quite slowly - appears to be thinking about this] because of the... [TV starts speaking]

2a:161 **TV: OK. Let's look at the other ones. You might find it easier to eliminate it if we carry on. Now nutrition. ...**

In the following example the teacher (**TU**) seemed to use redirection to resist the attempts by a pupil (**JB**) to redirect the conversation:

1a:295 **TU (teacher): We've shut the door [of the room in the thought experiment about seeing in the dark].**

1a:196 CS: But if we shut the door...

JB: But say if we had blinds, some of the light can still get through...

TU: No, we've sealed it all up [indicating with her hand sealing the blinds]. Totally dark - no light shining through the windows.

1a:297 JB: Wouldn't you just go over to the window and undo the blinds?

1a:298 **TU: No. We've got a torch.**

In this passage the pupil (**JB**) appears to be resisting the idea that a room with no windows and no sources of light in it could be completely dark. Many children think that light is unnecessary for vision and that it is possible to see in a pitch dark room according to Ramadas and Driver (1989). In this conceptual conflict the teacher (**TU**) appears to be resisting **JB**'s attempts to suggest that even a very dark room will have some source of light such that it will be possible to see faintly.

4.2.2 Clarify

The next most frequently used technique in these data was termed 'clarification', and involved summarizing what had been said or requesting more detail. Both types are illustrated in the following example where the teacher (**TY**) gradually clarifies the naïve

concept expressed by AC in line 5a:57; that condensation involves air turning into water (Driver, 1994, p. 82). This pupil may not know that air is a mixture of gases which sometimes contains water vapour (Driver, 1994, p. 108):

5a:53 AC: Because the coffee is hot and the glass [AC touches the ceramic mug] is kind of cold - it was cold probably - there is like condensation going on the edges [MG puts her hand up - TY leans over to look into the mug].

5a:54 **TY (teacher): Of the -**

5a:55 AC: Cup.

5a:56 **TY: OK. Yes. I can see that. And how do you explain that?**

5a:57 AC: ... The hot air rises and it hits the cold surface and turns into water.

5a:58 **TY: So the air turns into water.**

5a:59 AC: Yes. No, the surface.

5a:60 **TY: The surface.**

5a:61 AC: The hot air. [AC nods]

5a:62 **TY: Does what?**

5a:63 AC: Turns into water. [AC is leaning his head on his hand covering his mouth a little - he laughs a little as he says this]

5a:64 **TY: So air turns into water.**

5a:65 AC: Yes.

5a:66 **TY: When it hits a cup.**

5a:67 AC: Yes. If it is cold.

5a:68 **TY: If the cup is cold then the air hits it -**

5a:69 AC: Hot air.

5a:70 **TY: If hot air hits a cold cup then the air will turn into water.**

- 5a:71 AC: [Pause - AC looks round at the other students as if for help - MG has her hand up - TY smiles at AC]
- 5a:72 **TY: I'm only checking. Is that what you mean?**
- 5a:73 AC: Yes.
- 5a:74 **TY: OK. Thank you. [TY turns to MG]**

In this passage the teacher (**TY**) summarises what AC says six times (5a:58, 60, 64, 66, 68 and 70) and requests more detail four times (5a:54, 56, 62 and 72). The techniques of 'summarising' and 'requesting more detail' were subsumed into the category of 'clarify' during the coding (see section 3.11 for coding within grounded theory) as they were frequently used together as in the example above. This persistent use of clarification draws out the naïve concept which **TY** summarises in line 5a:70 above. The detail of this thinking was not fully expressed in line 5a:57 where it was first mentioned, as the fact that the air is hot might only have been significant for AC in causing the air to move. This series of clarifications shows that AC (at least by the end of this conversation) is asserting that air must be hot to form condensation on a cold surface. During all 18 interviews clarification was coded 763 times, so may be said to be a substantive code.

Corroboration for the interpretation that teachers sometimes use clarification in order to promote conceptual change, may be found in the verbal protocol interviews. For example, in the following extract in italics the teacher (**TU**) is watching their own conversation with two pupils (CS and JB). Lines 1a:348 and the start of 1a:349 were not in the video which **TU** watched. CS appears to hold the naïve concept in line 1a:349 that light hitting something is a sufficient explanation of how we see things, which is well known in the literature (Driver, 1994, p. 41). The section in normal script after the extract in italic is what the teacher said whilst listening to the video:

1a:348 TU: How come it [light] gets to your eyes then?

1a:349 CS: *Because when I'm looking I'm looking kind of where the torch is going. Where ever the torch goes I'm looking...*

TU: OK, it has landed on teddy.

CS: *[VP video starts here] It has landed on teddy. I see him.[CS is standing up. TU is holding the teddy up]*

TU: How come you see him?

CS: *Because the light...*

JB: *[Interrupts] Because light is reflecting off it.*

1a:350 **TU: [TU looks at JB while he speaks then looks back at CS] What do you [CS] mean by reflecting again? You said that earlier.**

1a:351 CS: *Reflected is where... You're standing in front of the mirror, you're standing in front of the mirror and you see stuff. That is called reflecting and you can see it like rebounding.*

TU: Rebounding. So what is rebounding?

1a:352 CS: *[Still on her feet] the light is going...*

TU: So the light is hitting teddy, and then it is rebounding off teddy [mimes with her hand light going from the torch, hitting the teddy and then bounding off towards CS's eyes].

1a:353 BN: *No.*

CS: *No, not literally like rebounding. It is shining onto him so it light up.*

1a:354 **TU: OK, so it is shining on.**

CS: *It is shining on*

TU: You hold it [the torch]. So it goes on.

CS: *So it goes straight to teddy.*

TU: But how does it get to your eyes?

CS: Because I'm looking, where I'm looking, where ever the torch light is I see it [shows what could be something coming from her eyes to the teddy - unclear]. So I can see the teddy and it all depends whether the light of the battery - whether the batteries are like half dead. You can't really see much.

1a:355 CS: So I can probably only see to your [TU's] jacket. But then if I - if it was a full battery probably like see quite a way. You can like see teddy from quite a far distance.

1b:70 TU (teacher): [Whilst video of 1a:349 is playing] So again I'm happy with that. I've checked what she means. [pause] My arms are saying what the answer should be [indicates this with her hands]. And she is still not picking up on it. Again I've tried to prompt her into the right answer, my arms, my pointing. [pause] I think she has got the concept that distance the light levels decrease [TU looks at JR as says this]. [pause] She is using her experience that in dim light you only see things quite close to you but in - the further away it is the less light is returning.

1b:71 TU: So she does have the concept that it is coming back. But it is not going into the eye and being processed by the brain. That is the bit that she is missing isn't it. Or appears to be missing.

So CS appears to have a naïve concept (1a:349) that light hitting the teddy is a sufficient explanation of how she sees it. Another pupil (JB) suggests that light reflects off the bear, and CS explains that reflection means to rebound off something. But CS is unwilling to accept that light rebounds off the teddy and restates the naïve concept twice (1a:353 and 354). **TU** tries again in line 1a:354 to effect conceptual change by requesting clarification as to how the light gets to the eyes. During the verbal protocol interview (1b:70) the line “I’ve checked what she means.” was also interpreted as clarification in this study. The teacher then acknowledges that she is trying to indicate to CS with her body language

what ‘the answer’ is, and that CS does not pick this up. In line 1b:71 **TU** interprets what CS has said suggesting that CS begins to understand that light bounces off the teddy during the extract, but does not appear to have linked this to the idea that scattered light must enter the eye for something to be seen. This passage illustrates just how challenging it can be for practitioners and pupils during such conceptual conflicts to interpret what each other means in real time. In addition, the understanding of complicated scientific concepts emerges, sometimes, from a soup of naïve concepts, and no teacher can ever be completely sure what a particular pupil means at any one point. This may be likened to the famous idea in military strategy of the fog of war:

Lastly, the great uncertainty of all data in war is a peculiar difficulty, because all action must, to a certain extent, be planned in a mere twilight, which in addition not unfrequently like the effect of a fog or moonshine gives to things exaggerated dimensions and an unnatural appearance. (Clausewitz, 1832, p. 189)

Clarification, either by summarising or requesting more detail, appears to be one technique teachers use to guide children through the complicated process of conceptual change.

4.2.3 Transfer

The experienced Advanced Skills Teachers who took part in this study sometimes told pupils things, confirmed the truth of a statement or refuted what someone had said. The codes of ‘tell’, ‘confirm’ and ‘refute’ were grouped together and termed ‘transfer’ during the coding of these data. Transfer was coded 414 times in all the interviews. In the following extract the teacher (**TY**), a physics specialist discussing a key concept in biology, uses both redirection and clarification (for example in 5a:352) among other techniques which will be discussed later in this chapter, but between 5a:365 and 374 the teacher reluctantly tells the pupils the end and then the start of the word ‘respiration’. In

5a:376 the teacher confirms that the pupils have found the word. Later in the same extract **TY**, with possibly a little irony, refutes what he has interpreted as a naïve concept expressed in 5a:390-393 that plants take oxygen in through their roots (this will be discussed below). Many children consider breathing and respiration to be synonymous (Haslam and Treagust, 1987, p. 203) and considerable research has been done exploring children's naïve concepts concerning this challenging scientific term, with many researchers noting that children rarely think that plants respire (Driver, 1994, p. 66).

Aerobic respiration is the process by which living organisms, or their components, take oxygen from the atmosphere to oxidize their food to obtain energy. Anaerobic respiration is the process by which organisms or their components, obtain energy from chemically combined oxygen when they do not have access to free oxygen. (The Penguin Dictionary of Science, 1979)

Hence breathing is an element of aerobic respiration. Many children confuse respiration, the process by which energy is converted in living organisms, with photosynthesis (Driver, 1994, p. 67):

photosynthesis The process by which green plants manufacture their carbohydrates from atmospheric carbon dioxide and water in the presence of sunlight. (The Penguin Dictionary of Science, 1979)

Plants make their food in their leaves through the process of photosynthesis, and use respiration to release energy from that food. Both photosynthesis and respiration are enormously challenging concepts for children, and a full understanding of these ideas would be unlikely in children of the age group who took part in this study. However, the children themselves raised the naïve concept of 'taking in oxygen' (5a:351) as being a characteristic of living things:

5a:350 **TY: [...] let's say that we can change whatever we like -**

- 5a:351 MG: Yes, I'd change - I mean yes. Which ones take oxygen and have an effect on all things living.
- 5a:352 **TY: OK, so [for something to be living] it has to have an effect on all things that are alive and it takes oxygen. Right. Anyone else agree or disagree? [Pause - AC puts his hand up] AC.**
- 5a:353 AC: What she just said 'it takes in oxygen'. I don't think trees take in oxygen I think they take in carbon dioxide and let out oxygen.
- 5a:354 **TY: Right.**
- 5a:355 AC: That is why they say don't cut out rain forests. Don't cut down rainforests and everything because you need to get rid of the CO2 in the atmosphere.
- 5a:356 **TY: OK, so does that mean that they are not living?**
- 5a:357 AC: They're probably living because they're breathing. So that is my little -
- 5a:358 MG: Maybe just breathing anything [unclear].
- 5a:359 **TY: OK.**
- AC: In most cases they'd have to be breathing.
- 5a:360 **TY: OK. I'm wondering - I'm hoping the answer to this question is 'yes' - if there is another word you guys mean when you say 'breathing'. I think it is a word you have used before, probably in Year 6. And it probably begins with R [pause] and I reckon this might be the key to fixing the rest of it.**
- 5a:361 AC: Could you help us out?
- 5a:362 **TY: It begins with R.**
- 5a:363 AC: Could you tell us what it ends with like how you do in class?
- 5a:364 **TY: tion.**
- 5a:365 **TY: It begins with R and it ends in tion.**
- 5a:366 MG: R tion. What?

5a:367 AC: Rtion. [AC laughs]

5a:368 **TY: That sounded as if it began with A. SP, I bet you know it.**

5a:369 SP: Redution? [sic]

5a:370 **TY: I think you just made up a new one. It sounds like Harry Potter spell.**

5a:371 AC: Redution! [AC waves an imaginary magic wand and laughs]

5a:372 **TY: I wonder what it might do? No, it is not redution.**

5a:373 MG: Radiation!

5a:374 **TY: No. Res.**

5a:375 AC: Respiration! [Others say the word simultaneously - unclear - several students laugh]

5a:376 **TY: Told you you knew it. So, can anyone tell me about R spiration? [sic]**

5a:377 MG: Um. Taking something - breathing something in to - that will help that thing carry on living.

5a:378 **TY: OK. Show me breathing? [The students laugh - AC starts to breathe loudly]**

5a:379 AC: No, no, no.

5a:380 **TY: No! That was good breathing.**

5a:381 AC: OK, it was breathing, but breathing can be done like this. [AC breathes more normally]

5a:382 SP: He doesn't want [unclear].

5a:383 **TY: I can't tell if you're breathing or not. Tell me how the plant over there is breathing? [Pause]**

5a:384 AC: It is breathing, but I don't know how!

5a:385 **TY: OK. Does anyone agree? Is the plant breathing?**

- 5a:386 MG: The leaves might be moving a tiny bit. [MG indicates a very small amount of movement with her hand] We can't see.
- 5a:387 AC: But that is probably because of the wind.
- 5a:388 **TY: So to breathe things have to move?**
- 5a:389 Several students: [Unclear - but clearly 'no']
- TY: Hang on, DF is going to tell us.**
- DF: No. Um. With the air around the object it somehow - maybe the soil or something - takes it in - goes through the stem of the plant [unclear].
- 5a:390 **TY: So the soil takes the -**
- 5a:391 DF: Air.
- 5a:392 **TY: Air. Through the -**
- 5a:393 DF: To the roots. Then through the stem.
- 5a:394 **TY: OK.**
- 5a:395 DF: And then spreads it around the plant.
- 5a:396 **TY: OK. Where is there more air going to be? Up around the leaves, or down by the roots?**
- 5a:397 DF: Up by the leaves. [DF laughs]
- 5a:398 **TY: Up around the leaves, so might you want to change your idea at all?**
- 5a:399 DF: [DF starts as if she has just thought of something] The air goes from the top of the plant [DF mimes this] to the bottom.
- 5a:400 **TY: OK, how?**
- 5a:401 DF: Um
- 5a:402 **TY: AC, breathe again. [AC does this] Have you ever seen a plant do that? When a plant has been doing some really hard work out there in the garden have you ever seen a plant do that? No?**

5a:403 MG: Maybe with humans you have to move, or animals you have to move, and plants they just - they can do it secretly.

5a:404 **TY: [Unclear] So it is like magic? And you said humans and animals.**

5a:405 MG: No, just animals. I changed it to animals.

5a:406 **TY: Because -**

5a:407 MG: Because like a dog would move when it was breathing and so on. All things with like a face.

5a:408 **TY: So animals are things with faces. [TY gives thumbs up and smiles] Love it.**

This passage illustrates how experienced teachers transfer information to pupils by telling, confirming and refuting. When **TY** suggests that the pupils mean something else when they use the word ‘breathing’ and that this may be key in ‘fixing the rest’ (5a:360) this was interpreted as refuting the naïve concept that all living things breathe (5a:351). One pupil (AC in 5a:353) has refuted another by suggesting that trees don’t take in oxygen (a naïve concept), but take in carbon dioxide (a scientific concept). The teacher redirects the conversation about plant breathing in 5a:360 to get the pupils talking about respiration. Pupils usually learn about respiration in primary school in the UK. The way **TY**, after a direct request for clarification from a pupil in 5a:361, tells the pupils the word respiration in stages (starting at 5a:362) demonstrates the tactical use of transfer as a teaching technique (see section 4.4). The teacher clearly does not want to tell the pupils this if he can help it and gives hints that the pupils already know this word (5a:360 and 368). The understanding of DF in the passage from 5a:389 to 399, where the issue of whether plants take air in through their roots is discussed, may be complicated by the difficulty many children have with the idea that a gas is something that exists and that air is a mixture of gases (Driver, 1994, p. 104). Plants do take oxygen in through their root

hairs which they use for respiration so that the roots can grow, so if DF is referring to oxygen, she is actually correct. **TY** uses humour several times in this extract (for example 5a:370, 380 and 402), picks up a pupil on the naïve concept that humans are not animals (5a:404), and interprets what MG has said in 5a:407 as meaning that animals are things with faces (another naïve concept).

The interpretation that teachers and pupils use transfer as a technique to promote conceptual change could sometimes be substantiated using triangulation from VP and RD interviews. For example, participant teachers sometimes acknowledged that they would sometimes tell pupils things:

1b:25 **TU (teacher): ... we'd talk about those kinds of concepts. But I think at the end I would definitely stop and give them a definitive answer. I wouldn't just keep letting them go round the houses. The scenario there is lovely to explore their thinking and see where they're at, but at some point I think you have to tell them as it is. And give them the facts as we know them.**

The passage quoted earlier (5a:350-408) amply illustrates pupils 'going round the houses', and transfer appeared to be an important techniques, used many times in all the EMT interviews, to guide and control the direction of these complicated discussions. Participants are aware they sometimes refute the thinking of others. For example:

2c:5 **TV: [...] I take corrective actions by just saying, 'OK, this is the bit where you got it a bit wrong.'**

In another example the teacher **TY** acknowledges that he is resisting refuting what a pupil (DS) has been saying:

5a:588 *SP: It reflects from the torch to the teddy.*

5a:589 *TY: So the light reflects from the torch to the teddy [TY mimes this with his hand] and - [TY raises his eyebrows]*

5a:590 *SP: And you can see it.*

TY: And you can see it. Thank you.

5b:38 **TY:** They're being incredibly polite, [TY laughs] "Sir, we've told you this three times and you still haven't got it." [TY and JR laugh] Um. So at the beginning with DS I let her go. She told me everything she wanted to say, without answering the question. And then I posed the question again. And I can't remember now if I changed it slightly to try and jump her back [TY mimes this with his body] to where I wanted her to be. I accepted what she told me, didn't say whether it was right or wrong, but tried to refocus her on what I actually wanted to know.

Hence **TY** in 5b:38 notes ironically that the pupils have repeated a naïve concept (that light hitting a teddy is a sufficient explanation for how we see the bear) three times and have begun to be exasperated that **TY** has not confirmed their reasoning. The teacher (**TW**) in the following extract again expressed a reluctance to refute when a pupil has made a grammatical error:

3b:42 *JR (researcher): And there was - DL uses the word 'condensating' [sic] at one point. And then straight afterwards you use the word 'condensation' - I found that bit at the end [pause]*

3b:43 **TW (teacher): Is it about sort of highlighting what they've done well in their answers?**

3b:44 *JR: Were you correcting her in some way?*

3b:45 **TW: Did she say it wrong and I corrected her?**

3b:46 *JR: She said condensating [sic]. And you said condensation.*

3b:47 **TW: Ah. That's naughty [TW is smiling]. You're not supposed to correct without explaining are you. I don't know if I misheard her.**

JR: Yes, yes.

TW: ... or whether I was really explaining it to the others. I can't remember at this moment what I was

doing. But usually it is about - for me - pulling out the word they've used that is correct and that we should use. I wouldn't normally intend to correct her, and would have wanted to use what she used and say, I like that word, so I'm going to use it myself. [Pause] But I can't remember if I was correcting her or not.

In this extract the teacher (TW) in 3b:47 notes that she would tend to use the correct words that pupils have used rather than incorrect ones. She says that she might have been talking with DL, but with the real intention of telling others in the group the correct word. This was interpreted as a combination of transfer and stratagem (see section 4.2.6). In addition she suggests that she sometimes temporarily employs the incorrect word a pupils has used, perhaps so as to see if it is necessary to tell, confirm or refute herself, or whether the pupil might correct themselves later, or another pupil might intervene to help (the 'use of timing' as a technique will be discussed in section 4.2.11).

There appears to be overwhelming evidence that in these data, teachers and pupils use the technique of transfer to tell, confirm and refute what each other says, sometimes in sophisticated ways.

4.2.4 Use a learning method

Learning methods (also called reasoning methods) used by professional scientists were explored in a study by the philosopher Darden (1991, p.244; see section 2.3). Children in this present study were found to use some, but not all, of the methods that professional scientists use. Learning methods are:

[A] plausible hypothesis for a reasoning method that could have contributed to the change that did occur. (Darden, 1991, p. 15)

Darden divided her findings into three groups: methods for producing new ideas, for theory assessment and for anomaly resolution. The published papers, notebooks and other sources Darden examined, contained evidence of twenty-eight learning methods this

group of scientists appeared to use: seven for developing new ideas, eleven for evaluating them and ten for dealing with anomalies. In the present study learning method was coded 374 times.

In the following passage a student (MG) proposes the theory that everything that is living has an effect on everything else that is living (5a:335) which is a naïve concept. Next the teacher (TY) challenges MG to state an example of something non-living that doesn't affect everything else. This technique of theory assessment was described by Darden (1991, p. 32) as checking for 'explanatory adequacy' and means that the theory explains the data. Hence, if MG already has an example of a non-living thing which does affect other things, then the theory is inadequate. MG first proposes a clock (with a smile), which she recognises immediately as something which does have an effect on living things. This is similar to the technique for anomaly resolution Darden describes as 'delete a component' (Darden, 1991, p. 269). MG tries again with the example of a brick (5a:339). The result of this discussion is that MG refines the theory in 5a:349 by suggesting that living things 'have an effect on other living things' and breath oxygen. This appears identical to the technique for producing new ideas used by professional scientists identified by Darden (1991, p. 244) of 'begin with a vague idea and successively refine'. Though this discussion starts and ends with naïve concepts, this is no different to the way the work of many professional scientists may be perceived in hindsight. For example, the Ptolemaic system of astronomy began with a naïve Earth-centred system and, through the addition of epicycles to explain the retrograde motion of planets, arrived at another naïve theory (Hoskin, 2003, p. 15).

5a:335 MG: Because they breathe oxygen. Because that is what it is. They breathe oxygen and carbon dioxide comes out. Not that they breathe carbon dioxide - because - and I think it is because it has an effect on

everything else living. So everything that is living has an effect on everything that is living.

5a:336 **TY (teacher): So that is one of the tests we could do for whether or not something is living. OK. So pick something on there [the mats] that is non-living and tell me how it doesn't have an effect on anything else.**

5a:337 MG: [Pause] [With a smile] A clock [TY smiles as well]

TY: Mm? [TY cups his hand around his ear]

MG: A clock.

5a:338 **TY: OK. What effect does the clock not have on anyone else or anything else?**

5a:339 MG: OK, a brick [MG smiles]

5a:340 **TY: OK. What if I drop a brick on - let's be kind -**

MG: Let's say AC.

TY: Yes [with a smile - everyone laughs] would it have an effect on him?

5a:341 MG: I don't think there is anything there.

AC: No.

TY: We could argue that couldn't we!

5a:342 AC: It feels on my head - no [unclear]

5a:343 **TY: Well it would probably at least make a dent. Wouldn't it.**

5a:344 AC: Probably not, I have a metal head. [AC and TY laugh]

5a:345 MG: You would feel it. OK. So -

5a:346 **TY: So, in that case, is the brick living or non-living?**

5a:347 MG: Living [said quickly] but, it is not actually living.

5a:348 **TY: OK. So is 'doesn't have an effect' or 'does have an effect on something'. Is that going to be a good test for whether something is living or not?**

5a:349 MG: No. What would be is if it is 'has an effect on all things living' and breathes oxygen.

This short passage illustrates the sophisticated use by a pupil and a teacher of learning methods to produce a new idea, assess theories and resolve an anomaly as described by Darden (1991). In addition, the three techniques of redirect, clarify and transfer (sections 4.2.1, 4.2.2 and 4.2.3) can be seen in 5a:340, 346 and 343. Each of the techniques identified in these data is introduced in order of the frequency with which it was used (see section 4.3).

There was some evidence that children might be using some naïve learning methods (Zimmerman, 2005, p. 17). This present study did not investigate conceptual change strategy as children undertake scientific activities. So the data on children's cognitive processes while they develop hypotheses, experiment and evaluate evidence is limited by this context (see Table 2 in section 2.3). Nevertheless there were some indications that the learning methods the children were using were not always the same as those which professional scientists appear to employ according to Darden (1991). For example in the following extract the group discuss water freezing and ice melting. Children usually do not think a change of state (such as frozen water melting to become liquid water) happens at a specific temperature (Cosgrove and Osborne, 1980). The scientific finding that pure water freezes at 0° Celsius and pure ice melts at 0° Celsius (at atmospheric pressure) is very challenging for children (and many adults):

6a:148 [...] **What temperature does water freeze at?**

6a:149 JP: Is it minus - It might be about minus five.

6a:150 **TZ: Minus five. [TZ points at VG]**

- 6a:151 VG: I was going to say between like minus five and minus ten. Something like that.
- 6a:152 **TZ: Between minus five and minus ten. [TZ points with a flat hand to JW]**
- 6a:153 JW: Um - zero. Zero point one. [TZ indicates AS]
- 6a:154 AS: I thought it was like minus a hundred.
- 6a:155 **TZ: Minus a hundred. [TZ appears to have a very slight change in facial expression - like a very slight smile]**
- 6a:156 AS: I thought it was really low.
- 6a:157 **TZ: Really low.**
- 6a:158 JP: [Unclear]
- FL: I thought it was really cold because like freezers and radia - not radiators - [AS laughs] and fridges they are usually about minus a hundred and twenty or something like that.
- 6a:159 JP: No they're not. [JP shakes his head]
- [...]
- 6a:173 JP: - you've got the melting point and freezing point. And we were told that the freezing point was, I think minus one - or zero. And the boiling point for water was a hundred. And like each um like each certain thing would have a certain boiling point and freezing point and - that's what I thought.
- 6a:174 **TZ: So you're correct to say each pure substance has a set boiling point and freezing point.**
- 6a:175 FL: Because sometimes like outside in the puddles when it gets really cold in the winter -
- KG: It freezes.
- FL: - it freezes over.
- 6a:176 **TZ: OK.**
- 6a:177 FL: So obviously if you're not going to be minus -

- 6a:178 JP: Yes, but it is not minus a hundred is it.
- 6a:179 FL: It is not going to be minus a hundred.
- AS: Yes, I got the hundred from [unclear - the boiling point?]
- 6a:180 **TZ: So it is not going to be minus a hundred.**
- 6a:181 FL: It is going to be close to zero, maybe -
- [...]
- 6a:195 **TZ: Is freezing point different from the melting point?**
- 6a:196 JP: Yes. [Very confidently]
- 6a:197 VG: Yes, because -
- JP: One's cold, one's hot.
- VG: I was going to say, because your like freezing point has got to be colder for the liquid to actually freeze -
- KG: And the melting point - [Said simultaneously with VG above]
- VG: - and the melting point -
- KG: - goes down.
- VG: - is where it goes from like ... from basically being frozen to actually melting and turning back into a liquid so it needs to be hotter and colder. [JP starts speaking in 6a:198 while VG says this]
- 6a:198 JP: So ... so ... so ... so in like water's case, if it was boiling point it would turn into a gas, and freezing point it turns into a liqui - um a solid sorry.
- VG: Solid.
- 6a:199 **TZ: OK. So if we had to explore that. I mean I know we've focussed a lot on this ice at the moment. So if we had to explore that, and change our perceptions, what practical could we do to try and change that thinking? Or trying to get an answer.**

6a:200 JW: Would you basically get the block of ice, and then ... maybe leave it out in the sun but keep an thermometer on it and go back to it every 5 10 minutes and record the time. And then see when it has completely melted.

One pupil (AS) says that she thought that water froze at minus a hundred degrees Celsius in line 6a:154. She later explains that she got the number 100 from the boiling point of water (6a:179). But another pupil (FL), who appears to share the same naïve concept as AS, explains that she thinks freezers are at minus 120° Celsius. The teacher requests clarification about whether freezing point and melting point are different (6a:195) and then redirects the pupils towards the idea of doing an experiment to resolve this question (6a:199). The experiment proposed by JW (6a:200) appears to involve a naïve learning method of recording how long it would take for a block of ice to melt, an experiment which would not resolve the question of whether the melting point and freezing point of water are the same. The pupil does not appear to have matched the experiment to the question.

In the following extract from an RD interview I asked the teacher directly about specific practices or ‘strategies’ they used. The answer illustrates how participant teachers appear to be aware that children sometimes use naïve learning methods:

2c:13 JR: Thank you. Are you conscious of applying specific teaching practices in your everyday work. Specific strategies or ...

2c:14 **TV: Well um, in science if we're talking about strategies we're talking about - we have got a national program which is 'how science works'. It is all about querying - putting everything in doubt. Whatever you see, don't always take it for granted. You've got to question it. What you see may not be real. So, and then you've got to investigate. You start with a question. You try to investigate this. You may or may not get the answer to your question, but at least you get to see - when you don't**

get the answer to your question you've got to ask yourself the question why you didn't get that answer. What is it that has been an obstacle to this. Was the way you tried to test it, was it wrong?

Hence this teacher (TV) was conscious that the experimental method a child used to investigate a question could be flawed. In a later RD interview I tried to probe experiences of naïve problem-solving, but the answer from TW focussed on the naïve epistemological beliefs of pupils:

3c:28 JR: Could I talk with you a little bit about children's problem-solving strategies?

TW: OK

JR: I think sometimes children's problem-solving strategies are very similar to adults' problem-solving strategies. You know, sometimes we have ways of solving the sorts of issues that are coming up here. But sometimes they're different. I wondered if you had any experiences of, you know, almost naive techniques. So not naive concepts, but naive...

3c:29 **TW: I think one of the naiveties that comes up there is firstly that everything they're told must be true. It is a bit like, you've seen it in a newspaper so it must be true. So there is that. But there is also, 'there must be an answer'. Or that there is a right answer. I think that is probably the biggest difference, as you get older you go, you accept that you're not always right, or people are not always right, or there isn't always a perfect answer. Particularly in science, although science is kind of billed as having the answers to things. I think that is probably the most stark difference. [...] I think we school that into them. Because there are right answers at school and you get ticks and crosses if you get it wrong. And then you're tested and you will pass. So we teach them that there is only one right answer and then throw questions like that at them and go, "Well, there are many answers." [TW sits back crossing her arms imitating the teacher and laughing] "What? There can't be." [TW imitates a pupil] [...]**

So this teacher (**TW**) suggests that some pupils think that ‘I have been told something, therefore it is true’, and ‘there is always a right answer’. She notes that school assessment culture and scientists themselves may encourage this naïve thinking and how disconcerting it might be for pupils when teachers and scientists point out that concepts are only ever disproved in science, many scientific questions have not been resolved at all and the scientific community is in constant dispute about competing theories. Conceptual ecology includes concepts, ontological categories and epistemological beliefs (see section 2.2). **TW** above appears to be talking about the naïve epistemological beliefs of the pupils.

4.2.5 Support

Participants supported each other directly or indirectly in a number of different ways and this was coded 265 times in 16 of the 18 interviews. The context explored here did not lend itself to exploring challenging behaviour and how this is managed, but this did occur on a few occasions:

1a:208 CS: No. No. [Shaking her head]. You're [JB] saying that a tree isn't a living thing [JK talking with JB behind his hand]...

JB: A tree is a living thing.

CS: What did you say earlier then?

JK: A mushroom wasn't alive.

CS: And also that mushrooms don't like live...

JB: Mushrooms don't come out your bum or something. [Laughs and puts his face in his hands on the desk]. Oh no, I've just said that wrong haven't I.

1a:209 **TU: Where does the milk come from? OK. Take yourself outside for one minute and calm down and then you can come back in a minute when you can explain yourself properly [pointing to the door - JB moves immediately].**

Emotional and/or behavioural management may have indirect effects on conceptual change. So, for example, the 53.8 seconds of debate which JB missed while waiting outside following the extract above might have influenced his understanding.

Another type of support was providing verbal prompts to help children express themselves. This can be described as ‘scaffolding’ (Sawyer, 2006, p.123) and this was used regularly. In the following example the teacher stops before completing the sentence giving an opportunity for the pupil (BN) to finish the idea:

1a:310 **TU: OK, what are you saying about light. Light has to be... [pauses]**

1a:311 BN: Moved

TU: and

EM: Controlled.

TU: So we've moved it.

The second prompt in this extract (1a:311 ‘and...’) indicates to the pupil that more is needed and so was coded as a request for clarification. A second example of the use of scaffolding shows a teacher helping a pupil to break down an argument into steps:

3a:136 **TW (teacher): Excellent, so add a little more detail to that. So let's go through the steps. GS has walked over [TW mimes this as she says it] and he put his hand on the handle. Tell me step by step about the energy and what is happening.**

Participants were aware they used scaffolding:

4c:36 **TX (teacher): I've seen teachers be very open, and it just all falls flat. Because they're trying - students haven't got the skills. If it is not structured then it will fall flat. Whereas if they're given structure - to structure their thinking, then you get something more productive.**

In addition to the emotional/behavioural support and scaffolding discussed above, participants sometimes needed physical help. In the following example a pupil (UA) and the teacher (TW) help another pupil (DL) lift a small whiteboard off the desk:

3a:319 **TW (teacher): Right. Would you like to show each other your pictures. Just have a little look round. At what you can see from each other [this is said in a slower measured way as TW looks at the pictures herself]. And then would anyone like to explain their pictures? [LM puts hand up first then GS and then UA]. [TW and UA are helping DL who is having trouble lifting the whiteboard off the desk] Is it stuck? Right. Lift it up. [TW is helping] Your nails are a bit of a hindrance. OK. Go on then LM. Hold it up so everyone can see your picture. And you can explain to us what you're showing.**

The instruction above to the pupils to show each other their pictures may be interpreted as encouraging participants to help each other. It was also coded as an example of using the group to influence conceptual change, a technique which will be discussed later in section 4.2.10. This teacher might have had a hidden motivation in getting pupils to see each other's work in that the pupils may be able to identify naïve concepts in the work of others and/or be prompted to see problems in their own drawings. This technique was called the 'use of a stratagem' and will be discussed next.

4.2.6 Use a stratagem

There were 208 examples in these data of participants attempting what was interpreted as a stratagem:

Stratagem n. a plan or scheme, especially one used to outwit an opponent or achieve an end: a series of devious stratagems (Oxford English Dictionary)

The fact that a technique is used relatively rarely may not diminish its usefulness for promoting conceptual change. To outwit someone can involve the use of better reasoning,

but this technique, which emerged during the coding of these data, involved deception.

Deception has been defined as:

a distortion of perceived reality (Whaley, 1982, p. 182)

This study does not explore any moral implications of deception (though deception was never used in a deliberately harmful way by any teacher during this study). Two kinds of deception are possible according to Whaley (1982) whose typology proved useful in interpreting these data: dissimulation (hiding the real) and simulation (showing the false); both of which can be further subdivided. The three types of dissimulation are masking (make invisible), repackaging (disguise) and dazzling (cause someone to lose clear vision). Three types of simulation are mimicking (through imitation), inventing (displaying a different reality) and decoying (diverting attention). For example, a duck hunter might dissimulate by hiding behind a bush (masking), wear camouflage (repackaging) and hunt from a place and at a time of day such that the sun is in the eyes of the prey (dazzling). This predator may also simulate by making quacking sounds (mimicking), and put a model duck in a pond (inventing the fake reality of a happy duck feeding and providing a decoy from the hunter). Teachers and students appear to use all six types of deception stratagem and this category emerged from the data during this study. Interpretation of deception is inherently difficult, and misunderstanding is possible in many instances. The triangulation of meaning in this context could be complicated by a natural hesitation of participants to acknowledge what could be deceptive activities (which in itself could be seen as dissimulation). Examples of all six types of deception will now be quoted with evidence from VP and RD interviews which supports these interpretations.

Teachers sometimes hide their intentions. In the following extract the teacher appears to mask (make invisible) a request by a pupil (GS) to speak:

- 3a:115 GS: I was going to say the top bit [GS is standing up and reaching towards the cup] it stays at the top bit. When it gets to its boiling point - because if it was a kettle it goes really really quick up in the air. So the particles just go really quick. [TW is nodding] Like I said [unclear but may be 'and frees itself in the air'] [TW nods and smiles]
- 3a:116 **TW: But we've actually got the opposite happening here haven't we. Because our cup of tea is sadly not boiling. It is not that the particles are going to get [indicating with her hands particles moving into the atmosphere] out, get free. What is going to happen to their energy? [TW looks at DL]**
- 3a:117 GS: [Puts his hand up and says 'Oh' - TW continues to look at DL as if not noticing GS - VH has her hand up slightly but not as enthusiastically as GS]
- 3a:118 **TW: [Pause] It is something to do with... KG, can you just remind us what you said? [GS puts his hand down]**

In line 3a:117 the pupil GS makes very clear both verbally ('Oh') and physically (he raises his hand and waves it around) that he wishes to speak. The teacher (TW) looks at another pupil (DL) while GS is doing this in what appears to be an attempt to redirect DL to speak. VH also wishes to speak as she has her hand up. DL does not say anything. After a pause, while GS still has his hand up, TW asks another pupil (KG) to clarify something that he said earlier. With only 7 people around a small table and GS sitting directly opposite TW there is no possibility that the teacher missed the request from GS. Hence the interpretation of this passage involved the teacher deliberately giving the impression that she was unaware of GS's intervention in order to redirect the conversation in a way which she judged to be more productive. This stratagem is commonly referred to as 'turning a blind eye' in the UK. Participants were aware that they hid things from each other:

3b:37 **TW (teacher):** [Pause - TW has a puzzled expression as the clip stops] I'm intrigued as to why you've chosen that clip. I'm not sure if I gave too much away by just describing the things as I passed them round.

So this teacher is being cautious not to reveal too much.

Another type of deception involves repackaging something to change the appearance. Both teachers and pupils disguised their intentions on many occasions and in the following extract from a RD interview a teacher explains how and why they might do this:

4c:32 **TX (teacher):** [...] So you stop the class - they're off task - [...] you ask them kind of research based questions. Always pose it from a point of view that you're doing research [...] - that you're not emotionally involved. [...] "So OK, you're off task, on a scale of 5 down to 1 [TX holds his fingers up] how on task were you?" They give you this [TX holds two fingers up] and they give you this [TX holds his middle finger up]. And all this. "And OK, well my challenge is I'm going to ask you again in ten minutes and I want you to have at least moved up by one or two. So what are we going to do to make sure that happens?" [...]

In this passage the teacher (TX) makes explicit that he camouflages classroom management as research. He describes the perception he wishes the pupils to have of what he is doing (for example that they think he is not emotional about what has occurred). The use of two fingers or one by a pupil to a teacher is an unambiguous challenge to authority in the UK, but TX makes clear that in such circumstances he would use timing (section 4.2.11) before evaluating progress in improving behaviour with the pupils.

Causing someone to lose clear vision is called 'dazzling' by Whaley (1982). This was not observed very often during the interviews (five times). The following example

illustrates a teacher (TU) describing how she might intervene as regards challenging behaviour by making use of this conduct:

1c:39 **TU (teacher): Behaviour management strategies are more about positive reinforcement and a lot of, "Yes, I'm really interested in your opinion. Yes, OK, you think that's a bit radical. Let's go with it. Oh, you want to blow up the balloons and not use them for the experiment. OK, so what are we going to do with them then?" And I'll take it down that route and then bring them back round [indicating this with her hand] to the main task in hand.**

Hence this teacher describes indirect behaviour management. She requests clarification from the pupil about how the balloons will be used. If the pupil responds to this polite question they might be distracted from their challenging behaviour.

The three types of deception just described (masking, repackaging and dazzling) involved dissimulation (hiding the real). The last three types encompass simulation (showing the false). In these data teachers sometimes imitated a person who does not understand (see 3a:108, 3a:538). This is a well-known rhetorical technique called Socratic irony.

Socratic irony, n. a pose of ignorance assumed in order to entice others into making statements that can then be challenged. (OED)

For example:

1a:317 **TU (teacher): [...] How do we get to see teddy?**

1a:318 CS: You see teddy by [shining? - unclear] the torch.

1a:319 CS: You've got the torch. You're looking round the room. You go, "Where's my teddy?" I've got to find my teddy. I've never like gone to bed without it.

1a:320 **TU: That's good.**

CS: You're looking around - you're looking around the room and you...

TU: I'm looking round [mimes looking left and right without moving the torch].

CS: ...and you find it with the torch.

TU: I'm looking around [as before].

1a:321 **TU: I'm looking around. Can I see teddy?**

BN: Use the torch! [smiling]

CS: That's what I'm trying to say.

TU: Oh, I'm moving the torch as well. [as if surprised]

1a:322 **TU: So I'm not just looking, I'm looking and moving the torch. [mimes looking left whilst shining the torch to the right, then looking right whilst shining the torch to the left].**

1a:323 JB: [Laughs]

BN: Wait!

JB: You have the torch and your eyes. [miming using his pen as the torch showing torch being shone in the direction he is looking in].

JK: Why are you [BN] doing it like that? [miming the way BN is holding the torch at arm's length].

1a:324 **TU: So I have to keep my eyes with with the light. Why? [Pulling a face as if TU doesn't see the need for this].**

1a:325 JB: Look. The light is like that. [Stands up and uses his pen as the torch] You walk round the room, you have the light - looking where the light is shining [walks round the room miming using the torch correctly].

1a:326 **TU: OK, so look where the light beam goes.**

In this extract the teacher pretends six times that she does not understand what to do. First she looks left and right, but doesn't move the torch (1a:320), forcing the pupils to explain that both torch and eyes must move. Next she looks one way whilst shining the torch in

the other direction, by which she indirectly points out to the pupils that their explanation is not yet sufficient. Even when **TU** appears to understand what to do in 1a:324, she pretends that this requires an explanation. The laughs and smiles by pupils during this exchange (for example 1a:323) indicate that they know what **TU** is doing. This experienced Advanced Skill Teacher who specialises in science poses as someone ignorant of how to use a torch.

In the following extract the teacher (**TW**) watches herself invent a new reality of “monster eyes” during a VP interview and then comments on what she was doing. The idea that we see by something coming out of our eyes is well known in the literature and is often called the ‘active eye’ naïve concept (Driver, 1994, p. 43):

3a:358 **TW (teacher):** *So it bounces back. So light bounces on my eye and then bounces back to you? [TW mimes light coming to her own eyes and then bouncing off her eyeballs] So is there light coming out of my eyes? [TW looks around as if demonstrating light coming out of her eyes sweeping the room]*

3a:359 **DL:** *No.*

UA: *No. [Who in 3a:357 has said light does come out of his eyes]*

3a:360 **TW:** *I'd have monster eyes! ZZZZ. [TW mimes something streaming out of her eyes like a very realistic monster and smiles]*

3a:361 **UA:** *No. The light source that comes - when that hits it - when that hits an area the light bounces into your eye so you can actually see where it is.*

3a:362 **TW:** *Oh, I see! ...*

3b:93 **TW:** **I was just messing with him again. But he then explained it more clearly afterwards. And that is a standard misconception that people draw line diagram and light comes out of their eyes. So I was just trying to get him round to - and he knew the**

answer, he got it there in the end. ... I was just highlighting the inaccuracy.

The teacher acknowledges in 3b:93 that she never thought that light came out of her eyes. However, having expressed the mischievous nature of her comment, she clarifies that this has nevertheless prompted UA to appear to change his mind. Line 3a:362 is another example of imitation (see above). Pupils also invent:

4a:465 DM: [JS has looked at JR. DM places the teddy back in the middle of the table, then picks teddy up as if teddy is attacking JS and then places teddy back in the middle of the table]

The stratagem of decoying (diverting attention) can be seen in the following extract from a VP transcript where the teacher (**TY**) watches an extract from the EMT interview (5a:474-484) before commenting on this:

5b:56 *CLIP 13: MRS GREN [ID 5a:478-484] 5a:474 TY: No. Mrs - [Pause]*

5a:475 *PP: Sirik? [Unclear - but a surname]*

5a:476 *TY: No.*

5a:477 *AC: Mrs [unclear - another surname - this is a joke and AC laughs with others]*

5a:478 *TY: No. Mrs GREN?*

5a:479 *AC: Oh yes! We did that in science. [AC is speaking with MG]*

[TY and JR laugh]

MG: Are you talking to me. I don't remember.

AC: In Miss [a teachers' name] - I can't remember if it was with TY or with Miss [same name].

5a:480 *TY: It definitely wasn't with me.*

5a:481 *AC: We actually wrote, Dr GREN or something. MRS GREN or something.*

- 5a:482 *Several students: Yes.*
- 5a:483 **TY: Yes? Well what was that all about then?**
- 5a:484 *AC: I don't know. [SP and PP laugh]*
- 5b:57 **TY: [TY is shaking his head] [TY and JR laugh] "Oh yes, we do know it, but don't understand what it is for."**
- 5b:58 *JR: And the chronology of it - this was right at the end. [JR laughs and TY nods]*
- 5b:59 **TY: But also the fact - so badly have they not got it that it could possibly be DR GREN [TY smiles]. [TY and JR laugh] And not only that he has remembered it being written on the board, but he can't remember if it was [the name of a teacher] or me who did it. Oh my dented ego! [TY and JR laugh] And I think there were some bull shit agreement at the end there - I think SP, it sounded like PP as well, was doing an "Oh yeah." when they actually meant, "What?" [TY smiles]. [Pause] [TY and JR laugh]**

So in 5b:57 with irony, and again in 5b:59, the teacher (TY) suggests the pupils (SP and PP) do not actually understand and are attempting to distract attention from this fact. Next we turn to a more straight-forward instructional technique, where teachers use a variety of activities to promote learning.

4.2.7 Use an activity

The particular task pupils do (for example an experiment, worksheet, sorting activity etc.), and the wider context within which this task takes place, probably influences conceptual change. However, this cannot be examined in detail in this present study because of necessary limitations of the methodology (see Chapter 3). Participants were asked to use specific tasks: a discussion using a cup and bowl of ice cubes as a visual aid, a living and non-living card sort activity and a drawing and labelling activity describing how they would see a teddy bear in a dark room using a torch. Even with these

limitations, participants did use a variety of activities which were not suggested by me as part of the research methods (section 3.4) and sometimes changed the activities. The use of an activity was coded 142 times during 17 of the 18 interviews. The following extract illustrates the innovative adaptation by a teacher (**TZ**) of the drawing task which was part of the EMT interview. The pupils had been asked to draw what they thought before talking, but the idea of drawing again after the discussion was not part of the research methods.

6a:588 **TZ: [...] So actually light must travel - the light from the torch is travelling in all directions -**

JP: Yes.

TZ: - if light hits the teddy -

FL: [Unclear]

TZ: - OK, but the light that hits the teddy then must do something - must do what VG?

6a:589 **VG:** Sort of like bounce -

JP: Reflect.

VG: - reflect and bounce back to -

6a:590 **TZ: Into your - [TZ pauses]**

6a:591 **VG:** Eyes.

6a:592 **TZ: Eyes [TZ sits back a little as she says this]. OK. So on the opposite side now, based on that ever so small discussion, how might you change what you've drawn?**

6a:593 **KG:** Can't I just do it on there [add to her original drawing], just do another little line?

6a:594 **TZ: No. Do it a completely new [TZ mimes turning the page over with her hands] - just a sketch. How might you change your ideas? [Pause]**

6a:595 **AS:** Urr. I can't really draw. ...

In line 6a:592 this teacher redirects the group towards a new activity which was not part of the questioning route for this interview (see Appendix B). The pupils make a second drawing to illustrate how their ideas have changed. One pupil (KG) wishes to amend her first drawing, possibly for reasons of efficiency, which TZ rejects as an option in 6a:594. This may suggest that the teacher wishes the pupils to have two separate drawings which they can then compare, which might help them see how their thinking has changed. Figure 9 below shows what one pupil (VG) drew before the discussion (6a:515) and afterwards (6a:592). The first of these drawings illustrates the naïve concept, well known in the literature (Driver, 1994, p. 43 or Heywood, 2005, p. 1454) where the ‘active eye’ idea is combined with the concept that light is necessary to see. The second drawing shows conceptual change towards the way physicists explain sight, but the fact that the arrow leading from the torch to the teddy bear hits one part of the bear, and the arrow from the bear towards the eye leaves from a different part of the teddy might indicate that the science here has not yet been understood fully. In addition the arrow leading to the eye in the ‘after’ drawing does not go directly to the pupil of the eye in the drawing. Both of these issues might be the result of the pupils being asked to make a rough sketch rather than a careful drawing, but they could indicate naïve thinking.

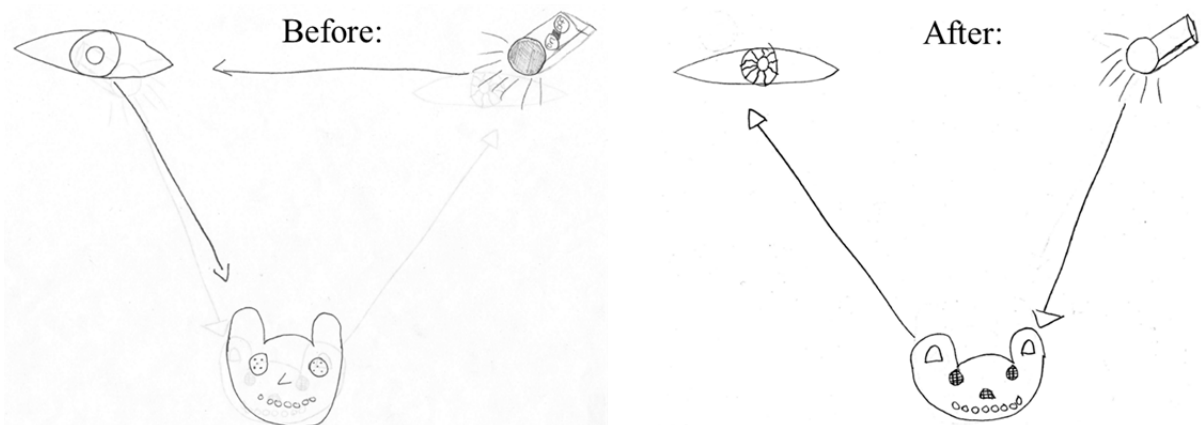


Figure 9: Drawings before and after discussion explaining how a teddy bear can be seen in a completely dark room using a torch (by a pupil VG during interview 6a)

When watching the video clip of the extract above as part of the VP interview, this teacher commented:

6b:80 **TZ: [...] This idea that it [light] must go to the eye - enter into the eye, for us to see is lacking I think from there. ... Again, ... near the eye [TZ turns the drawing she is holding over - unclear which one this is from this angle] but not actually in the eye. Very important for their understanding [TZ puts all the drawings together, taps them on the table to align the pages and places them on the table in front of her]. But it's changed [TZ looks at JR]. It has definitely changed. For most of them [TZ and JR smile]. [...]**

Hence this teacher adapted the activity and used it to assess conceptual change during the EMT interview. Other examples where an activity was adapted included the cup of tea and bowl of ice cubes being passed round participants for them to feel (3a:30) and the use of an extra set of the living and non-living cards by a teacher to demonstrate a group answer (3a:152). During a different interview another teacher commented:

1c:17 **TU (teacher): [...] in the classroom when I got a misconception like that [...] I would get something concrete. Do an experiment, or talk it through with them, or model something in a different way.**

Hence comments during the VP and RD interviews support the interpretation that ‘use an activity’ is one technique teachers use to promote conceptual change.

4.2.8 Condition

Participants attempted to associate a learned response with a stimulus and/or to modify behaviour as a result of a consequence (either a reward or punishment), and this was coded 137 times in 12 of the 18 interviews. Conditioning in learning was examined by Lieberman (1999, p. 104). The following extract illustrates the use of verbal and non-verbal encouragement, in what appears to be an attempt by the teacher to guide the thinking of the pupils towards a discussion about energy and temperature. The

effectiveness of the use of praise by teachers has been extensively explored in the literature (Kounin, 1970; Brophy, 1981; Wilson and Mant, 2011), but for the present study at issue is how praise appears to be used in combination with all the other techniques described in section 4.2 in tactical and strategic ways, with the intention of promoting conceptual change. The effectiveness of the tactical and strategic use of techniques in encouraging learning is not what this study explores.

- 3a:99 GS: [Has hand up and really wants to come in] Miss you know particles in a [solid?] - in - it is quite close to each other.
- 3a:100 **TW: Mmm. [Nodding and leaning forwards]**
- 3a:101 GS: So in a solid it is just close together, so when it melts it vibrates I think and it goes...
- 3a:102 **TW: There is a good word. Keep going...**
- 3a:103 GS: It goes apart to a liquid [TW is nodding] and when it goes to its boiling point it starts um... going [TW nodding]
- 3a:104 **TW: Right, so someone, a person maybe, not even a particle, is mov...**
- 3a:105 GS: Going hyper.
- 3a:106 **TW: ...is going hyper. What have they got more of?**
- 3a:107 GS: Energy
- 3a:108 **TW: Someone said it. [TW points with index fingers of both hands] I think maybe one of the girls said it as well. GS, [sitting back in seat] excellent. Energy [Said with considerable emphasis and lengthening the word]. So when something has got a high temperature, really we're thinking about how much energy it has got.**

This teacher uses verbal and non-verbal encouragement 8 times in this passage above. She makes use of body language (nodding, leaning backwards and forwards), the stressing of words (what linguists call prosody; Ottenheimer, 2012, p. 73) and the words

of this pupil (3a:105-106) to lead the group towards a deeper understanding of the hot cup of tea.

Evidence from VP and RD interviews appears to support the interpretation that teachers use conditioning, in combination with the other techniques described in this chapter, to attempt to promote conceptual change. For example, in the following extract a teacher reflects on the way a pupil used the MRS GREN mnemonic for seven characteristics of living things which is used extensively as a theory in UK schools:

1c:23 TU (teacher): And I have drummed into them, 'If they can't do all seven [holding up fingers], then they're not alive are they.' and he stuck to my word didn't he. Because he couldn't find evidence of the mushroom moving. Therefore it wasn't alive.

Many children find the fact that all plants (and fungi) move challenging, and some think that plants have a different kind of life to animals (Driver, 1994, p.20). The rote learning of a mnemonic like this has been interpreted in this present study as conditioning (for another example see 5b:55 in Appendix E). In the example above the teacher notes that this conditioning has resulted in a child using a theory to resist conceptual change.

Another teacher mentioned association during a VP interview:

6b:23 TZ: [...]we can do an experiment to collect some data [...] If it disagrees with what they're thinking then there is going to be some cognitive conflict there really isn't there. [...] "Why is it? Is the theory wrong - Is the theory wrong or is the experiment wrong?" [...] by doing something a little bit more concrete they'll be able to have some physical association with something that they've seen moving on a thermometer [TZ mimes this] or recording. [...] and maybe have an understanding [that] their ideas are correct or not.

This teacher appears to be describing the association of a classroom activity (like seeing the alcohol in a thermometer moving during an experiment) with conceptual change. This

passage also illustrates how the teacher and pupils sometimes try and persuade each other to change their mind, which will be discussed next.

4.2.9 Persuade

Participant teachers argued that persuading pupils to change their minds about naïve concepts is challenging. In the following example the teacher (TW) refers to the naïve concept that when deciduous trees lose their leaves in winter they are non-living, and they come back to life in spring when they regrow their leaves again. This was stated by pupils twice in these data (1a:174 and 3a:233) and a teacher discussed this naïve concept in VP and RD interviews (3b:83 and 3c:31).

3c:21 **TW (teacher): [...] Because if you've got a thought in your mind. If you've always been told that something, you know like the tree dies in winter, then why would you change that thought unless something came across [pause] - someone just telling you that that is not right isn't going to tell you a lot, well that is what everyone is told, maybe what your mum has told you every day. Why would this silly teacher woman be any better than my mum?**

So just being informed that a long held concept is naïve is insufficient to bring about conceptual change according to this interpretation (cf. Posner *et al.*, 1982, discussed in section 2.2). The emotional attachment a pupil may have to an idea which came from a parent, is contrasted with one from a 'silly teacher'. Emotion and motivation within conceptual change were highlighted in the work of Pintrich, Marx and Boyle (1993) and frequently termed 'hot' conceptual change in the literature (see section 2.2).

Participants seemed to use a wide range of ways to persuade each other when attempting to promote conceptual change. The conceptualisation of rhetoric (the art of persuasion) by Aristotle (Kennedy, 1980, p. 69) is here adopted to help identify particular techniques the teachers in the study appeared to be using. Insights from the ancient

treatise 'On Rhetoric' by Aristotle are still used by modern rhetoricians according to Kennedy (1980, p. 290). Aristotle distinguished between internal and external modes of persuasion. The former are created by the person talking, and derive from the three elements of the act of speaking: speaker (*ethos*), audience (*pathos*) and speech (*logos*). So in the data, a teacher (or pupil) might use their own personal authority to try and persuade a pupil, they might call on the expertise of the group, or their words could be used to convince. The latter (termed external modes) are not created by the orator but can still be used, and include, according to Aristotle, the use of laws, evidence (both freely given and forced), contracts and oaths.

Evidence that participants use the first three types of rhetoric (the internal modes) are illustrated in the following extracts. Firstly an example where the personal character of the speaker is used to persuade:

2a:173 **TV (teacher): ...you can ask me if you have doubts.**

Secondly, the influence of the audience is evident in the following example. BN has been persuaded by the group to accept a naïve concept (tea left in a cold room becomes colder than the room temperature) which she had originally challenged:

1a:408 BN: When I saw the cup of tea I thought it would drop to the temperature, but when I heard everyone else's opinions it doesn't sound as if it would drop to the temperature straight away. Maybe a couple of hours later maybe. It would be colder than the temperature

1a:409 **TU (teacher): Well I think that you had some very very good ideas and sometimes you shouldn't be persuaded by one person or another. ...**

The teacher (TU) responded to BN by trying to persuade her not to be so easily influenced. Participants appeared to be aware of the persuasive power of the audience:

1b:29 **TU (teacher): I think if she has seen somebody putting it towards one of those piles she is asking a question. She is not sure. She is not sure. I think the**

tone with which it was asked means it was quite incredulous. Like, 'I don't really believe that that is what it is.' but she has seen somebody else putting it in that pile so the seed of doubt is there.

The subtle, and often hidden, effects of one child on the thinking of another is alluded to in the previous extract. The use of the group as a technique to promote conceptual change will be discussed next in section 4.2.10. One teacher was asked directly how they persuaded a pupil who disagreed with them:

2c:25 JR (researcher): [...] If a student disagrees with you, how do you persuade them?

2c:26 **TV: [...] If a student disagrees with me then I get other people to voice out their opinions.**

So it appears that teachers make use of the audience to persuade children to change their thinking.

Finally participants used deductive speech to persuade. To illustrate this the following logical argument will be analysed:

1a:196 EM: I'm basically saying that what you're saying is that if it doesn't grow it is not alive. So basically if it not growing it is not alive. So you're saying an old lady is not alive.

This last quotation illustrates what Aristotle called an Enthymeme (Kennedy, 1980, p. 70) and there are other examples in these data (for example 2a:255-259, 2a:358, 2a:437, 3b:77 and 3b:79). This is a loose type of syllogism, used in speaking with an audience rather than in a dialogue, where one of the premises is often suppressed. The argument is a *reductio ad absurdum* and is of the form: things that are not growing are non-living, old ladies are not growing (in stature), and therefore old ladies are non-living. So EM has accused another student (JB) of denying that all living things grow. The teacher challenges the second premise of this argument:

1a: 200 **TU (teacher): ... I also accept what [EM] is saying. An old lady doesn't necessarily get taller [showing this with her hand] she might even be getting shorter as she gets older. But she is still alive because there are still bits of her growing. So if she perhaps cut herself, [JB puts hand up] there would be new skin growing. Her hair would still be growing. So she is still growing, but not necessarily in height. So you're absolutely right to have that argument.**

Hence the modified argument is of the form: things that are not growing are non-living, old ladies are growing (just not in stature), and therefore old ladies are living.

The other four types of rhetoric (the external modes), which involve use of laws, evidence, contracts or oaths, are illustrated in the following extracts. Firstly the teacher sometimes recalled the group to 'laws' the pupils would acknowledge. Here **TU** acts a little like a referee at a sports match:

1a:24 BN: I think...
[JB tries to come back in.]
TU (teacher): Let BN have a go.

The law is that each person should take their turn. Pupils also used this technique sometimes:

1a:117 EM: A ball falling is [alive]. Because there is a person in it and there is the ball.

LN: No, it says the ball falling. [emphasising the word ball]

1a:118 JB: Everything that has to live has to have seven things to live.

Hence a pupil (JB) has proposed a law (the MRS GREN theory) as a way of resolving whether something is living or not.

Secondly participants sometimes used evidence for or against an argument. This was often in the form of a 'running commentary' from the teacher which was used to

remind a student of what they or others had said earlier. For example the following extract shows a teacher referring to evidence from earlier on in the discussion, and pointing out to pupils that they have made this argument several times:

1a:191 **TU (teacher): So if it is not growing you're saying it is dead. But when it is growing, and that is something you keep coming back to all of you, you've got this idea that if it grows then it is alive, if it doesn't grow... or am I not saying what you're saying...**

That extract finishes with a request for clarification (a technique discussed earlier in section 4.2.2). Sometimes evidence seemed to be being extracted from a reluctant witness:

1a:149 **TU (teacher): Let [JK] have a say. Come on.**

1a:150 JK: A plant is a living thing because it can die when you don't feed it or like give it water... because it rots.
JB: [unclear]

1a:151 **TU: So what makes something alive then? [to JK]**

1a:152 JK: When it can die. [JK smiles - seems unsure. CS smiles as well]

Thirdly at times in these data participants behaved as if there were a contract between them. For example the teacher in the following extract appears to adopt a leadership role in the discussion with the agreement of the pupils:

1a:292 **TU (teacher): OK, so a really really dark room. And we walk in through the door and teddy is in the middle of the room.**

EM: Got to make sure the TV is off.

TU: OK no TV on. Are we going to shut the door behind us in this dark room?

1a:293 EM: Yes.

BN: No.

TU: Oh, we'd better agree.

BN: No.

TU: I think we're going to shut the door.

JB: Why?

TU: I think we're going to go in the room we're going to shut the door. Can we see teddy?

1a:194 EM: Yes. [Still working on her drawing]

LN: Yes. [Still working on her drawing]

CS: No.

BN: No.

1a:195 CS: Not until you turn on the torch, because...

JB: Yes but you would if you left the door open...

TU: We've shut the door.

The teacher above responds to the disagreement between EM and BN in 1a:293 over the issue of whether to shut the door by first suggesting that a consensus on the mental model being used (an imagined pitch black room) is necessary. When BN and JB continue to argue against this suggestion (the end of 1a:293) **TU** overrules their objections by stating that the discussion will be about a room with no sources of light. JB has another go in 1a:195, but **TU** just restates the contract; the door is shut. Continuing to repeat an instruction until a pupil complies is sometimes called the 'broken record' by teachers.

Finally teachers in this study very occasionally sought to persuade with a sort of personal guarantee, which was interpreted as an 'oath'. For example, a teacher might refer to themselves or someone else as an expert, and use this to establish the authority of what they say:

2a:241 **TV (teacher): Is there any question you want to ask me about anything that you have [indicating with his fingers something in the mind]?**

Persuasion of the seven types described above was coded 131 times, but some types appeared to be used more frequently than others. Table 6 below indicates how many times each type of persuasion was identified:

Type of persuasion	Number of references
Speaker	13
Speech	64
Audience	13
Law	13
Evidence	26
Contract	1
Oath	1

Table 6: Number of references to each of the seven types of persuasion identified in these data

The techniques presented in this chapter are listed in order of the frequency with which they were used, and the interpretation rests upon less and less evidence as each is introduced. Hence the findings about persuasion (section 4.2.9), the use of grouping (section 4.2.10) and timing (section 4.2.11) and the idea that there may be other techniques (section 4.2.12) are tentative suggestions and further research would be necessary to establish the trustworthiness of these interpretations (see section 3.10 and chapter 6).

4.2.10 Group

This study involved each teacher working with a group of three girls and three boys for reasons discussed in the methodology (section 3.5). In normal classrooms, the teacher has various options available as to how the class is grouped. For example, they can use whole class teaching, the whole class in groups (either equal in size or different sizes), individual teaching or some combination of individual work and group work (Forsyth, Jolliffe and Stevens, 1999). The influences on conceptual change of different types of grouping cannot be explored in depth in this present study because of the

methodological constraints just mentioned, but small scale group effects on the pupils were noted, and the teachers sometimes referred to grouping issues. In the following example a question was directed by one pupil (UA) to another pupil (GS), but the latter did not understand the question. The teacher (TW) redirected the question to yet another pupil (DL) in the group who answered the question:

3a:225 UA: [...] I'm just asking this. As... When you [GS] said the tree, you have to water the tree. [...] why does [the tree] have instructions to say on a hot day use photosynthesis or on a cold day or a rainy day take water from the roots? So I was just wondering - what is your... What would you [GS] say about that?

3a:226 **TW (teacher): Can anyone answer that?**

3a:227 GS: I didn't understand what he said.

3a:228 **TW: Do you [DL] want to try and answer it?**

3a:229 DL: I did. I understand what you're [UA] saying like. On a day - if we know we're thirsty then we'll take water because it is hot. And he [UA] is saying how will the tree know to do that if it didn't have a brain. Something to think about. And I think - I think they sort of - they don't have a brain, but they have something that tells them to do this on a certain day.

Hence there were some examples in these data where teachers made use of the group in order to promote conceptual change. In the RD interviews teachers sometimes talked about the use of grouping as a pedagogical technique.

2c:20 **TV (teacher): [...] I try to do as much practical stuff as possible - as far as I can - so that I can have the opportunity to go and discuss with smaller groups their ideas, so I can pick up misconceptions.**

So this participant describes using an activity (section 4.2.7) in order to be able to interact with small groups (section 4.2.10) to help the diagnosis of naïve concepts. Small group work was seen as useful:

1c:14 **TU (teacher): it is definitely beneficial. If I spent one session like that with a group of five once a term then I think their learning could shoot through the roof.**

4.2.11 Use timing

Participants could often choose to act now, later or never. Adjusting the timing of what one does or others do, is available as a technique for influencing the thinking of pupils and can be used to adjust the pace and/or the order in which activities occur. For example, in the following extract the teacher attempts to bring the card sorting to an end using the classic pedagogical technique of counting down from 10 to 1. First **TU** tells the pupils to do this quickly (transfer - section 4.2.3), she then uses non-verbal communication by miming running and then holding her watch, and finally she starts counting down (all in 1a:120). She stops the count down in 1a:121 in order to clear some space for JK so he could see both mats together (support - section 4.2.5). She informs the pupils that she is going to be strict about the time, and then restarts the count-down from 10 in 1a:122.

1a:119 JK: I've got two bicycles.

TU: Look at the pictures carefully.

CS: They're both bicycles, it's just one's got a person on it.

1a:120 **TU: Do it quickly. [standing away from the table - miming running with her hands. Then shows her watch holding it with the other hand] Right, ten, nine,**

1a:121 **TU: [JK] Can I move this so you have space. [moves cards on table]**

1a:122 **TU: I'm going to be quite strict on this. Ten, nine, eight, ... seven, (counting more slowly), six, five [collecting bags in] [helps JB lay out his cards more neatly]. Right, those on that pile go on that picture**

and those on that pile go on that picture. So shall I help you... three, two

JB: I swear you was on six. [JK and TU laugh]

1a:123 LN: Miss do you live on [a particular] road?

TU: That is the school address love not my address. Well I might live here. I've got a cardboard box under my table and I sleep there. [laughs]

LN: But Miss you're a Mrs. You've got children. [TU is helping JB lay out his cards. TU does not answer LN's question.]

1a:124 **TU: Right, so what I want you... you know when we did the activity similar to this when we did about solids, liquids and gases. I want you to tell me why we've put them in those particular piles. OK. So if we just go through a few of them. If we choose [JK's] one here 'the spider'. Has everybody got it on living?**

1a:125 Everyone: Yes.

TU: Why?

The subtlety of the use of timing here may be seen in 1a:122-123, where the teacher changes the pace at which they are counting between the number seven and six, perhaps to give the pupils a little more time to get the mats sorted, whilst simultaneously collecting the bags the cards came in (possibly so that they did not obstruct the view of pupils of each other's mats) and helping JB to arrange his cards more neatly having asked if he wanted help. The number four is missed out and the count-down finishes on the number two. JK jokes about the flexible way **TU** has counted. Then LN attempts to redirect the conversation (whilst **TU** continues to help JB) by asking if **TU** lives on a particular road. First **TU** refutes that idea (transfer - section 4.2.3). She then jokes that she is never allowed leave the classroom and finally ignores LN's question (two examples of the use of a stratagem - section 4.2.6). The outcome of this exchange is that the pupils are

ready, with JB achieving sufficient order among his cards at the end of 1a:123 for the teacher to proceed. Finally TU redirects the conversation by reminding the group of an activity they have done before (use an activity - section 4.2.7), and introducing how she intends to make use of the cards which have been sorted onto the living and non-living mats (1a:124). From when TU intervened as regards timing in 1a:120 until the cards on the mats are used in the next activity (1a:124) lasted 1 minute and 12 seconds on the video. This passage illustrates how complicated changing from one activity to another can be in a classroom, and a few of the subtle ways in which experienced teachers use timing to help this process.

4.2.12 Other techniques

Other types of teaching and learning techniques are of course possible, but were either not used by the participants in this study or missed in the analysis of this huge data set. For example, threats and punishment could be used to attempt to persuade pupils to change their thinking, this was not observed in these data (and many might consider such behaviour unethical).

In this section the teaching and learning techniques identified in these data were described. These were redirecting the conversation (section 4.2.1), clarifying by either summarising what has been said or requesting more information (section 4.2.2) and transferring information by either telling someone something, confirming what had been said as true, or refuting a statement (section 4.2.3). Learning methods used by professional scientists and naïve learning methods were both used by teachers (section 4.2.4). Participants helped each other in a variety of ways (section 4.2.5) and deceived each other (section 4.2.6). Activities were employed (4.2.7) and participants appeared to use conditioning (section 4.2.8). Seven types of persuasion were identified in these data (4.2.9), teachers grouped children in different ways (section 4.2.10) and timing was used

(4.2.11). The analysis separates these techniques into convenient labels, but the speed with which these interactions between participants unfolds means that few participants would have much time to reflect consciously on what to do next. Hence the tactical and strategic use of techniques appears to be a tacit knowledge, with the grounded theory describing what experienced teachers do instinctively (see section 4.4 below). Before discussing the tactical and strategic behaviour of teachers in this study in more depth (section 4.4), the following section will explore what can be learnt from the frequency with which each teacher used particular techniques.

4.3 Strategic profiles

The idea of a ‘strategic profile’ is introduced in this study to describe the frequency with which particular teaching and learning techniques were used. The techniques in the previous sections were introduced in the order of the frequency with which they were employed, and the number of references to each one was included in each section. In this section the frequency with which each technique occurred is compared in Figure 10, whilst Figure 11 shows how often individual participants made use of a particular technique. Figure 12 shows how often teaching and learning techniques arose in each topic area. This illustrates how the use of particular techniques varied between the ‘hot and cold’, ‘living and non-living’ and ‘seeing’ discussions. However, the participant teachers and pupils did not spend the same time on each question, so a comparison of the relative weighting a specific technique was given between different topics is not possible with Figure 12. To remedy this, Figure 13 shows how often teaching and learning techniques were used during each question as a percentage of the total number of references for that question. This allows comparison between the different ‘domains’ explored in this study. So, for example, the frequency of a particular technique

in the biology topic ('living and non-living') can be compared with that in the physics topic ('seeing'). For a review of the evidence for domain specificity in conceptual change research see Vosniadou, Vamvakoussi and Skopeliti (2008, p. 15). All four graphs (Figure 10, Figure 11, Figure 12 and Figure 13) were made using coding of the six EMT interview videos while the three topics were being discussed. In total this involved 5 hours and 18 minutes of video data with 4520 references coded. For comparison the entire data set for this study comprised 14 hours and 49 minutes of video, with 21,612 references. Added to each graph are columns in black or grey which show naïve concepts, scientific concepts, conceptual change, strategic friction (section 4.6), conceptual conflict (section 4.1) and logistics (see section 4.7).

The strategic profiles are likely to depend, to a significant degree, on the particular context explored in this study (EMT, VP and RD interviews - section 3.4). This thesis never intended to establish an objective measure of the strategic profile of participants (section 1.0). Indeed this study used grounded theory methods, so the codes and coding structure changed as the study progressed, as would be expected from this methodology (chapter 3). Hence Figure 10, Figure 11, Figure 12 and Figure 13 can only illustrate the concept of a 'strategic profile'. The trustworthiness of these data will be examined in depth in section 6.2. How this concept could be developed in future work, which may need a different methodology, will be discussed in the conclusion (chapter 7). Nevertheless, a brief and tentative analysis of these graphs follows, which shows how they can be used to compare the use of techniques by the six participant teachers in this present study. This analysis is analogous to the use of statistics during a rugby match. Such data may show a territorial advantage or an imbalance in possession which may be significant in one team winning, but it is perfectly possible to have almost no possession of the ball and to play the game almost entirely in your own half, yet still win the game.

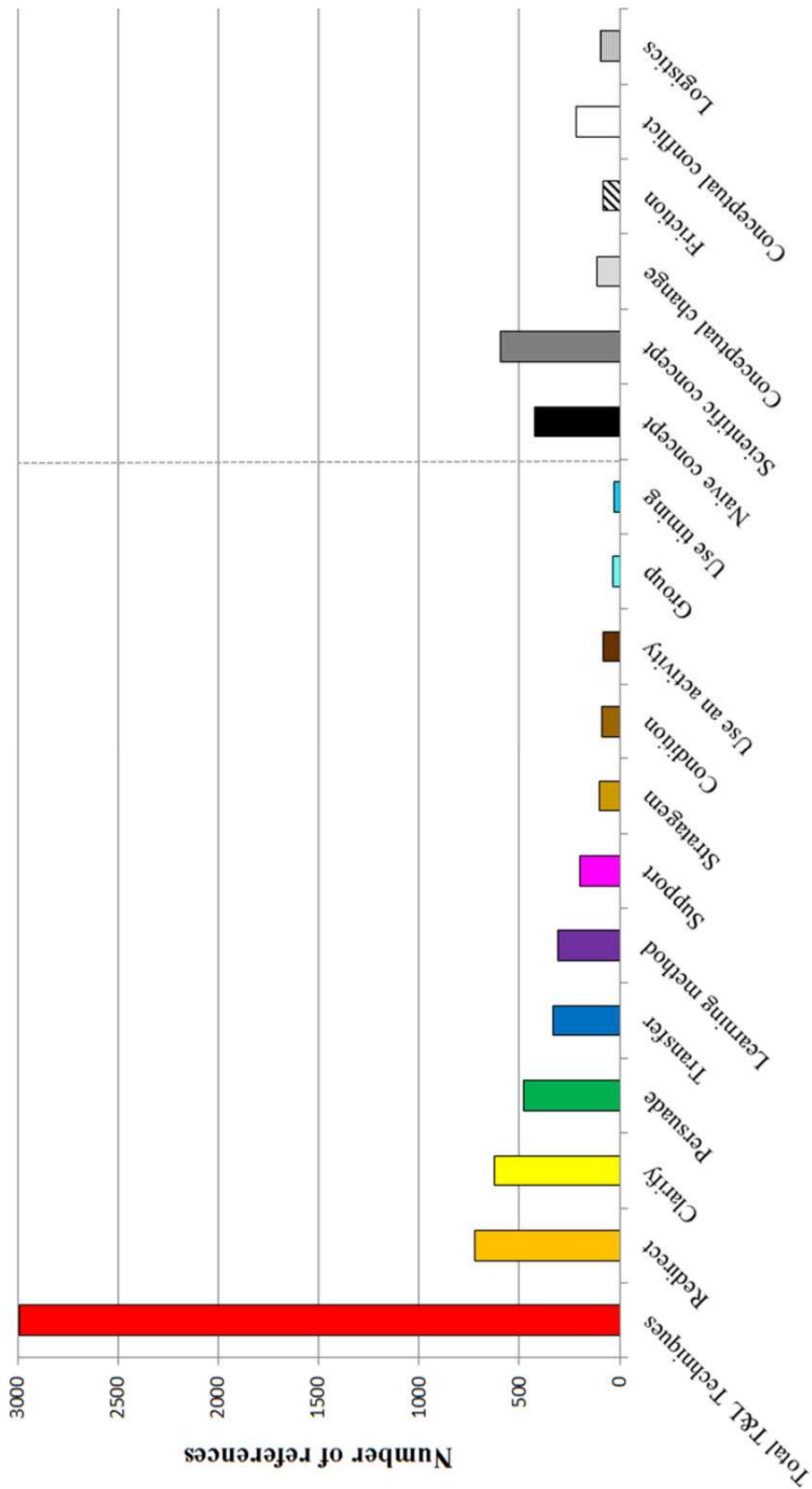
Figure 10 below shows how often teaching and learning techniques were coded in all the EMT interviews. In total the 11 techniques were coded 2,994 times over the six EMT interviews while the three key questions were being discussed. Redirect, clarify, transfer, use of a learning method, support and stratagem represent the vast majority of these references (92%). Hence, in the context explored here, ‘use of an activity’, condition, persuasion, group and ‘use timing’ were used relatively rarely. However, the frequency with which a particular technique is used says little about how effective it may be in promoting conceptual change. The effectiveness of instruction was not investigated in this present study. There were slightly more scientific concepts expressed than naïve concepts. I find it interesting that twenty-six times as many teaching and learning techniques were coded as incidents where there appeared to be evidence that conceptual change had occurred.

The strategic profiles of the individual participant teachers in the EMT interviews (Figure 11) illustrates variation in the use of techniques by these six experienced teachers in this context. For example the teacher in interview 2a (**TV**) attempted to persuade more than average (mean persuasion was 268). Participants **TV**, **TY** and **TZ** used more teaching and learning techniques than **TU**, **TW** and **TX**. The low use of ‘transfer’ by **TU** (interview 1a) and **TV** (interview 2a) was probably influenced by the evolution of the coding. Many more scientific concepts were expressed during the EMT interview led by **TV** than by the other teachers, but the amount of conceptual change which occurred in this interview was similar to the other interviews. This may suggest that ensuring that children express many scientific concepts does not necessarily lead to more learning. **TZ** (interview 6a) used the technique of transfer more frequently than other participants.

All that can be learnt from Figure 12 is that many more teaching and learning techniques were used during the ‘living and non-living’ card sort activity than during the

other two topics. As discussed earlier, Figure 13 allows some comparison between the ways techniques were used in each of the three topics. As a percentage of the total number of references for each question, the ‘hot and cold’ activity (question 4a) involved slightly less techniques than ‘living and non-living’ card sort (question 4b) or the discussion about how we might see a teddy bear in a dark room (question 4c). However it was necessary for this study that the order in which the three topics were discussed was the same in all the EMT interviews, and this may well have had a significant effect on these data. This might have been caused by unfamiliarity with the research context during question 4a which diminished in the later interviews, but could suggest participants gave different weighting to particular techniques when working in different domains. Any such conclusion must remain very tentative for the reasons discussed earlier, but do suggest that this methodology could reveal something of the domain specificity of conceptual change pedagogy.

To undertake more detailed analysis of the patterns within these data is not wise given the uncertain and evolving nature of the coding inherent in a grounded study like this (see section 3.11). All 18 interviews could be recoded, preferable by a team of researchers so that inter-rater reliability could be established (see section 3.7.3), and it may be possible to confirm or reject these interpretations, but that would be another study and is not necessary in order to answer the current research questions. This chapter turns next to a discussion about how the techniques were used tactically and strategically in order to promote conceptual change.



Teaching and learning techniques

References = 4, 520 (overall 21,612) Time = 5 hours 18:00 (overall 14 hours 49:17)

Figure 10: How often were teaching and learning techniques used during all EMT interviews?

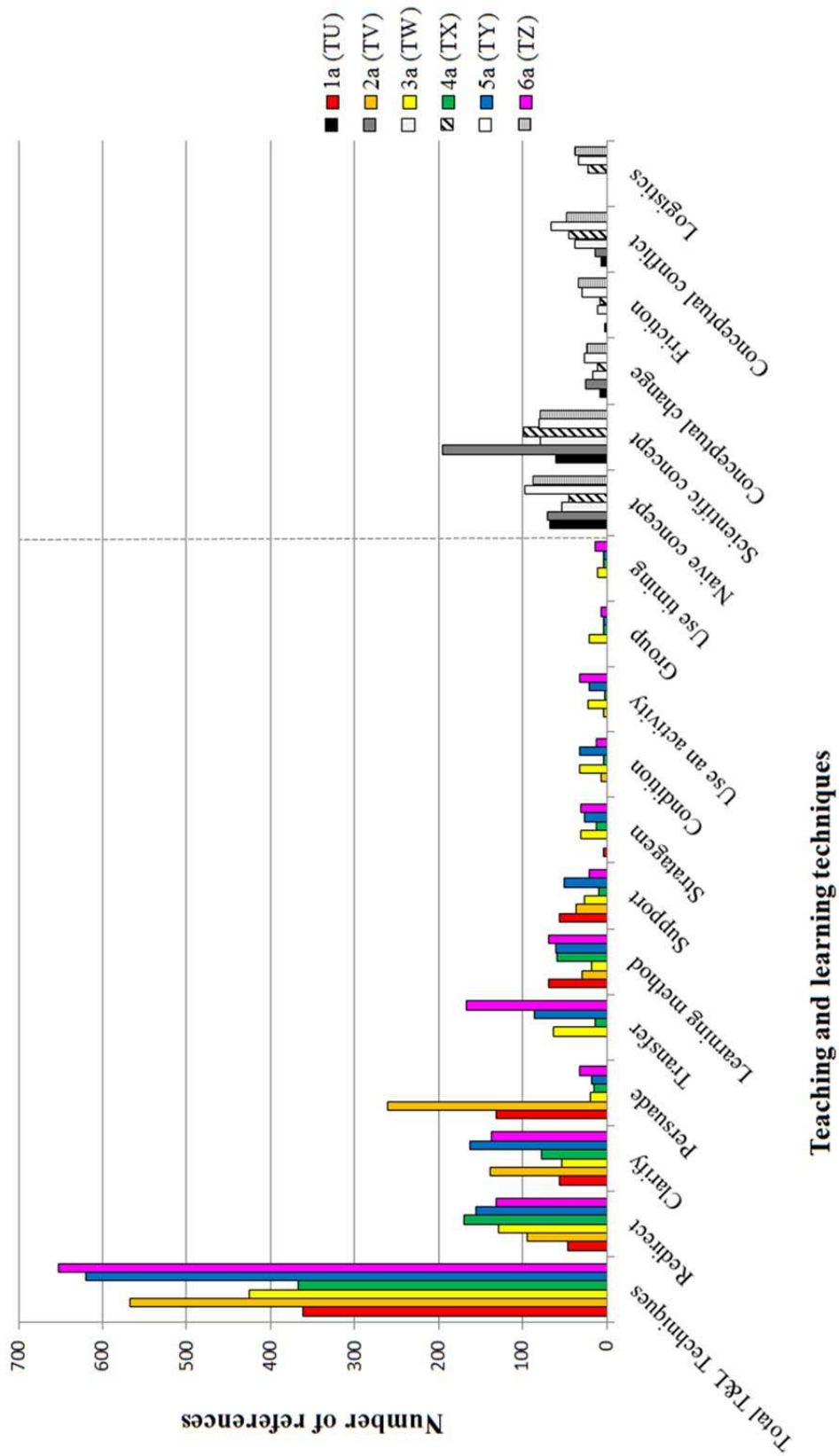


Figure 11: How often were teaching and learning techniques used during each EMT interview?

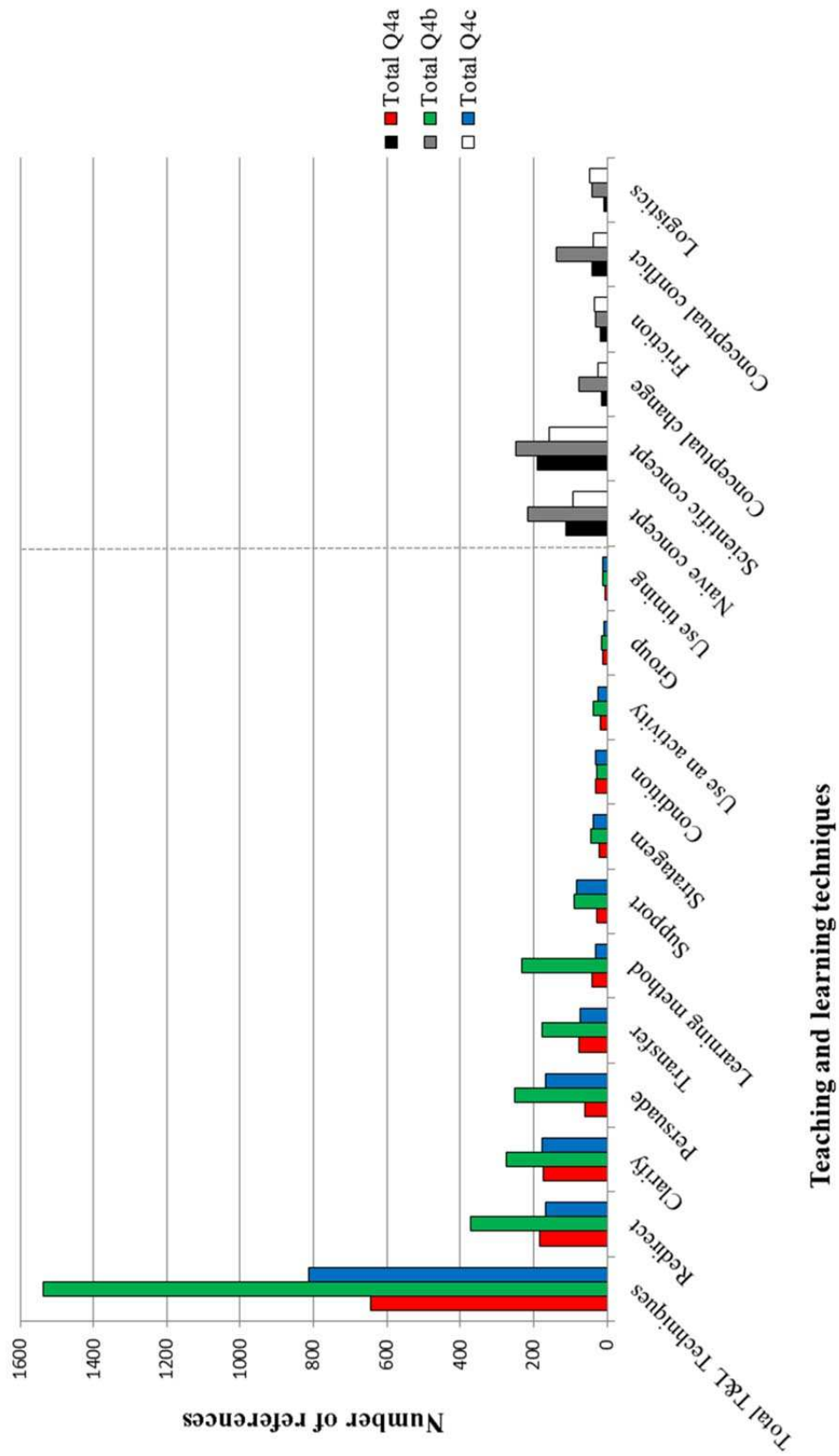


Figure 12: How often were teaching and learning techniques used during each question over all EMT interviews?

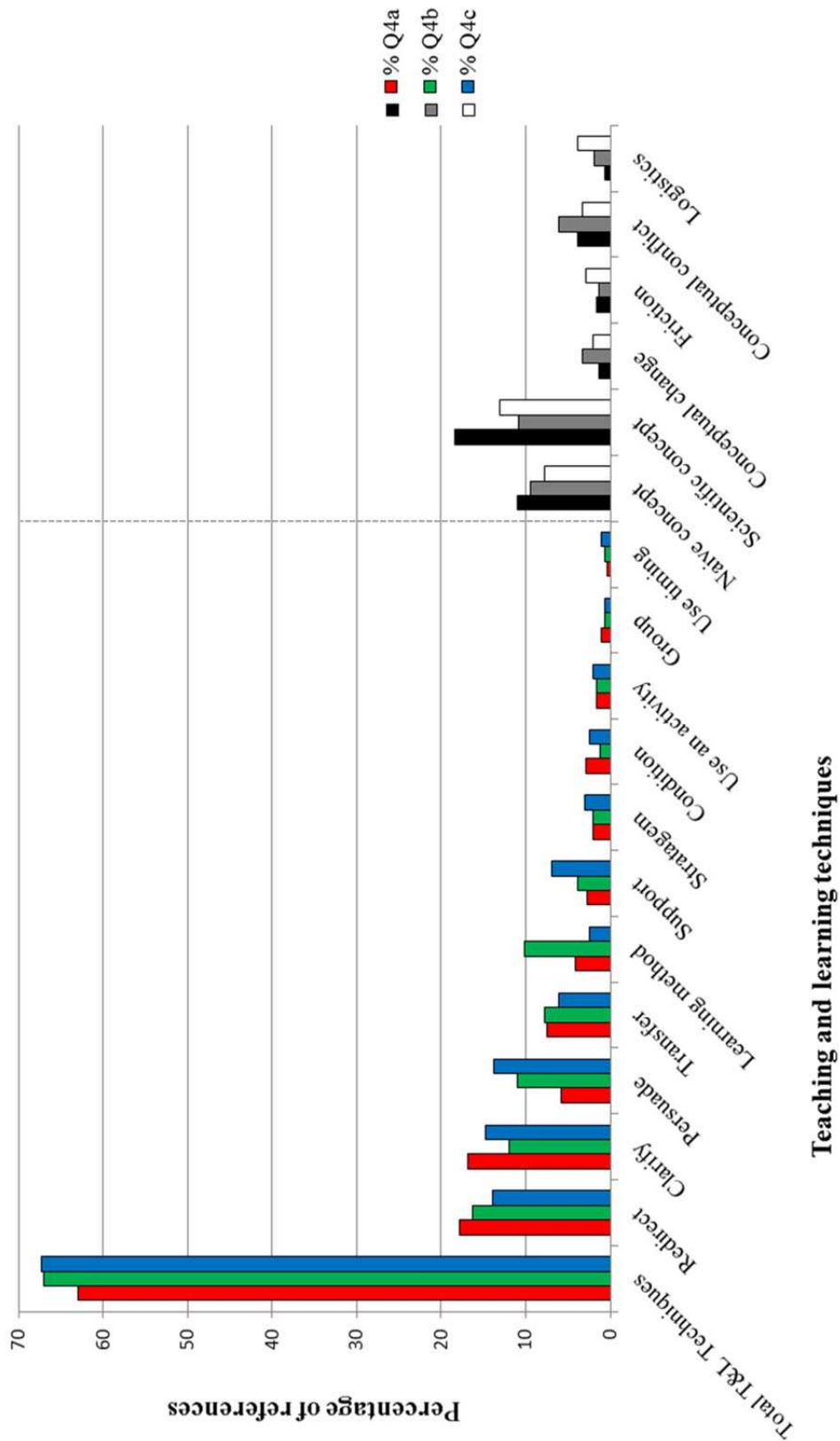


Figure 13: How often were teaching and learning techniques used during each question as a percentage of the total number of references for that question over all EMT interviews?

Chapter 4 - part 2: Tactics and strategy

4.4 Tactical and strategic behaviour

Tactics is the theory of the use of teaching and learning techniques in a single ‘conceptual combat’ (section 4.1). Strategy is the theory of the use of such conceptual combats to try and meet an objective (here conceptual change). A chess player may know how to move the pieces (the ability to use the teaching and learning techniques available), yet not be able to take those of an opponent (bad tactics). Winning lots of chess pieces (good tactics) does not guarantee winning the game (good strategy). Attempting to identify direct effects in the classroom from this theoretical distinction would be pedantry (Clausewitz, 1832, p.179). However Clausewitz goes on to argue that it is the first role of theory to clear up confusion.

Tactics and strategy are two activities mutually permeating each other in time and space, at the same time essentially different activities, the inner laws and mutual relations of which cannot be intelligible at all to the mind until a clear conception of the nature of each activity is established. (Clausewitz, 1832, p.179).

In business, executive directors are tacticians whereas non-executive directors are strategists, whereas in this present study teachers appeared to be taking both roles. Evidence has been presented of participants engaging in conceptual conflict (section 4.1) and using a range of teaching and learning techniques (sections 4.2 and 4.3). Tactics and strategy are interpretations of the bigger picture. Firstly a transcript extract (1a:129-201) will be used to illustrate how teaching and learning techniques are used tactically. The aim of this ‘thick description’ is to explain the behaviour of participants, and the context within which it occurs, in such a way that the tactics exhibited here can be understood (Geertz, 1973, p.5). This passage was selected because it is particularly rich and was discussed by the teacher during a VP interview (1b:32-37), but in many ways it is very

similar to the other six and a half hours of EMT transcript. Secondly, some evidence from VP and RD interviews will be used to support the interpretation of the tactics in this passage. Thirdly a range of teacher behaviours which have been identified in the literature, will be analysed to show how the grounded theory which has emerged during this study can provide an alternative interpretation of these phenomena. This study argues that the tactical and strategic use of the eleven teaching and learning techniques, which constitute the grounded theory emerging from this study, are consistent with the discoveries of some other classroom strategists (for example Kounin, 1970 and Kyriacou, 2009). Finally strategic behaviour of participants will be explored.

The passage below represents one conceptual conflict which lasted from 1a:129 until 1a:201 (a period of 10 minutes and 21 seconds) and it will be quoted in full and then discussed in order to illustrate the tactical behaviour of participants.

1a:129 **TU: OK. Right, so we've all agreed on the spider haven't we. OK, so let's turn that over then. If we all agree. What about mushroom?**

1a:130 LN: Depends whether it is dead or alive.

TU: What do you [LN] mean dead or alive? Who has got it on living? [BN, CS and JK put hands up then EM and LN - JB does not put hand up]. Everybody got it on living? Where is your [JB] mushroom?

1a:131 JB: On non-living [said quietly whilst pointing in an exaggerated way at the card which is on the non-living mat].

1a:132 **TU: On non-living. Why have you put mushroom on non-living?**

1a:133 JB: Because it doesn't live [said with feeling].

JK: Yes it does.

LN: Yes it does.

JB: It is like you said. It has got to move.

1a:134 **TU: Mushrooms don't walk or swim or fly.**

1a:135 Everyone except LN and JK: [unclear as several students talking at once]

1a:136 **TU: [To EM] Let him [JB] have his say and then you can argue with him. Like a good scientists we have to also listen to the other person's point of view.**

1a:137 JB: A mushroom can't move. It can't move at all because it doesn't have roots and the actual person has to feed it to make it grow. It can't feed itself.

TU: [putting finger to lips to stop BN interrupting] Let him have his say. That's not fair is it? Go on. [to JB]

1a:138 JB: Yes. That is what I wanted to say... and just like [LN] said a dog can feed itself.

1a:139 LN: Yes, but a fish can't and they're a living thing?

EM: Exactly.

1a:140 JB: No they don't. If it is on the side of the tank they can just

1a:141 LN: You'd have to put the food into the tank.

1a:142 JK: But that's not [unclear]

1a:143 **TU: Shall we not think about pets. Shall we think about them in the wild. [lots of students talking at once - unclear] Let [BN] have a turn then [CS]. They said that they did think that a mushroom was alive.**

1a:144 BN: Yes because whereas plants, with water, they grow and they eat the soi [stops before pronouncing the whole word 'soil']... is it the soil or the water?

1a:145 JB: The wa [stops before saying whole word 'water' - agitated waves hand at BN then sits back folding arms - TU does not turn her attention from BN] Look, a plant is not a living thing!

- 1a:146 BN: [To TU] And they [plants] grow and they eat and they're living [meanwhile JK suggests to JB that plants are living - JB disagrees] because they breathe as well. And a leaf is [alive] and so is a tree.
- 1a:147 JB: Miss [pointing at BN's cards] a plant is not a living thing because you need to feed it.
- 1a:148 CS: It is! It can die.
- JB: You need to give it water [unclear - but continuing to argue with CS]
- 1a:149 **TU: Let [JK] have a say. Come on.**
- 1a:150 JK: A plant is a living thing because it can die when you don't feed it or like give it water... because it rots.
- JB: [unclear]
- 1a:151 **TU: So what makes something alive then? [to JK]**
- 1a:152 JK: When it can die. [JK smiles - seems unsure. CS smiles as well]
- 1a:153 JB: A tree is a living thing.
- 1a:154 **TU: What if I said to you [looks at JK's cards then at JB's - points to JB's car card] 'My car'. My husband might come in and say to me, "Oh, the car died on me today."**
- 1a:155 JB: You told us the other day that it has to have seven things in it...
- 1a:156 EM: It has to be MRS GREN [Mnemonic used to remember the seven characteristics of life].
- 1a:157 JB: Yes, and he says, "My car's died on me." because he hasn't got no fuel in it or something. [CS puts hand up]
- 1a:158 **TU: OK, so it is somebody using [CS puts hand up] the expression my car died on me but it is not actually alive.**
- JB: They need to put some petrol in it. [JB says this whilst TU is still speaking]

TU: OK, so...

1a:159 EM: Miss can I... I just think that a plant and a mushroom is a living thing because when you think of a plant it moves because it grows and can sway in the wind...

1a:160 **TU: But isn't that the wind moving it? It is not the plant moving it.**

1a:161 EM: Yes, but it can move and it can grow.

BN: [Quietly whilst EM continues to speak] The wind is a living thing. [She holds up her 'wind' card. She smiles in an embarrassed way as CS, LN and JB begin to laugh].

EM: The plant has leaves and its leaves will grow. Its leaves can move [indicating leaves shaking in the wind using her hands]. Like a tree. [JB laughs, puts his head on his hands on the desk. LN is laughing as well. EM glances at LN] And if say, I don't know, ...

1a:162 **TU: [to JB - stops EM, speaks quietly and leans forward on the desk towards JB] Is there something the matter?**

1a:163 JB: [BN] said that the wind is a living thing. [JK laughing].

1a:164 **TU: We'll come back to that. [Hand held palm downwards towards JB]. And I don't think we should laugh at anybody's answers. [Shaking head slightly]. You didn't like it when somebody said something to you just now did we? You said a word wrong, so we're not going to do it to somebody else. OK, [EM] I'm sorry to interrupt you**

1a:165 EM: A plant can move because its leaves will grow and then they'll flap about and then and it can grow. It [the plant] eats the soil. Because the soil goes up into its roots...

1a:166 BN: No water. [goes up into the roots]

1a:167 **TU: You [BN] think it is water going up into its roots. You see you [EM] said soil goes in the root.**

[BN] didn't like that answer, she said it is water going into the roots.

1a:168 CS: Soil is like nutrients and water helps it grow.

JB: Miss... **[TU holds up a finger to JB glances at him briefly and then continues to listen to CS]**

CS: I've got a little seed. Say I've just planted a sunflower or something, I plant it in my garden. I have to like grow it or plant it in soil. If I just plonked it onto my pavement, 'Oh be careful don't stand on my seed'. It won't grow because it hasn't got nutrients from the soil. But if it is in the soil and all that all the nutrients will go into the seed and help it grow and all the roots need nutrients to make it and so make it work.

1a:169 **TU: [To JK] That is a really good answer isn't it.**

JK: Yes.

1a:170 BN: You do need water.

CS: Yes, you do need water to grow it and help the soil to...

1a:171 **TU: So you need soil, and you need water.**

JB: [Simultaneously] Plants don't have roots. [JK reacts - JB realises he has said the wrong word]

TU: I thought you said mushrooms didn't have roots?

JB: I mean I mean plants do have roots, plants do have roots. But I mean, they [plants] can't move their leaves. They don't because...they have... [unclear]

1a:172 JK: Miss was talking about they turn to the sun [mimes turning plant with his hands].

1a:173 JB: Yes, that is what trees do. Tree is not a plant.

Everyone except JB: Yes it is!

LN: What is a tree then?

JB: It is a tree. A tree is a tree.

1a:174 JB: It is not a living thing when there are no leaves on it. [points at tree through the window which has lost its leaves].

1a:175 **TU: So when the leaves drop off. Those ones [trees] out there they're not alive.**

1a:176 JB: Not really no. But when...

BN and CS: [Both disagreeing - unclear]

JB: They grow back.

1a:177 **TU: Are they dead those trees?**

1a:178 JB: No, there are little things that fall off them. They're like circular seed things aren't they.

1a:179 **TU: How can just a bit of the tree be alive and the rest of it be dead?**

1a:180 Several students at once: [unclear]

TU: [shows palm downwards to CS and turns to face her]

CS: It is either dead or alive. You can't really choose.

1a:181 JK: You can get an axe.

1a:182 **TU: Are you [JK] dead or alive?**

1a:183 JK: I'm alive. [smiles]

1a:184 **TU: You can't be a bit dead or a bit alive. You're either dead or alive.**

JB: Yes, but miss...

JK: You can be half alive.

1a:185 **TU: So do you [JK] think plants can be the same? [Before he can answer CS comes in]**

1a:186 CS: My aunt died, but she didn't even know that it was coming because she had cancer she didn't really know that she was going to die. She thought that the doctor was going to treat her and make her better, but they didn't actually know that she was going to die. So you

can't really predict whether a thing is dead or is going to die or whether it is alive.

1a:187 JK: If you get an axe and chop it and it is like all sort of...

1a:188 CS: Yes

1a:189 JK: ...inside [unclear - could be dead wood inside indicates half alive half dead?]

1a:190 CS: There is this tree on my family's drive and it was cut down last year and no... but it didn't grow. It hasn't grown since. And it hasn't got taller and it hasn't developed leaves. It hasn't even got twigs or anything. It is just like a stump. [JB is moving one of the cards on his mat and showing it to JK] It won't really grow from that.

1a:191 **TU: So if it is not growing you're saying it is dead. But when it is growing, and that is something you keep coming back to all of you, you've got this idea that if it grows then it is alive, if it doesn't grow... or am I not saying what you're saying...**

1a:192 EM: Not technically miss. Because an old lady, take old ladies for instance, they don't... once you stop growing, let's say eighty, seventy, [JB has put his hand up] [TU: **Shush, shush**] [EM puts her hand up - then starts to use it to show the height of the old woman] say you were this height when you're old you sort of shrink [showing height getting less with hand].

1a:193 **TU: OK. Did everyone hear what she said? An old lady is not alive because she is not growing anymore.**

1a:194 EM: Yes. So...

JB: Old ladies are alive! [laughs]

?: [unclear]

JB: As long as she has a heart she is alive, isn't she!

1a:195 JB: As long as she has a heart she is alive. A lady that is walking along the street and her heart stops she is dead. [touches his heart whilst miming walking]

1a:196 EM: I'm not saying that.

TU: [JB... JB...]Listen to what she says.

EM: I'm basically saying that what you're saying is that if it doesn't grow it is not alive. So basically if it not growing it is not alive. So you're saying an old lady is not alive.

1a:197 CS: What I was trying to say was that it was cut last year. It doesn't take like two years for a tree to grow into like a beautiful and fantastic

1a:198 JB: It takes up to fifty or sixty years to grow I think.

1a:199 CS: No, because I planted a little tree in my backyard and...

JB: A little one? A little one?

TU: [JB]

CS: No, it wasn't exactly tiny, but it was growing. But I knew it was alive because trees were... no... all the leaves were all green and...

BN: People are different to plants.

1a:200 **TU: People are different to plants. You're right. But I also accept what [EM] is saying. An old lady doesn't necessarily get taller [showing this with her hand] she might even be getting shorter as she gets older. But she is still alive because there are still bits of her growing. So if she perhaps cut herself, [JB puts hand up] there would be new skin growing. Her hair would still be growing. So she is still growing, but not necessarily in height. So you're absolutely right to have that argument. Right, let's just...**

1a:201 JB: Miss, you know milk. It is a living thing...

The teacher (**TU**) above asks whether mushrooms are living or non-living (1a:129), an issue recognised in the literature as problematic (Tamir *et al.*, 1981, p.241-248) and chosen as a card for the sorting activity for this reason. A pupil (LN) counters by suggesting it depends whether the mushroom is alive or dead (1a:130). Some non-living

things are dead (i.e. they were living) but many were never living, a distinction many children find difficult (Carey, 1985, p. 25). **TU** considers exploring ‘alive and dead’, but quickly returns the discussion to the issue of whether mushrooms are living or non-living by assessing where pupils have placed their mushroom card (1a:130). In this present study formative assessment is considered to be the tactical use of a number of techniques in combination (for example clarify and redirect) whereas summative assessment is interpreted as the ‘use of an activity’. Avoiding the problematic issue of the difference between ‘dead’ and ‘non-living’ can be considered a tactical withdrawal. All pupils but one (**JB**) have placed mushroom on living, and **JB** does not put his hand up when **TU** asks the group which of them has put this card on their living mat. From the video it appears that **TU** has seen both that **JB**’s mushroom card is on non-living and that he has not put his hand up with the others. Hence the line “Where is your [**JB**] mushroom?” may be interpreted as the start of the conceptual conflict. This line is not innocent, and **JB**’s reaction in 1a:131 (his unusually quiet tone and exaggerated pointing at his card) indicates that he may not particularly wish to be singled out as holding a different view to the other pupils. **TU** summarises **JB**’s point, and then requests clarification from him (1a:132). **JB**’s first argument is to assert more loudly (in contrast to 1a:131), and with some feeling, the truth that mushrooms don’t live. Two other students then flatly refute this claim (1a:133). **JB** counters by calling on the authority of **TU** (“it is like you [**TU**] said”) and using an enthymeme (section 4.2.9): all living things move, mushrooms don’t move, therefore mushrooms are non-living. **TU**’s summary of this enthymeme in 1a:134 is far from neutral. She stokes the conceptual conflict by humorously inventing a fake reality of mushrooms walking, swimming or flying. **TU** is a biology specialist who knows well that mushrooms are living and that they move, yet here she pretends to side with **JB**’s naïve concept (see section 4.2.6 on stratagems). In effect she is inviting the others to

take JB's point seriously, and counter his argument with something stronger than the refutation used in 1a:133. As a result, pandemonium breaks out in 1a:135 for a moment, with everyone talking at once. **TU** acts like a referee (in section 4.2.9 this type of persuasion was understood as the use of a 'law') and informs EM that JB will speak first, and that she (EM) can then argue with him. **TU** then makes a point about 'good scientists' listening to each other (1a:136), which again is establishing or referring to a 'law'. EM has not of course had the opportunity to answer JB's first enthymeme yet (1a:133). JB then makes three further arguments. Firstly: living things move, mushrooms can't move because they don't have roots, therefore mushrooms are non-living. The idea that roots might have something to do with movement appears to be naïve (plant roots move, but plants do not use their roots to move themselves – JB might be considering roots as similar to animal legs). Secondly JB argues that living things feed themselves, mushrooms need to be fed (a naïve concept), therefore mushrooms are non-living. **TU** manages the behaviour of a pupil (BN), who is attempting to interrupt JB, by suggesting this is not fair (again a reference to a shared yet unwritten law). Finally JB points out that one of his adversaries (LN) has already argued (it is unclear where) that living things can feed themselves, dogs can feed themselves, therefore dogs are living (1a:138). The use of evidence as a means of persuasion was discussed in section 4.2.9. LN counters that there exists a living thing (a fish) that cannot feed itself (another naïve scientific concept). In this way LN attacks JB's first premise. JB disputes this by claiming that just because an owner has put food in a fish tank, it does not follow that the fish is not feeding itself (1a:140). LN presses her point by repeating it in 1a:141, and JB appears to be struggling by 1a:142. The teacher (**TU**) comes to the rescue (support - section 4.2.5) by redirecting the conversation away from pets, perhaps because pupils may understand that wild fish must be capable of feeding themselves (being able to absorb in some way nutrition is one

of the characteristics of living things). **TU** then redirects the conversation to another pupil (**BN**), and reassures yet another (**CS**) that it will be their turn after that (1a:143). The teacher summarises **BN** and **CS**'s point from earlier, that they thought mushrooms were living things.

The section of this conceptual conflict just described in reality lasted 1 minute 46 seconds. This particular conflict continued for a further 8 minutes and 35 seconds in as much detail as has been described so far. This complicated interaction between participants illustrates the context within which conceptual change occurs. The noise and bustle of a real classroom, where many try to talk simultaneously, is removed from this sanitised version. How can any new teacher be prepared for such a conceptual maelstrom? Each technique used by teacher or pupils in the extract above, can be identified using the typology which emerged during this study (section 4.2), but this thesis argues that the why, when, how, where and who (from Kipling's, 1902, poem, "I keep six honest serving-men") are just as important as the 'what' in interpreting these data. Hence the need for analysis which acknowledges the tactical ways in which techniques are used within a conceptual conflict such as the one above.

The **VP** and **RD** interviews gave some corroboration to the interpretation that teachers sometimes made tactical decisions while attempting to promote conceptual change. For example, in interview 1b:32-37 the teacher (**TU**) watched the video of a short section of the conceptual conflict described above (1a:130-137). **TU** noted the tension between **JB** using a theory (for example that living things move) and the other students being intuitively aware that mushrooms are living (1b:33). **TU** interprets the naïve concept that plants cannot feed themselves, as emanating from the experiences of farming and gardening. She is proud of **JB**'s determination, whilst acknowledging that he is wrong (1a:34). **TU** speaks of other techniques she could have used tactically:

1b:34 **TU (teacher): [...] I think that is something I'd really like to think about later. How we get round that. The plant one is easier. Because even in their own experiences they can talk about leaves moving and flowers and sunflowers - and you can even show them an animation of a sunflower moving round through the day. And I suppose one of the other things I would do, if he persisted in that opinion, is I'd probably go away and I'd look for evidence and video clips of mushrooms and the hyphae, that kind of thing. Searching out the minerals. In the same way that a root does.**

So **TU** acknowledges that the techniques she uses to help children accept that plants move (which could involve reminding children that some flowers close at night and open again in the morning) may not be adequate for achieving the same aim where mushrooms (a fungi) are concerned. She suggests a different technique which she might try (like the use of an activity like watching a video). This illustrates tactical awareness of the need to change the techniques being used in some way when a conceptual battle is being lost. Following on from the passage quoted above (in 1b:35) **TU** discusses how **JB** cannot think beyond the law that all living things move. She suggests that **JB** might be influenced by a feeling of loyalty towards her as his teacher, and that he may be trying to please her (c.f. section 4.2.6). This represents a teacher reflecting on the aim of a pupil and is described as strategic awareness in this present study.

Several specific types of teacher behaviour have been described in the literature which will now be discussed to show how the idea of techniques being used in tactical and strategic ways is an alternative to these interpretations. For example group focus, 'withitness', momentum, the ripple effect, overlapping and smoothness were all discovered by Kounin (1970) in his seminal work on classroom behaviour management. Cognitive matching and differentiation were discussed by Kyriacou (2009, p.29 and p.60). In addition 'detachment' and 'giving an out' emerged as codes during the analysis

of these data, and both will be discussed below. In this present study it is suggested that all these terms can be understood as intelligent use of the teaching and learning techniques described earlier (section 4.2). To illustrate this point, an example of each of these will now be given and discussed briefly. The following extract illustrates group focus (the teacher ensures all pupils are engaged in the same activity), momentum (maintaining the flow of the lesson), and overlapping (attend to more than one thing simultaneously).

1a:92 JK: That is like when you have a shower before you go in the water it feels really cold.

TU (teacher): Definitely. [listening whilst getting card sort activity out]. Terrible isn't it. The one good thing about having a freezing cold shower before you go for a swim is the pool feels warmer!

1a:93 JB: Yes but when...

CS: [unclear]

1a:94 **TU: What I'm going to ask you to do now, sorry to interrupt you, is inside here are some pictures. You've got two grids and I want you, as quick as you can, so this one is the first thought.**

This present study offers the alternative interpretation of this passage which does not contradict the interpretation above which used the terms developed by Kounin (1970). The teacher in 1a:92 is simultaneously preparing an activity and confirming what a pupil has just said ('use an activity' and confirm). She then redirects in 1a:94 and gives some emotional support to the pupil she has just interrupted. These techniques are used tactically to ensure the new activity starts quickly and that the transition is covered by a conversation.

The following extract could be interpreted as illustrating 'withitness' (the awareness of what is happening in the classroom), smoothness (the ability to keep on

track), the ripple effect (where speaking with one person is used to influence another person or persons) and differentiation. Again the tactical and strategic use of teaching and learning techniques may be used to interpret the same data:

3b:72 **TW (teacher): So the first thing what I was doing was - well UA had obviously finished, so I thought he - I'd never leave a child who has finished an activity. It is just an opportunity to engage in discussion. Same with DL, but also to reassure the others that they didn't have to hurry up because UA was finished. So I'll keep him busy while they're still thinking. They might be listening at the same time, but they were all pretty busy. And I didn't question what he said. It wasn't about discussing whether he was right or not, it was just getting him to talk while we got set up really. Or not set up, but you know everyone finished the activity and had enough time [said with emphasis]. Same with DL. And by talking about the criteria they were using, I thought it might give others ideas - you know, just to have a little system. It could be anything, but especially when you've got to split things into two piles, you've got to be thinking, why. [Pause] Why you're putting them into two piles. And then it suddenly occurred to me they might not necessarily know what everything was. Both LM and VH are not first language English. They're both [from an eastern European country]. It suddenly occurred to me that there were a few words they might not have recognised. Most of them were quite straightforward, but that is why I went into 'embryo'.**

The teacher (**TW**) first suggests a new activity (section 4.2.7) for the pupil (**UA**) to give the others a chance to finish (use timing - section 4.2.11). She describes talking with one pupil with the intention of being overheard so as to help other pupils with a learning method (stratagem, support and use a learning method - sections 4.2.6, 4.2.5 and 4.2.4). Once again, the grounded theory (chapter 4) is adequate to explain these data.

Cognitive matching is the ability to pitch the learning at the appropriate level for each individual (Kyriacou, 2009, p.29). The following extract can be interpreted as demonstrating cognitive matching. First the teacher watches the extract in italics during a EMT interview, then she comments on this during the VP interview:

1b:7 *CLIP 2: cold [ID: 1a-89] EM: Because in your body you have a certain temperature, called body temperature basically, so when it is freezing cold outside the warmth of the tea...*

TU: So this [indicating the cup of tea]

EM: I don't know how to put it. ...will make you feel warmer.

TU: So it [heat energy?] is going into your body.

EM: ...and make you be warmer because the heat is actually going inside your body. So on a [TU talks over the clip at this point] boiling hot day in August or the summer if you have a, if you have like ice in orange juice let's say and drink it, the cold, the coldness of the ice will go into your body and make your body temperature even colder [TU continues to listen whilst removing the cup and bowl from the table.

1b:8 **TU (teacher): Because of the misconception of the [...] child I'm interrupting and correcting as I go along reinforcing. So the first child I just let her be. The second one I'm prompting and encouraging. That is interesting to think that you're guiding the learning of one and challenging the thoughts of another. And I'm just trying to think to myself whether it is because one child in my mind is of higher order in all the assessments I've given her so I'm leaving her be and the other one doesn't have such high assessments so therefore I've nodded I've encouraged I've prompted and reinforced.**

This teacher refers at the start of 1b:8 to a clip she has just watched (1b:4). She compares the way she did not intervene with one child (with CS in 1b:4 she 'let her be', interpreted here as the use of timing - 4.2.11) and corrected the naïve concept of another pupil (a type

of 'transfer' where the teacher refutes what has been said). **TU** reflects on the difference in the way she has intervened with these two pupils, suggesting that this may have been influenced by her prior knowledge about these learners. Hence cognitive matching (Kyriacou, 2009, p.29) may be explained using the typology for pedagogy developed in this study (chapter 4).

Two other types of tactical and strategic behaviour were identified during this study where participants consciously did not do something they would have normally done. Firstly 'detachment', which describes the teacher 'stepping back' and deliberately not intervening, is illustrated by the following excerpt. It corresponds to a decision to not redirect:

6a:107 **TZ (teacher): [...] I'm just going to sit back and let you discuss and then I'm going to intervene**

6a:110 JP: [Unclear]

VG: Yes, I was going to say they're both like -

KG: And the ice turns -

VG: Yes, its - the ice is sort of like melting just turning into room temperature - sort of like getting colder.

6a:111 AS: And that's turning from a solid to a liquid.

6a:112 JP: I think what will happened [sic] is when the ice is melted it's still would have to take a while to get to -

VG: Room temperature [simultaneous with JP below]

JP: - room temperature because where it is ice is will still be cold, so you're going to have to wait.

VG: [Simultaneously with JP but talking towards TZ whereas JP is speaking towards FL] we still have the temperature of the ice - actual ice [unclear]

6a:113 FL: [Simultaneously with both JP and TZ at the end of 6a:112 above] The tea takes less time than ice to get to room temperature because that [the ice] is like freezing

whereas, even though it is hot like, it is not as hot as like -

KG: It is not boiling.

FL: - the tea pot. It is not going to be at a hundred degrees [unclear - could be 'exactly'].

6a:114 **TZ: So we've established, I just sat there and listened, there is something that is - a change in temperature is going to happen. This hot tea is eventually going to become - [TZ pauses]**

6a:115 JP: Room temperature.

6a:116 **TZ: - room temperature.**

Here the teacher tells the pupils that she will not interfere with the discussion thereby forcing the pupils to change how they interacted within the group. In the passage pupils can be seen using some of the techniques described in this chapter (for example VG confirms what KG has said in 6a:110, a type of 'transfer'). After 39.7 seconds **TZ** rescinds this detachment using the clarification (summary) in 6a:114. She again explains to the pupils that she had detached herself. There was some evidence from other teachers during VP and RD interviews that participants at times deliberately stopped using particular techniques for tactical reasons. For example the following extract is from a VP interview where the teacher has watched an extract where condensation was being discussed (3a:54-64):

3b:64 **TW (teacher): [...] In an ideal world I wouldn't say anything. And they'd bounce around [TW indicates the conversation bouncing between pupils with her fingers] - they just need a bit of poking, and just a reminder [...] So you have to just nudge them into re-explaining it. Um. [Pause] I think there is something I try and do all the time, because I think it is more powerful if they get it from each other than it is from me.**

So **TW** justifies the rationing of her own interventions during discussion on the grounds that pupils interacting with each other is more ‘powerful’ than with her. One teacher commented during a RD interview:

4c:6 **TX (teacher): [...] I want to keep my input into lessons as minimal as possible.**

Eventually I decided that detachment could adequately be explained as the strategic use of timing, so this was removed as a code.

Secondly another type of behaviour was coded as ‘giving an out’ during the analysis. This was described by one participant:

5b:20 **TY (teacher): [...] So I'm giving them an 'out', rather than, "This is what you said! I'm going to hold you to it."**

This was interpreted as a strategic decision not to summarise what someone has said (clarify - section 4.2.2), or use it as evidence (persuasion - section 4.2.9), in order to prioritise the emotional wellbeing of a pupil. Being reminded of a naïve concept can be embarrassing. This awareness could be linked to the ‘hot cognition’ strand within conceptual change research discussed in sections 2.2 and 4.2.9. Again, it was decided that this code was unnecessary.

This thesis holds that strategy is a challenging concept to describe, and that understanding the idea does not make someone an expert strategist. How to make someone an expert strategist is beyond the scope of this present study. The relation between strategy and the techniques described in this chapter may be likened to the way a novice and a virtuoso pianist both have the same keys available to press. The difference lies in when and how to play each note, the complicated combinations used in series or parallel, the ability to listen to, and play with, other musicians and how experience (prior knowledge) informs a performance. In addition professional musicians have a certain

resilience to the unexpected which might disconcert a novice (see the discussion of strategic friction in section 4.6). In a similar way the eleven techniques identified would be familiar to most new teachers, but the examples used in this chapter have been included to illustrate sophistication in their use. The experienced teachers in this study often used these techniques with exquisite timing and expressed themselves with great subtlety. They interacted with several pupils simultaneously and a single word, phrase or action was frequently interpreted as having multiple purposes. This skill in the use of techniques during and between periods of conceptual conflict was termed ‘tactics’. In addition I argue that these data also reveal strategic awareness. Certain passages from the interviews hint at the way participants guided what they did, and were aware of the intentions of other participant. This is described here as strategy.

In the following extract from a EMT interview the pupils discuss whether intelligence is a characteristic of living things. The passage could be interpreted for the tactical use of a whole variety of instructional techniques during a conceptual conflict, but is included here as this teacher described her strategy during this clip when watching it back as part of a RD interview. The EMT extract will be quoted first, before the RD transcript is quoted and then discussed:

3a:195 GS: [Living things have] got to have some form of intelligence. [TW looks upwards as if thinking about this] It has got to have some form of knowing what it is doing for it to be alive.

3a:196 **TW: Has it? Does a tree know what it is doing?**

3a:197 UA: [Pause] Well, [pause] well, if you think about it the cells that make up a tree the nuclea [sic], the nucleus, it gives out instructions so it must know what its instructions to help the tree survive. [TW looks over at VH and LM]

3a:198 **TW: What do you [VM] think? Do you agree? Do you think a tree knows what it is doing?**

- 3a:199 GS: No.
- DL: No. [unclear as very quiet]
- 3a:200 **TW: You've [LM] put it in living. So have you [GS].**
- 3a:201 GS: Yes it does, because if it doesn't know what it is doing it won't grow. Because you need to have some sort of brain which would make be able to have the intelligence to grow.
- 3a:202 **TW: Does it take intelligence to grow?**
- 3a:203 GS: No, it doesn't take intelligence - it needs to have some [DL has hand up] sort of intelligence to grow. It doesn't have a brain, but it must have something in it - maybe... I don't know what it has in it but it has something in it to make it grow.
- 3a:204 **TW: You're working with some very difficult ideas here [The tone this is said with is lower and conveys respect for the ideas being discussed]. There is not necessarily a right answer to this. You're doing really well guys. DL.**
- 3a:205 DL: I think it doesn't know what it is doing. I think it just takes food and then it is like - it is like humans. If they don't have a brain, it wouldn't really matter that much. The world wouldn't be the same, but they would just eat and they would just do what they do [GS, VH and LM all have their hands up - GS very high, VH and LM much lower] - It wouldn't...
- 3a:206 **TW: Can we think of examples of things that have brains but perhaps don't know things?**
- 3a:207 GS: Animals
- UA: Perhaps a fish, because they've got - or a goldfish, because they've got a three second memory.
- 3a:208 **TW: Apparently it is a bit better than that. Yes, but we know them not to be exactly really clever.**
- 3a:209 UA: As GS said about the brain, as I said about the nucleus, that could be considered considering the number of cells that make up a single tree the amount

of nucleuses could [TW smiles] be considered the brain of it - of the tree.

3a:210 **TW: So would you say that a tree would be cleverer than a daffodil, because it is bigger?**

3a:211 UA: Um. Well, [TW is smiling] it all depends on the number of cells it has compared to the daffodil I would say.

3a:212 **TW: That is an interesting way of measuring it. No one has a perfect way of measuring intelligence. What do we do in school to try and measure intelligence?**

3a:213 DL: Tests.

3a:214 **TW: Could you give a tree a test? [Smiling]**

3a:215 UA: No.

Others: No.

3a:216 **TW: Well, not a real one. VH.**

3a:217 VH: I think the tree doesn't have a brain because if you put on water it grows. But if not it is dying if you don't put on water.

3a:218 **TW: Yes.**

3a:219 VH: It doesn't have a brain.

3a:220 **TW: But by saying it can die, does that mean you agree that it is living?**

3a:221 VH: Yes.

3a:222 **TW: So what do we think? Do you have to be able to know things to be alive?**

3a:223 GS: No, because probably - VH said you have to water it, then it gets its gets its - it goes to its roots and stuff to make it grow. And I think that the leaves as well help by photosynthesis.

3a:224 **TW: Mmm. Wow, there's a nice word. UA.**

3a:225 UA: As GS said, I'm just giving a... I'm just asking this. As... When you said the tree, you have to water the tree. Nature must take its course for everybody. Everything must eventually die. There is no stopping that. I understand that. But, um, when nature takes its course the roots actually take water, as you said, but what - what exactly um makes the tree - the nucleus - why does it have instructions to say on a hot day use photosynthesis or on a cold day or a rainy day take water from the roots? So I was just wondering - what is your... What would you say about that?

3a:226 **TW: Can anyone answer that?**

3a:227 GS: I didn't understand what he said.

3a:228 **TW: Do you [DL] want to try and answer it?**

3a:229 DL: I did. I understand what you're [UA] saying like. On a day - if we know we're thirsty then we'll take water because it is hot. And he [UA] is saying how will the tree know to do that if it didn't have a brain. Something to think about. And I think - I think they sort of - they don't have a brain, but they have something that tells them to do this on a certain day. [TW indicates with her hand that GS can come in - he had his hand up].

3a:230 GS: I think the sun really helps them a lot. I think literally - because it can take food whenever it wants [VH puts her hand up] the sun just needs to be in this direction - so that is why I think um the rain can't really get to its roots because the leaves are blocking it. So... [GS stops. TW nods to VH that she can come in]

3a:231 VH: I think the tree doesn't have a brain, but the way [unclear] the tree grow - if you put water and - yes - first you put the seed, what tree you want to grow. And then when the wind comes it actually grows and with the [unclear - 'suns rays?'] it actually grows a lot more. And - yes, because it is raining it grows [unclear - tailing off]

3a:232 **TW: [Coming in quickly] So... I really like UA's question. It was a really good one. You could say the same for animals as well. Like how does a dog or a cat know that it needs to eat or go and have a drink or any of those things. But that word know**

**[holding her hands together as if holding the word]
I think we're getting a bit stuck on that [GS and
KG have hands up, but TW goes with LM who also
has her hand up but much lower down]. [...]**

In commenting on this exchange during a RD interview this teacher weighs up particular techniques which are available. She is conscious of thinking in the 'back of your mind' whilst teaching about objectives. The way that overall aims guide the tactical use of teaching techniques is here understood as strategy.

3c:22 *JR (researcher): Just there you used that word, "Not telling." Are you conscious of things that you're not telling them deliberately.*

3c:23 **TW (teacher): Oh I'm deliberately not telling the lots of things. Because you have a desperate urge to just go, "No, no a tree [is] living." ... Because you want them to have the science right. In the back of your mind you're always thinking, not in this case, but generally, "Oh, they're going to have a test soon". ... they can't be writing that a [tree] has got a brain, because that is wrong. However, the process they're going through is more valuable than any test will ever pick up on. So I'm acutely aware of - and it is not an accident that I haven't just gone, "No, you're wrong." ... I think on occasion if something is absolutely wrong you do have to point that out, because you're not doing anyone any favours by going, "Think that still." But it doesn't create learning to just go, "No, that's wrong. This is what you've got to do."**

3c:24 *JR: And in sort of parallel with that question, not showing something, do you think sometimes teachers might show things they know not to be right as part of the...*

3c:25 **TW: Oh yes. ... a test paper said this the other day. You drop a hammer and a feather at the same time, which, if either [TW says 'if either' with a sly tone and expression on her face], will hit the ground first? Based on Galileo's thing. Well it is a trick question. And the kids are all saying, "Is this a trick question?" Because they've seen one or two trick**

questions. You do because then you can have a whole discussion on, "Well, actually..." And so on and so on. But yes, teachers do deliberately... I don't think they're trying to mislead, because they would never then go, "Carry on thinking that." They'd always address the misconception, ... So yes, I think teachers definitely do that. [TW laughs].

This passage sums up some of the techniques that teachers use (section 4.2). It also describes how techniques are used tactically. But the line 'the process they're going through is more valuable than any test will ever pick up on' (3c:23) expresses beautifully, in my opinion, the strategic consciousness of this teacher. The aim of changing the naïve concept that a tree has a brain is evaluated alongside the aim of getting pupils to pass the test. Strategy is expressed in the decision that there is something happening in this exchange during the EMT interview which was more important than both conceptual change of a naïve concept and the passing of a test.

Strategy can be seen both in what teachers do, and in what they do not do. In the following example the teacher (TY) talks about sacrificing a legitimate conceptual conflict about the incorrect use of the word 'conduct', in order to focus on the strategic aim of 'more easily fixable misconceptions' (promoting achievable conceptual change). The passage in italic is a transcript of the EMT interview this teacher is listening to. Normal script shows where the teacher comments during a VP interview:

5a:196 PP: The steam has slowly - like wears out. ...

5a:197 TY (teacher): And how does that relate to the tea getting -

5a:198 PP: It is just like - there is hardly any heat going to the - conducting the bowl. To the bowl. And that is how like the water gets warm, but it is not being warm because there is no steam. [TY looks at the ceiling] ... There is no heat.

5a:199 *TY: OK, right. So at the beginning of the experiment I think what you're suggesting is that there is a lot of steam, and that the steam melted, or helped to melt the ice, and at the end of the experiment there wasn't a lot of steam and so the melting stopped. ... Is that right?*

5a:200 *PP: Yes.*

5b:29 **TY: [...]** So what I was doing - I let him say his piece, and then reworded it. [TY looks at JR] And then checked - which he didn't get - I don't think he worked out why I was waiting at the end [TY laughs]. Checked that he was going to agree that that is what he meant by [what] he'd said. Changing a little bit along the way. And what I didn't do, right until the end, which surprises me now, is ask, "What do you mean by, 'the steam wore out?'". Because that is what I was going after. Um. And I think I got side tracked because he was coming up with a really good model for what might have happened. But the bit I'm int- proud about is that I let go of the bit about the incorrect usage of conduct. Because - these are chronological aren't they? [TY is asking JR] That we'd done that. We weren't going to fix it. And I'm actually surprised because that is one of the things that I've been most irritated about myself this year [TY smiles] - that I get stuck in a rut - I home in on one little thing that they didn't get right, that at the time feels really important that we fix it - at the expense, I think, of further exploration of other probably more easy - easily fixable misconceptions.

Once again the teacher describes techniques he is using, and ones he would have used in hindsight. Letting go of an aim to correct a particular naïve concept in order to fight more winnable conceptual conflicts is here interpreted as strategy. This same teacher was asked directly during a RD interview if there were particular strategies he used. For example:

5c:9 *JR: [...]* Are there particular strategies that you're consciously employing?

5c:10 **TY: ... Um. [Shaking his head] Probably no.**

5c:11 *JR: Or is it intuitive?*

5c:12 **TY: [Pause] I think probably if I wound it back to different times the answer would be yes. ... But I'm really conscious now that when I try to model stuff for [...] [s]tudent teachers and Newly Qualified Teachers - that I can't put into words, or I can't any longer [TY smiles] do what I was making [the students in interview 5a] do, which was put into a logical sequence why I do things. I just know [...] that I do them. And I do them because it works. Um. Principles [...] I guess the big one I aim at doing is making sure that everyone has a go. And making sure that everyone goes out feeling more confident than they did on the way in, even if they are not necessarily any better at doing what we hoped they would be able to do.**

Here **TY** acknowledges the tacit knowledge he employs (Polanyi, 1966; Elliott *et al.*, 2011, p. 83). **TY** describes how the pragmatic decision to use a technique “because it works” replaced the use of learned techniques from earlier in his career.

In the following extract the teacher describes how the ‘use of an activity’ and group techniques may be used for the aim of classroom management.

5c:14 **TY (teacher): [...] I've never known them not be able to parrot MRS GREN. I was really surprised. And I've - we've done sort tasks before [TY mimes this with his hands] and I guess normally I'm not very ... attentive when they're doing them. I suspect that that is probably a task where I trust the science will happen, and so I'm using it for behaviour management instead, and I go round and make sure that people are actively engaged.**

So this teacher is comparing the way he would normally employ an activity like the card sorting with the way it was used during the EMT interview. The usual MRS GREN ‘conditioned response’ (section 4.2.8) was missing with this particular group, which led to the activity raising a host of naïve concepts. It highlights how the same technique can be used for very different aims and the way participants were aware of this.

Participant teachers seem to believe that some techniques are more effective than others and that there is no simple recipe for how to promote conceptual change. In the following extract the teacher (TW) proposes the ‘use of an activity’, avoiding using ‘transfer’ (tell), using timing to give pupils a chance to think, clarifying what they say, and redirecting the conversation as steps on the way towards conceptual change:

3c:20 *JR (researcher): Just generally, students during those videos had been expressing all sorts of concepts that could be described as naive concepts, and that is not meant in any way pejoratively, are there general techniques that you might use for dealing with children's naive concepts?*

3c:21 **TW (teacher): I think it would depend on the particular concept. But I think touching, feeling and doing. Because if you've got a thought in your mind... someone just telling you that that is not right isn't going to tell you a lot, ... But letting them work it out themselves. ... almost by not telling them ... Or just questioning them [TW mimes something which indicates questioning in cycles or over and over again] about it until their logic falls apart. "Are you sure about that. Well, what about this?" Or, "what about that?" or "What about the other?" Until they go, "Oh, that can't be true because it doesn't work. It doesn't fit."**

The key point here is that the teacher is suggesting he would continue using the techniques at his disposal until he achieves his strategic aim. Hence there appears to be evidence that participants use the techniques described in section 4.2 in both tactical and strategic ways.

No instructions were given to the teachers as to what to do when a child expressed a naïve concept, yet when confronted by this thinking these teachers employed subtly different repertoires of techniques (section 4.2) which this study quantified using the concept of strategic profiles (section 4.3). This section has described some of the tactical ways techniques were used to promote conceptual change. In addition evidence was

presented of teachers behaving strategically, and describing their own strategy in these data. Participants encouraged some conceptual battles, yet avoided others. This supports the Clausewitzian interpretation which emerged during this study that tactics is the theory of the use of teaching and learning techniques in a single ‘conceptual combat’, and strategy is the theory of the use of such conceptual combats to try and meet an objective. Participants appeared to be making use of an extensive and tacit body of prior knowledge concerning what children think and what works in changing this thinking. These practitioners adapted rapidly to a new context (EMT, VP and RD interviews) and coped with huge resilience to the unexpected, to the extent of sometimes making use of the minor pedagogical disasters to promote learning (section 4.6) which will be discussed after different types of intervention by participants are outlined (section 4.5).

4.5 Direct and indirect intervention

Six different levels of intervention by participants with each other were observed, where the result was conceptual change. This describes the range of direct and indirect ways of influencing another person such that they will change their thinking. Firstly participants sometimes corrected, or attempted to correct, their own ideas. Secondly the teacher might try to influence the thinking of a pupil directly. Thirdly one pupil often tried to influence another. Fourthly the teacher might influence one pupil with the intention of influencing another. Finally a teacher may change their own thinking by themselves, or as a result of the influence of a pupil or pupils. These last two levels are not directly relevant to the research questions in this study so will not be discussed here. The following extract illustrates a teacher using several of these levels of intervention. Some children, particularly very young ones, think that anything that moves is living (Driver, 1994, p. 17). The two cards used are shown in below:

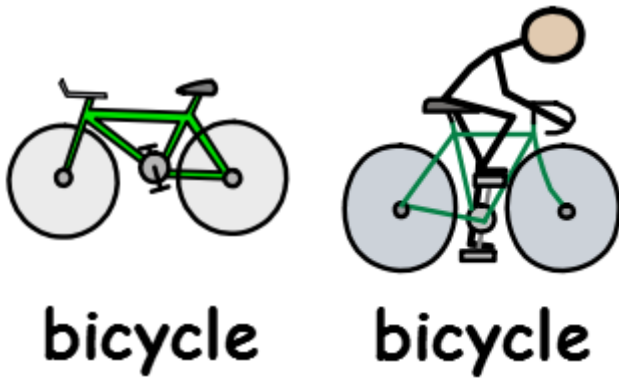


Figure 14: Pictures of the bicycle, and of the bicycle with rider, from the EMT card sort activity (© Widgit Software 2013 - used with permission)

The bicycle and rider is challenging for learners as the person is living, yet the bicycle is not (even though both move). The label points out that the object of interest is the bicycle rather than the person, but the following extract shows that this was not clear to all the pupils:

- 3a:178 **TW (teacher): ... GS, what was the one you've just decided to move. I think it is interesting that you've decided to move it.**
- 3a:179 GS: Bicycle, because on this bicycle there is just a bicycle bicycle. But on this one there is actually a person on the bicycle which... [Both cards have the word 'bicycle' written on them, one card has a picture of a bicycle, the other has a picture of a person riding a bicycle. GS has just moved the picture of the bicycle which has the person on it onto the living mat]
- 3a:180 **TW: LM you're nodding.**
- 3a:181 GS: Because a person is living, they're using their energy on the bicycle to pedal, it makes it [the bicycle?] living.
- 3a:182 **TW: Oh, OK. So, you talked about three different cards there [TW holds the two bicycle pictures up and the picture of a person so students can see them]. KG do you agree? Where have you put these three?**
- 3a:183 KG: Well, now from what GS has said I'm changing my mind and I'm putting the person on the bike on

living because - I don't really - I don't know miss [lifts and drops his hands in a sign of resignation?]

3a:184 **TW: You sound like you've been convinced.**

3a:185 KG: I wasn't sure where to put it, because it says just bicycle and I wasn't thinking - I was thinking just bicycle. You know, living or non-living. But after what GS has just said is making me think like it is true. Someone is riding on a bike.

3a:186 **TW: OK. So it sounds to me like it is a bit like the egg one. If it was just the word bicycle - or it was that one [picture of a bicycle without a rider with the word bicycle underneath it] where would you put that one [TW is holding up the card]?**

3a:187 DL and others: Non-living. [TW then puts that card on non-living]

So at the start of this extract the teacher (**TW**) notices that the pupil (**GS**) has spontaneously changed his mind about the bicycle. This corresponds to the first level of intervention (the pupil corrects his own thinking). **TW** requests clarification. In 3a:182 **TW** prompts another pupil (**KG**) to intervene (the fourth type of intervention) who **TW** may be relying on to help **GS** change his thinking. However **KG** starts to suggest that he has been convinced by the argument made by **GS** (3a:183 - the third type of intervention) before expressing his confusion over this issue. **TW** summarises this position in 3a:184 by way of clarification. **TW** resolves the issue by suggesting that the picture is causing the problem and determines that the pupils would place the picture without the rider on non-living.

The interpretation that there were different types of intervention which resulted in conceptual change was supported by the comments of participants. For example, in the following extract a pupil explains how the intervention of a teacher resulted in her changing her mind:

5a:635 MG: I think the light is travelling from the torch to the teddy and then the teddy is reflecting light to our eyes and we learnt that - you have ... I was kind of confused - I kind of forgot whether it was light goes to your eye and then to the object or the object then to your eye. But then now I remember in Year 6 I asked that question and the teacher explained that if the light was in your eye it is like you're shining the light in your eye so it makes it worst to see. So obviously it is the other way round, so that is why I drew it like this.

Hence this pupil (MG) explains that she had a naïve concept about seeing when in primary school (that light comes out of her eye), but that MG requested clarification from her teacher at the time who explained that if light originated in the eye then this would make it harder to see. This line of reasoning from the teacher ignores the fact that light does go into our eyes in order that we can see, but it appears to have helped MG resolve this naïve concept and remember at least one year later. In the following extract a teacher (TY) explains how he thinks teacher intervention can sometimes lead directly to conceptual change:

5b:66 **TY (teacher): [...] We have arguments that humans aren't animals. And the logic one for that one is, so we must therefore be plants. [TY and JR laugh] And you see the penny drop quite easily with that one.**

Interventions, whether direct or indirect, do not always work and these set-backs and failures will be discussed next.

4.6 Strategic friction

Any technique, tactic or strategy will sometimes fail in the complicated environment of a real classroom. This is analogous to the famous concept from military strategy of 'strategic friction', which proved useful in the interpretation of the data during this present study:

Everything is very simple in war, but the simplest thing is difficult. These difficulties accumulate and produce a friction, which no man can imagine exactly who has not seen war. (Clausewitz, 1832, p.164)

In this present study 186 examples of techniques, tactics or strategy going wrong were identified. This category, which emerged from the data during the analysis, is important as tactics and strategy were frequently used to respond to these minor disasters. One frustration some teachers might feel with optimistic strategies for conceptual change (section 2.5) is that they do not acknowledge the influence of strategic friction on what happens in classrooms. The following extract illustrates how a carefully-constructed ‘cognitive conflict’ (Posner *et al.*, 1982, p. 214) can go wrong:

1a:240 JB: A heart is a living thing. A heart is a living thing because if it wasn't living then we wouldn't be a living thing.

CS: [Simultaneously with what JB has just said] It [the heart] can't mate. It can't mate.

1a:241 **TU (teacher): So now [JB] is saying that the heart is a living thing.**

1a:242 JB: Yes. If we don't have a heart we wouldn't be here...

LN: That is true.

JB: ...nobody would be here.

1a:243 **TU: Could I ask a question. Where is the heart in the tree?**

1a:244 JB: In the middle of it.

1a:245 Several students at once: [unclear]

BN: No Miss. In a tree there is actually when you cut it like stuff coming out...

EM: Sap

BN: Yes, it is like blood.

1a:246 **TU: So you think plants have their own kind of blood?**

1a:247 CS: They have their own type of living because they might not even have our bl... they might not even have blood. They might just have...

EM: Sap.

1a:248 CS: Yes, whatever. Whatever they might....

JB: But...

CS: It could be anything. It could be stones as their blood. Crunched up stones. [Indicates many options by tapping the fingers on one of her hands]

The student JB proposes that a human without a heart is non-living. If the heart makes us living, it must itself be alive according to JB (a naïve concept). The teacher counters using the enthymeme (section 4.2.9) that trees are living, trees don't have hearts, therefore it is not necessary for something to have a heart to be alive. Unfortunately JB picks up on an alternative use of the word 'heart', meaning the core of a tree. This study argues that it is just not possible to predict the outcomes of exchanges between participants within a complicated social context like this, so even the tactics and strategy of expert teachers will fail sometimes.

In the next three sections some of the causes of strategic failure captured in these data will be described. Secondly the ways in which participants sometimes made use of these failures will be discussed. Finally it will be argued that it may not always be possible to know why a technique, tactic or strategy has failed.

4.6.1 Causes of strategic failure

Strategic friction appears to occur at four stages during communication. Firstly when an idea is expressed in a way that is incomprehensible to another participant. For example:

- 5a:9 DS: My name is DS and I like science because you can learn new things like that you didn't know before [said very quietly]
- 5a:10 **TY (teacher): You can - [TY cups his hands around his ears indicating that he didn't hear what DS said]**
- 5a:11 DS: [Louder] You can learn new things and you can do experiments. [TY nods]

Secondly, when what is communicated is not received correctly by another person. For example, one teacher watched a short clip where a pupil said:

1a:373 JK: When you see something it has actually come from your eye.

When watching this naïve concept being expressed during the VP interview the teacher commented:

1b:75 **TU (teacher): [...] I don't think I even heard [1a:373] in that situation. I think we probably miss a lot, especially in a big class where you're moving around. There's lots of things going on and I just don't - I didn't hear it in that small group setting, so I think it is even less likely that I would have heard it in a whole class setting.**

Thirdly, even if a participant has heard or seen what another has communicated, they may misunderstand. In the following example the teacher has just introduced the task about how we see a teddy bear with a torch:

5a:539 PP: I don't get this.

MG: [Quietly] We did it in Year 6.

5a:540 **TY (teacher): You don't get it. Shall I read the question again?**

5a:541 PP: Yes please. [The other students are drawing]

Fourthly, with any new idea mis-reasoning is possible. Different types of conceptual change were discussed in section 2.2. Such learning can result in scientific and/or naïve concepts being formed. Finally participants sometimes did not remember, or remembered

incorrectly, what had been said before. In the 21 minutes preceding the following extract, the pupils have been discussing living and non-living and have not mentioned the MRS GREN theory. The teacher eventually explores whether the pupils have forgotten this:

5a:474 **TY (teacher): [...]** Mrs - [Pause]

5a:475 PP: Sirik? [Unclear - but a surname]

5a:476 **TY: No.**

5a:477 AC: Mrs [unclear - another surname - this is a joke and AC laughs with others]

5a:478 **TY: No. Mrs GREN?**

5a:479 AC: Oh yes! We did that in science. [AC is speaking with MG]

MG: Are you talking to me. I don't remember.

AC: In Miss [a teachers' name] - I can't remember if it was with TY or with Miss [same name].

5a:480 **TY: It definitely wasn't with me.**

5a:481 AC: We actually wrote, Dr GREN or something. MRS GREN or something.

5a:482 Several students: Yes.

5a:483 **TY: Yes? Well what was that all about then?**

5a:484 AC: I don't know. [SP and PP laugh]

5a:485 **TY: Oh. [TY laughs]**

5a:486 AC: MRS G for something.

5a:487 **TY: MRS NERG or MRS GREN?**

AC: MRS NERG

TY: And you didn't meet it in Year 6 at all? With Mrs [surname of a teacher]?

5a:488 MG: We wrote it on the side and there were words [MG mimes this with her hand] to stand for - [TY nods] Yes. But I've forgotten.

Therefore there appear to be five causes of strategic failure which can be seen in these data: miscommunication (both in transmission and reception), misunderstanding, misreasoning and misremembering.

Strategic friction occurred at the levels of techniques, tactics and strategy. For example participants noted that teaching and learning techniques can be used inexpertly. Teachers sometimes make mistakes in the use of timing:

3b:58 **TW (teacher): [...] I think maybe I'd gone on a bit too much.**

On a tactical level mistakes can be made. For example a task may be too challenging for particular pupils. In the following example from a VP interview the teacher (**TW**) notes that the concepts being discussed would usually have been too challenging for pupils of this age. She notes that some of the pupils in the group had understood whereas other had not:

3a:131 *GS: You will put some of the heat from your hands into the cup.*

3a:132 *TW: That is true, [...]*

3b:67 **TW: There is tremendous high level science going on here. [...] The difference between temperature and energy [...] I don't know why I kept going on with it because I think I would have probably given up if it was a normal classroom - I would have felt, "OK, they're only in Year 7. We won't go." But they got there and I felt they could get there. At least three or four were totally on board with it. And they were understanding it and they were keeping going. I'd like to say the girls understood, but I'm not sure - especially now I can see their faces more clearly, exactly how much of that they took.**

Hence this teacher had a difficult tactical decision to make as to whether to stop this discussion as it was too difficult for some of the participants, or to continue as a few in

the group were able to follow this argument. Finally on a strategic level problems can occur. For example, teachers can get caught up in tactics, and lose sight of the overall aim:

6c:16 **TZ (teacher):** [...] **When it's on a whole class level you can only spend two three minutes with each pair or person, because otherwise that whole task might drag on for the whole lesson if you will - which is a shame, to take that richness from what they're saying. So I find that really difficult, because you can just get caught up with one person [JR nods] because you're unpacking what they're saying.**

Here the teacher describes how an intervention with an individual pupil must be balanced against the needs of the whole group, and how failing to get this right may cause problems (strategic friction).

4.6.2 Friction as an opportunity

Participants sometimes saw a failing strategy as an opportunity. For example, in the following extract the teacher (**TW**) is watching and commenting on a clip (in italics):

3a:197 *UA: [Pause] Well, [pause] well, if you think about it the cells that make up a tree the nuclea [sic], the nucleus, it gives out instructions so it must know what its instructions to help the tree survive. [TW looks over at VH and LM]*

3a:198 **TW: What do you [VM] think? Do you agree? Do you think a tree knows what it is doing?**

3a:199 *GS: No.*

DL: No. [unclear as very quiet]

3a:200 **TW: You've [LM] put it in living. So have you [GS].**

3a:201 *GS: Yes it does, because if it doesn't know what it is doing it won't grow. Because you need to have some sort of brain which would make be able to have the intelligence to grow.*

3a:202 *TW: Does it take intelligence to grow?*

[TW pauses the video at this point]

3b:78 **TW: I don't know what the answer is to this one is. [TW laughs] I mean I know scientifically the answer is "no", but ... I was just fascinated by what they were saying. I was absolutely fascinated by their reasoning, and their application of logic to something that can't be logical. It doesn't have a brain, it doesn't know what it is doing, but it is really nice that they think it is. ... I think like you said, it is a naive concept isn't it. Trees must know what they are doing, otherwise why would it not happen? It is kind of the assumption some people have that there must be a God, because otherwise why would all these things occur? Something must be controlling it.**

The teacher (TW) had the opportunity to 'correct' the naïve concept in line 3a:198 (that trees must be intelligent in order to grow), yet chose not to take it. Perhaps the teacher judged that the opportunity to talk with 11 year-old students about the nature of intelligence should not be missed. Failure to change a concept, or even change from a scientific concept to a naïve one, might be accepted by a teacher when a more important strategic gain is available (for another example see 3a:178-187).

4.6.3 The reason why strategy fails may not be obvious

The reasons why a strategy fails may not always be evident in the 'fog' of the classroom:

[T]he great uncertainty of all data in war is a peculiar difficulty, because all action must, to a certain extent, be planned in a mere twilight, which in addition not unfrequently like the effect of a fog or moonshine gives to things exaggerated dimensions and an unnatural appearance. (Clausewitz, 1832, p.189)

This famous point from military strategy was also made by a participant teacher speaking about the classroom:

6c:25 **TZ (teacher):** There is so much [going on]. You don't really appreciate what is going on in a classroom [TZ and JR laugh] - because it is just – [...] Because, you know, you're over there [TZ points to one side of an imaginary classroom in front of her], and there is a conversation about work that is going on over here [TZ points to an imaginary conversation which is taking place behind her head]. You know, you just hear snippets of it. [...] I'm still working on, is there a way which you can enjoy the dialogue? And be in control. And listen to everybody. ... I don't know. I don't know. I don't know. ... I'm still working towards that at the moment.

In the next example the teacher had been watching the group discussing whether trees need some sort of brain/intelligence in order to grow (3a:201):

3b:78 **TW (teacher):** [...] I really enjoyed this bit [3a: 195-232]. But I don't know that I guided them that well, because I'm not sure that I wanted to take it away from them. Do you know what I mean? [JR nods] I remember actually really upsetting a child once because I said - I jokingly said you couldn't talk to trees, and this child was nearly inconsolable, because apparently he talked to trees all of the time. I think there is a line between teaching science and is it OK for them to think at 11 years old that a tree cares what it is doing? There is a tiny little line

Predicting that pupils may talk to trees may be too much to ask of even the most sensitive of teachers. Hence strategic friction may be inevitable in real classrooms.

4.7 Logistics

Logistics in the military is defined as:

The organization of supplies, stores, quarters, etc., necessary for the support of troop movements, expeditions, etc. (OED).

The smooth running of the EMT interviews was dependent on many practical issues such as the distribution of resources, giving pupils enough space to work in, etc. Hence logistics in the classroom is here defined as the organisation of resources in the classroom

necessary to support learning and teaching. Participants referred to logistical issues 117 times. Many of these issues could not be easily predicted, so managing the logistics of the group as events occurred in such a way that these issues did not disrupt learning may be considered an important part of the role of the teacher. In the following example a logistics problem very familiar to teachers occurred:

5a:536 **TY (teacher): Can someone pass SP a piece of paper please. [Pause - TY is reading the questioning route] OK. Has everyone got a piece of paper and a pencil? Lovely. So here we go. ... Oops [the teddy bear falls over on the table and TY straightens it]. I'll just put him the right way up. Sorry.**

AC: That's terrible.

TY: And I'm going to read the question again. So here we go.

Here this teacher is trying to get the pupils to help pass paper to those who need it, preparing herself for the next activity in the EMT interview by using the questioning route (see Appendix B), checking that everyone has the resources they need, dealing with a fallen teddy, managing the amusing accusation from a pupil (AC) that allowing the bear to fall was some sort of dereliction of duty and starting the next activity (use an activity - section 4.2.7). The passage illustrates some of the practical problems teachers face in the classroom which are only compounded in a science laboratory when children start to experiment using all sorts of equipment.

4.8 Prior knowledge

The theoretical perspective underlying this present study (symbolic interactionism – see Chapter 3) acknowledges how prior knowledge influences our interpretation of the actions of others:

[H]uman beings interpret or 'define' each other's actions instead of merely reacting to each other's actions. Their 'response' is

not made directly to the actions of one another but instead is based on the meaning which they attach to such actions. (Blumer, 1969, p. 19)

Thus teacher, pupils and researcher each have knowledge which moulds not only their understanding, but even what they see and hear (Bruner and Postman, 1949, p. 218 and T. Kuhn, 1962, p. 63). For the teacher this might consist of subject knowledge, knowledge of teaching and learning techniques, knowledge of potential naïve concepts, naïve reasoning methods (Zimmerman, 2005, p.17), personal epistemological obstacles (Bachelard, 1938), knowledge of the epistemological obstacles of others, knowledge of one's own personality and that of others etc. etc. Some clues as to what this knowledge may be appear occasionally in the data:

1c:22 **TU (teacher): The thing that really [surprised me was] when JB was so adamant that [a mushroom] wasn't a living thing. That it was a dead thing. I don't think I really anticipated that. I think I had an unwritten assumption that he would know that the vast majority of foodstuffs would have been alive at one stage or other [TU shrugs - JR does as well afterwards]. And it just hadn't really occurred to me that he wouldn't get it eventually. That he would stick so rigidly to the rules. [chopping her hand – perhaps to indicate decisiveness] "But you said miss they had to do the seven things". [showing up seven fingers and speaking with a decisive tone]**

Here the teacher (TU) acknowledges that she did not expect a pupil (JB) to hold a particular naïve concept. She had the assumption that food generally comes from living things, and expected others to hold this. The failure to change this particular naïve concept came as a surprise. Clearly TU and JB did not bring the same prior knowledge with them to this interview and this had an impact on the ensuing debate.

4.9 Summary

This Chapter presents a grounded theory for how experienced science teachers promote conceptual change. Periods of ‘conceptual conflict’ were seen in these data (section 4.1). Teachers (and pupils) appear to use eleven ‘teaching and learning techniques’ (redirect, clarify, transfer, use a learning method, support, use a stratagem, use an activity, condition, persuade, group and use timing – section 4.2). The weighting participants gave to particular techniques was called the strategic profile and illustrated graphically (Figure 10, Figure 11, Figure 12 and Figure 13 – section 4.3). Tactical and strategic behaviour, sometimes simple and sometime sophisticated, were identified in these data. Furthermore a thick description of a passage from an interview was used to illustrate tactics and strategy (section 4.4). Tactics involved the use of teaching and learning techniques in, and between, periods of conceptual conflict. Strategy was how participants achieved their overall goals (which included conceptual change on occasion). Intervention was both direct and indirect and six different levels were seen (section 4.5). The failure of strategy (strategic friction) occurred frequently and the causes, how such events were used, and why it is not always possible to know why a strategy has failed were described (section 4.6). Effective and ineffective logistics sometimes influenced techniques, tactics and strategies employed by participants (section 4.7). Teachers and pupils brought considerable prior knowledge with them, and this appeared to influence conceptual change (section 4.8). Having described the grounded theory in this chapter, the next will look at the implications of this theory for the way researchers understand the integrated model for conceptual change (Klahr, 2000).

Chapter 5: Relationships and the integrated approach

5.0 Introduction

This Chapter addresses the second research question: how do the ways in which instructional strategy is understood within the conceptual change research community compare with the practice of experienced science teachers? Is the integrated approach to conceptual change useful for understanding relationships between instructional strategy, learners' reasoning methods and conceptual change? This present study will argue that causal relations between what teachers do and conceptual change is only possible to a very limited degree. Instructional strategy, learning methods and conceptual change are interrelated in complicated ways, so that simple interventions which appeared to result in conceptual change were very rare (section 5.2). The interpretation of these data in chapter 4 demonstrates how, in the vast majority of cases, the techniques a teacher uses do not directly cause conceptual change, and that conceptual change emerges during complicated extended group discussions (section 5.1). In addition, the pedagogic aims of teachers in this study frequently failed, which was described in the grounded theory using the concept of 'strategic friction' (section 4.6).

The extent to which the 'variables' of conceptual change, learning method and instructional strategy can be isolated will be questioned (section 5.1). Nevertheless these data suggest there are sometimes relationships between these variables (for example, between particular learning methods and conceptual change) which will be described in section 5.2. How instructional strategy is understood in 'integrated conceptual change' literature (section 2.6) will be compared and contrasted with the findings of this research (section 5.3). The issue of whether pedagogy causes conceptual change will be discussed (section 5.4) and the Chapter finishes with a summary (section 5.5).

5.1 Interrelations between conceptual change, learning methods and teaching strategy.

These data support the finding by conceptual change researchers (Klahr, 2000) that conceptual change, learning method and teaching strategy are inextricably linked (section 2.6). Firstly evidence for this integrated approach from this present study will be presented. Secondly the limited extent to which these ‘variables’ may occasionally be isolated will be discussed.

Evidence of the interrelations between strategy, reasoning methods and conceptual change may be seen in these data where a teacher suggested a pupil use a particular learning method or vice versa. This occurred 122 times. One of these examples will now be discussed to illustrate this point. A verbal protocol made whilst the teacher watched a short section of this passage was discussed earlier in section 4.1. In the following example a pupil (BB in line 2a:111) refers to a theory (‘seven characteristics of life’ which is often remembered using a mnemonic) commonly used in schools to decide if something is living or non-living. ‘Invoke a theory type’ was identified by Darden (1991, p.244) as a method used by scientists to produce new ideas. The teacher here (TV) does not allow herself to be distracted by a host of naïve concepts which the pupils express. She homes in on the scientific idea when it eventually emerges. This avoidance of engagement with naïve ideas in order to give time for the pupils to express the theory (a learning method), can be interpreted as a strategic decision (section 4.4):

2a:102 **TV: OK then. So, you have pretty much a good idea of what you consider as living and non-living. Right. Now, is there anything that you already had in mind about living things and non-living things before you put those pictures on those mats? Yes SF?**

- 2a:103 SF: I was going to say that living could be something that... [BB interrupts]
- BB: Moving around
- SF: Yes, is moving. Like a person has organs that keep us alive and stuff like that.
- 2a:104 **TV: Anything that moves about you would consider as living. [Slight question in the voice perhaps] Yes. Any other feature about the living things... [LD has her hand up].**
- 2a:105 BB: Anything that can... um... get nutrients.
- 2a:106 **TV: Anything that picks up nutrients from somewhere. Alright, so that's another one. What? OK. [inviting LD to speak]**
- 2a:107 LD: Anything that grows or develops into something else. For example a tree grows bigger and bigger, and a person grows bigger and bigger, and a dog grows bigger and bigger. But a brick would just stay the same size. It can't get physically larger.
- 2a:108 **TV: Yes. Alright. OK, and what would you say? [AC is trying to come in and TV invites him to speak]**
- 2a:109 AC: It is like something that can make its own decisions and not controlled by anyone else. Like a dog has got its own mind. But a brick, you move it around. It can't move by itself.
- 2a:110 **TV: I see. Any anything else you would like to - helps you decide whether living or non-living?**
- 2a:111 BB: You need to do MRS NERG.
- 2a:112 **TV: MRS NERG. OK. So you learned that where? Where did you learn that about MRS NERG?**
- 2a:113 BB: I learned when I was in Year 4.
- 2a:114 **TV: Right, can you tell me about MRS NERG then? Can you expand on that please.**
- 2a:115 BB: [pause] Nutrients... [pause]

2a:116 LD: Isn't it movement, respiration, [counting them off on her hand]

SF: Isn't it reproduction? [quietly to LD]

LD: No, reproduction is the second R I think.

SF: Yes.

LD: Yes. S is [pause]

2a:117 **TV: Sense? Sensitivity?**

LD: Yes, yes.

TV: To the environment. Yes? OK?

2a:118 LD: Nutrients, or nutrition [someone else says nutrition at the same time].

2a:119 **TV: And?**

2a:120 LD: Excretion, reproduction and fertilization [looking at TV as if not sure of this last one].

2a:121 **TV: Reproduction and G growth. Alright.**

LD: Oh yes. Growth.

The teacher (**TV**) interrogates the pupils about the reasoning behind their decisions to put some cards on the living mat and others on the non-living one. The explanations include scientific ideas like 'living things move', and naïve concepts like 'all living things have organs' (2a:103). The teacher summarises the scientific idea and ignores (or misses) the naïve concept (2a:104). **TV** prompts the pupils for more features of living things. Again the response is a mixture of scientific and naïve ideas. Living things do need nutrients, but 'developing into something else', 'making its own decisions', 'not controlled by anyone else', 'having a mind', 'being fertilized' are not criteria for whether something is living or not which biologists would recognise. The teacher is therefore making decisions not to investigate some of the thinking which emerges during this passage, perhaps with the hope that the pupils will eventually remember that they already know about this.

Finally one pupil tells the group that they need to use the MRS NERG theory (2a:111). This might have been prompted by the fact that three of the elements of this mnemonic have just been mentioned in the preceding discussion (movement, nutrition and growth), but as is often the case in these data, the origin of such understanding is unclear. What is not unclear however are the techniques this teacher has used which lead to this insight. For example redirect and clarify in 2a:104, and transfer in 2a:121.

This passage illustrates that conceptual change, learning methods and teaching strategy are not simple concepts which can always be isolated easily. However, it is sometimes helpful whilst analysing these data to consider the effect of a teaching technique on conceptual change, the effect of a teaching technique on a learning method, or the effect of a learning method on conceptual change. What this study indicates as regards these relations will be discussed next.

5.2 What do these data suggest as regards the relations between instructional strategy, learners' reasoning methods and conceptual change?

Occasionally the use, in a straightforward way, of a teaching technique or learning technique appeared to lead directly to conceptual change. These will be called straightforward successful interventions. However it was more common in these data for such changes to occur after prolonged conceptual conflict (section 4.1). There were 157 references out of all 18 interviews to conceptual change. There were probably occasions when pupils changed their thinking without indicating this overtly. The following extract illustrates how interventions are sometimes straightforward and successful. In this VP interview the teacher (TY) first describes how he struggles to understand what the pupil (MG) is thinking. The teacher has just watched the student on video arguing that all

things with faces are living. Finally this teacher gives an example of using a logical argument (*reductio ad absurdum*) which leads straight to conceptual change:

5b:66 **TY (teacher):** [...] MG's 'things with faces [are living]' - I'd forgotten that one as well. I actually thought - and again I thought as I watched it again that she had worked out that humans are animals. But that is not, I think, what she had worked out. ... But that - that one goes all the way up until the sixth form. We have arguments that humans aren't animals. And the logic one for that one is, so we must therefore be plants. [TY and JR laugh] And you see the penny drop quite easily with that one. Brilliant.

What makes the penny drop during the exchanges between participants during EMT interviews is usually unclear. For example in the following extract something clearly makes this pupil hesitate, but it is very hard to know what change, if any, has taken place here:

1a:144 **BN:** Yes because whereas plants, with water, they grow and they eat the soi [stops before pronouncing the whole word 'soil']... is it the soil or the water?

In another example of a straightforward successful intervention a student acknowledges that they have changed their mind (2a:66 and 68) and explains why:

2a:59 **TV (teacher):** So the heat is escaping easier with this one [indicating the cup of tea].

2a:60 **SF and others:** No. It [the mug] is keeping it more in.

2a:61 **TV: OK. Right. And if... what would happen then if it were metal container?**

2a:62 **LD:** A metal container would become hotter because if you've got hot tea in there and it is in a metal container, because metal is a conductor of heat [BB says conductor at the same time] and electricity. If you were to touch it then the metal would be as hot as the water inside it.

- 2a:63 **TV: So would it cool down faster with the metal?**
[Question directed at LD]
- 2a:64 BB: [Shaking his head].
- Another student [unclear who]: No.
- 2a:65 **TV: No? Even if it conducts the heat away? If it takes the heat away? It is a better conductor of heat? So does it not take the heat away from the hot tea?**
- 2a:66 [pause]
- LD: [With a smile] Yes. Yes it does.
- 2a:67 **TV: Why did you change your mind then?**
- 2a:68 LD: Because the metal is actually taking the heat from the water - from the tea - so that is making the tea colder and the metal container hotter
- 2a:69 **TV: OK.**

It appears that the intervention in 2a:65 causes this conceptual change. **TV** asks three times if the metal takes the heat away. Though phrased as a question, I interpret this as a ‘transfer’ (section 4.2.3) where **TV** effectively says, “Metal is a good conductor of heat energy, so heat would flow from the hot tea to the cold metal cup.” LD manages in 2a:68 to articulate this idea and adds the idea that this would make the tea colder. The moment the “penny drops” is very clear on the video from LD’s face (2a:66). As this suddenly makes sense she reacts with a change in expression from puzzled, to a swift tilting back of the head and then a smile. There are a handful of examples like this in these data of a teaching technique leading directly to conceptual change. Therefore there appears to be evidence in these data that relatively straightforward interventions occasionally lead to conceptual change. However, the explanations of conceptual change offered by participant pupils, could easily be post-rationalisation. When participant teachers say during VP and RD interviews what they understand to be the cause of a conceptual

change, they may of course be mistaken. The grounded theory in Chapter 4 represents only one of many ways in which these data could be understood and the examples of straightforward successful interventions cited above represent what appears to be a rare phenomenon.

Sometimes the use of learning methods by the pupils themselves leads to conceptual change. For example SF in 2a:103 expresses the naïve concept, well known in the literature (for example Driver *et al.*, 1994, p.17), that all things that move (and only those) are living. At this point she has already put the clock card on living (I took a photo of the table in 2a:99). By 2a:144 she acknowledges that she has changed her mind about the clock. SF picks up a card and moves it to her non-living mat (which appears to be the clock card) during 2a:133 whilst a discussion about the idea that living things needing to respire is going on. It appears that the introduction of the MRS GREN theory by another student (BB) in 2a:111 and subsequent discussion led to this conceptual change. The use of a theory type is understood as a learning method in this study (section 4.2.4). Hence on occasion, straightforward intervention leads to conceptual change, and this can be caused by the use of a teaching technique or a learning method.

In addition, teachers in these data sometimes suggest pupils use particular learning methods. This was coded 122 times during all interviews and included 46 proposals to use a theory type, 23 recommendations to visualise something, 10 suggestions for how anomalies might be resolved, and 5 invitations to use an analogy. Each of these four categories will now be illustrated with an example. In the following example the teacher (TV) suggests pupils use a theory type:

2a:312 **TV (teacher): OK. Right. So there are things that you can eliminate because they are things that do not fit with MRS NERG.**

Next the use of visualisation (in 1a:290) is used to explore the naïve concept that a light source is not necessary for someone to see (i.e. that some people can see in a pitch dark room with no light source present):

1a:287 **TU (teacher): So we've gone into a dark room.**

JK: Yes

TU: Can you see the teddy bear?

1a:288 JK: No, not without a torch.

1a:289 EM: Not technically without a torch because some people, some people like my Dad are really good at seeing in the dark because they stay up all the time, they never go to bed. Um, so basically

1a:290 **TU: So do we mean a dark room in our houses where there is a little bit of light coming in through the curtains or are we talking about a really [with emphasis and hand gesture] pitch black, like if you go into one of these rides at the fairs where it is totally black. Let's just make sure we know what type of room we're going in.**

JB: Thorpe Park [an amusement park]

1a:291 EM: I think we're talking about, if we turn all these lights off. Get loads of [indicating with her hand the windows] - put some blinds there. Make sure they're properly shut and we can't get

1a:292 **TU: OK, so a really really dark room. And we walk in through the door and teddy is in the middle of the room.**

EM: Got to make sure the TV is off.

TU: OK no TV on. Are we going to shut the door behind us in this dark room?

1a:293 EM: Yes.

BN: No.

TU: Oh, we'd better agree.

BN: No.

TU: I think we're going to shut the door the door.

JB: Why?

TU: I think we're going to go in the room we're going to shut the door. Can we see teddy?

1a:294 EM: Yes. [Still working on her drawing]

LN: Yes. [Still working on her drawing]

CS: No.

BN: No.

Line 1a:289 may suggest that the pupil (EM) thinks that light is unnecessary for us to see and that all, or some, people can see in total darkness (Ramadas and Driver, 1989). Children who live in the countryside are less likely than those who live in towns to think this, and many children think cats can see in pitch darkness (Fetherstonhaugh and Treagust, 1992). The teacher guided the group in line 1a:290 to consider a pitch black room with no sources of light. In 1a:293 one pupil (BN) appears to resist the idea of such a room and another pupil (JB) questions the need to close the door. This reluctance might reflect the fact that the experience of pitch black is very rare now (photographic 'dark rooms' are a thing of the past and not everyone will have experienced so called amusement rides in absolute darkness). This teacher guides the pupils to a point where the pupils themselves are able to understand that they don't agree about this idea (line 1a:294). Hence the way this teacher encourages pupils to visualise the 'completely dark room' appears to have contributed to conceptual change.

Participant teachers sometimes suggested ways in which pupils could resolve anomalies:

6a:186 **TZ (teacher): [...] If we had to do an experiment to change that thinking, what do you think we could do? To try and prove or disprove that idea?**

So the teacher is encouraging the pupils to design an activity which might resolve an anomaly which could lead to conceptual change. Finally it was sometimes suggested to pupils that they could use an analogy:

3a:104 **TW (teacher): Right, so someone, a person maybe, not even a particle, is mov...**

3a:105 GS: Going hyper.

3a:106 **TW: ...is going hyper. What have they got more of?**

3a:107 GS: Energy

Here the teacher (TW) in line 3a:104 suggests the pupil (GS) imagines that a particle is like a person who is moving. GS takes this analogy up in line 3a:105 and translates it into his own words. TW takes up this vocabulary (line 3a:106), before requesting clarification. GS may not have known that particles moving faster have more energy, but he does seem to know that people ‘going hyper’ are more energetic. This is an example of the use of a bridging analogy (Brown and Clement, 1989, Scott, Asoko and Driver, 1991 - see section 4.1) to promote conceptual change. Children’s naïve ideas about energy are legion (for example Driver, 1994, p. 143), so what GS has now understood may still prove to be problematic.

On one or two occasions (out of 21,612 references) a teacher (TW) suggested a pupil (KG) use a teaching technique with another pupil:

3a:366 **TW (teacher): Ooo. Nerves. Interesting GS. Does anyone want to kind of summarise that? [TW indicates with her hands bringing something together?] So what must there be in your eye? [UA has hand up. KG puts his hand up]**

3a:367 KG: Eye socket that can like send - like the brain sends messages to the eye [KG indicates something going from his brain to his eye with his hand].

So in line 3a:366 TW invites someone to use the technique described in this present study as clarification (summarise) which was discussed in section 4.2.2. When KG takes up this challenge in 3a:367 he summarises both verbally and with a gesture what appears to be a naïve concept (that when we see the brain sends signals to our eyes, rather than the other way round).

In this section I have argued that there is some evidence in these data that straightforward use of particular teaching techniques sometimes leads to conceptual change. This was qualified with the observation that no interpretation, even of what appears to be simple, is ever guaranteed in a complicated social context such as this. It was also argued that pupils use learning methods, teachers occasionally prompt pupils to use a particular learning method, and very rarely a teacher encouraged a pupil to use a teaching technique with another pupil. All three of these practices might result in conceptual change. Most of the time conceptual change appeared to occur during protracted conceptual conflict (section 4.1) and an obvious cause of these changes was uncommon.

5.3 How does the view of conceptual change strategy explored here compare with other understandings?

Studies from within conceptual change literature which investigate different types of instruction were reviewed by Zimmerman (2005, pp.81-86) and include lab and classroom based studies. Instructional techniques investigated in this literature include didactic teaching, using examples and probes (Chen and Klahr, 1999); direct instruction to “vary one thing at a time” or VOTAT (also known as ‘control of variables’ strategy or

CVS – Toth, Klahr and Chen, 2000; Klahr, Chen and Toth, 2001; and Klahr and Nigam, 2004); interpretive and experimental support (Reid, Zhang and Chen, 2003); allowing performance-level practice and metastrategic-level practice (D. Kuhn *et al.*, 2000); the instruction to “find out about just one feature to start” (D. Kuhn and Dean, 2005); use of a non-traditional context (D. Kuhn and Dean, 2008); and scaffolding (Metz, 2004). Underpinning all these studies is the understanding that strategy is a plan and that experimental studies can determine how effective this is in making children change their thinking. The idea of a mapping of instructional techniques to “types of pupils” emerges again (c.f. Clement, 2008, p.445 – quoted in section 2.5)

Klahr and Nigam [2003] suggested that the next set of issues to address include determining the kinds of individual difference characteristics that account for some students benefiting from the discovery context, but not others. That is, which learner traits are associated with the success of different learning experiences? Answers to such questions would facilitate a match between types of students and types of pedagogy for a “balanced portfolio of instructional approaches to early science instruction” (p. 666). (Zimmerman, 2005, p.82-83)

This present study, whilst acknowledging the important lessons such research has for teachers, holds that this ‘portfolio’ model of instructional strategy has serious limitations. The assumption above that once individual difference characteristics have been determined, this will account for why a technique works with some pupils and not with others, betrays a very optimistic view of strategy (section 2.5). Any repertoire of techniques, though useful, must be used together skilfully in order to be effective in promoting conceptual change.

The extraordinary synthesis of more than 800 meta-analyses by Hattie (2008) reviews studies by Wise (1996), Guzzetti *et al.* (1993), and Horak (1985) which investigated methods to promote conceptual change. The number labelled ‘d’ in the

following quotations refers to the ‘effect size’ which has a maximum value of 1. An effect size of 0.4 or more indicates when “the effects of innovation enhance achievement in such a way that we can notice real-world change” (Hattie, 2008, p. 17). An effect size on less than 0.4 suggests an intervention is ineffective.

There are many successful methods for engendering conceptual change in science. Guzzetti, Snyder, Glass, and Gamas (1993) Found that learning charts ($d = 0.43$), discussion webs ($d = 0.51$), and augmented activation ($d = 0.43$) were more effective than activation of prior knowledge ($d = 0.10$) and question-answer-explanation ($d = 0.02$) in reducing misconceptions from reading science texts. Texts are the most effective way to eliminate misconceptions, either when text is refutational or when text is used in combination with other strategies that cause cognitive conflict. These refutational texts created a form of cognitive dissonance in students’ thinking and thus students could be taught to explain why the misconception was incorrect ... (Hattie, 2008, p.148)

This present study questions any assertion that there is any one “most effective way to eliminate misconceptions”, and that a teacher may or may not discover what works during the interaction with real unpredictable learners. It is helpful to know that:

Wise (1996) examined a number of teaching strategies, and found the following effects: teacher questioning ($d = 0.58$), focusing strategies ($d = 0.57$), manipulation strategies (work or practice with physical objects, $d = 0.58$), enhanced materials (teacher modification of instructional materials, $d = 0.52$), use of immediate or explanatory feedback ($d = 0.32$), inquiry strategies ($d = 0.28$), enhanced context strategies (e.g., field trips, games, self-paced learning, $d = 0.26$), and instructional media ($d = 0.18$). He concluded that active construction of meaning is most often likely to occur "when science teachers use strategies that require students to be both physically and mentally engaged" (Wise, 1996, p. 338). (Hattie, 2008, p.148)

Though good science teachers might have guessed that active, mentally engaged children may learn better than those who are inactive and “switched off”, there are extremely important and useful insights which come from the meta-analysis by Wise. However, instructional strategy is presented as the use of evidence to select the most appropriate

instructional technique. Whilst this may be helpful in planning lessons, this present study suggests that the heart of strategy is what happens next. The ‘attained curriculum’ results from strategy which straddles both the ‘intended curriculum’ and the ‘implemented curriculum’ (Millar, Leach, Osborne and Ratcliffe, 2006, p.117).

5.4 Does pedagogy cause conceptual change?

Simple interventions which appeared to lead directly to conceptual change were extremely rare in this present study (section 5.2). Instructional strategy, learning methods and conceptual change are interrelated in complicated ways. Epistemological divergence between those who seek exact laws in the social sciences which describe causal relationships between observable phenomena, and those who argue that the human subject is only intelligible as a unique historical actor, originates in the work of Kant according to Ashley and Orenstein (1998, p.276). Kant argued that our knowledge about ourselves, as subjects with free will, is qualitatively different from our knowledge about matter and the ways in which it interacts. A long dispute about this issue began in 1883 when Menger (*ibid.* p.275) argued that the social sciences should use the same methods as the natural sciences. Von Schmoller (one of Weber’s teachers) responded that understanding social interactions could not be separated from the study of culture and history. This began a movement which became known as the ‘historicists’. Within this school of thought, Dilthey and Rickert claimed that general categories of analysis do not exist in the social sciences. Weber, from within this same school, rejected this position. He also argued that the fundamental perspective of the social sciences was interpretivist, which is the position adopted in this present study, rather than positivist (Chapter 3).

Interpretation necessarily involves a movement between part and whole according to Spinoza (1670), who applied this ‘hermeneutic circle’ to both Holy Scripture and

nature according to Ramberg and Gjesdal (2005). In complicated social contexts like those used in the research methods of this present study (section 3.4), the interpretation of a part, for example how a teaching technique might influence conceptual change, hinges on the interpretation of the whole (for example the teachers' strategy), which itself must be understood in relation to its parts (cf. Dillon, 2008, p. 413). Hence the arguments in this study must move back and forth between the particular and the general. Chapter 4, in which the grounded theory is developed, continuously returns to the words of participants. Clausewitz, whose understanding of military strategy proved useful in the interpretation of these data (section 2.5), echoes this point:

[It] is particularly necessary that in the consideration of any of the parts the whole should be kept constantly in view.
(Clausewitz, 1832, p.27)

Aspects of the grounded theory could be tested using experimental methods (see Chapter 4). However, any understanding of how teachers promote conceptual change (and the relationships between instructional strategy, reasoning methods and conceptual change) must acknowledge the importance of the particular historical and cultural context of the participants in the classroom being studied. Hence this study does shed light on how experienced teachers promote conceptual change, but also argues that a sophisticated understanding of strategy is necessary when interpreting complicated data like these. In addition, the integrated approach to conceptual change (section 2.6) appears to be useful in interpreting the complicated interactions between participants in this study, but not if strategy is understood as merely a plan.

A distinction between knowledge and understanding was drawn by Kvanvig (2003):

The central feature of understanding ... is [it] requires the grasping of explanatory and other coherence-making relationships in a large and comprehensive body of information.

One can know many unrelated pieces of information, but understanding is achieved only when informational items are pieced together by the subject in question. (Kvanvig, 2003, p.192)

Conceptual change literature is a large body of information. Understanding how this literature may help when a teacher encounters naïve thinking involves, according to Kvanvig, constructing coherence-making relationships from elements within this huge body of knowledge. The grounded theory in this present study represents a tentative attempt to do just this. This field is now so complicated that practitioners will need the help of the research community in order to understand and implement conceptual change pedagogy, and they deserve more than simplistic ‘research-based’ tips or toolkits (for example DiSpezio, 2010).

Some argue that:

[T]eaching is not a cause of learning outcomes: it facilitates them. (Hewson, 1992, p.6)

This thesis argues that the tactical and strategic use by teachers of various techniques are one of many interrelated factors which cause children to experience conceptual change. Concepts used by researchers like conceptual change, reasoning methods and instructional strategy may be inherently imprecise, and are not simple variables that can be isolated.

5.5 Summary

The ‘variables’ of conceptual change, learning method and teaching strategy can only be isolated to a very limited extent. All three of these elements are inextricably linked (section 5.1). Nevertheless evidence of straightforward simple and successful intervention, which resulted in conceptual change, though rare, was present in these data (section 5.2). Conceptual change was much more likely to happen during frequent and complicated conceptual conflicts (section 4.1) where teachers used the tactical and strategic behaviour described earlier (section 4.4). Straightforward successful intervention used teaching techniques and learning methods. In addition, one teaching technique involved staff suggesting that pupils use a particular learning method. Finally teachers on a couple of occasions suggested that pupils should use a teaching technique. Conceptual change researchers appear to be referring to straightforward successful intervention when they speak of ‘strategies for conceptual change’. Data in this study suggests that such interventions are rare and the Clausewitzian understanding of strategy (section 2.5) may be helpful to understanding and explain the practice of experienced science teachers (section 5.3). The extent to which pedagogy can ever be described as causing conceptual change was discussed (section 5.4). Having described the findings of this study in chapters 4 and 5, we next turn to the role of the researcher, the trustworthiness of the results, and a discussion of practitioner and researcher interactions.

Chapter 6: Discussion

6.0 Introduction

This thesis proposed a grounded theory for the techniques, tactics and strategies experienced science teachers appear to use to promote conceptual change (Chapter 4). This theory was then used to investigate how instructional strategy, learners’ reasoning

methods and conceptual change in school science are related (Chapter 5). The relationships which emerged from these data were compared and contrasted with the ‘integrated’ approach to conceptual change from the literature (section 2.6 and Chapter 5). Some researchers are very aware of how complicated instruction for conceptual change can become (for example Zimmerman, 2005, p. 90 - see section 2.6). In addition I acknowledge that teachers, on occasion, may perceive researchers to be offering a simplistic conceptual change pedagogy when this is not the case. However, some researchers do appear to envisage a simple mapping of techniques to particular types of conceptual change (for example Clement, 2008, p. 445 - see section 2.5). The perception by some teachers that some researchers may not fully understand what happens during conceptual conflict may contribute to the divide between research and practice (Duit *et al.*, 2008, p.629). Simple successful interventions which appear to change naïve thinking do happen, but in these data this was very rare in comparison to conceptual change which emerged during prolonged conceptual conflicts (chapter 5). Conceptual conflict in classrooms is a messy and complicated affair where techniques, tactics and strategy each fail at times (section 4.6). Pedagogical decisions are made rapidly and are often based on limited information. Hard and fast rules for how to behave in such an unpredictable environment are of little use to teachers. The typology of instructional techniques and the ideas of tactical and strategic levels of analysis could provide a framework for dialogue between researchers and practitioners, and perhaps even help narrow ‘the gap’ (Duit *et al.*, 2008, p.629).

Chapters 4 and 5 raise a number of issues which will be discussed next. How the researcher affects the processes of data collection, data analysis and theory generation will be explored (section 6.1) and the overall trustworthiness of the findings will be evaluated (section 6.2). How conceptual change researchers and teachers perceive each

other will be discussed in section 6.3. Ways in which differences in interpretation between participants were managed is the subject of section 6.4. This Chapter finishes with a summary (section 6.5).

6.1 How does the researcher affect the data collection, data analysis and theory generation in this study?

This section explores how the researcher's actions, omissions or presence directly or indirectly affected the data collection, data analysis or theory generation. Researcher effects can distort both the phenomena being investigated and the research process (see section 3.6). Care was taken throughout this work to minimize both of these hazards. However the interpretivist methodology acknowledges that within this social context the researcher is another participant, and having no influence would be impossible. Firstly situations where there is evidence of influence will be described. Secondly potential effects on the study of my presence will be discussed where a significant effect is suspected. Finally potential influences of non-participants will be mentioned briefly.

6.1.1 Reflections on researcher effects in these data

During the VP interviews participant teachers were asked to do something very challenging and potentially embarrassing (section 3.4), so one purpose of the initial visit was to reassure participants and to build enough of a relationship that they would be comfortable talking with me about issues arising from the video clips:

1b:1 *JR (researcher): [General instructions about the VP interview – see Appendix E] Please don't worry if you can't make sense of what the children say in some of these clips. Some of the ideas which came up are very challenging even for trained scientists. Since I started exploring children's naïve concepts I've discovered several of my own! Please just say if you'd like to 'unpack' an idea together. I'm aware that you're being asked to do something which is difficult, namely to respond immediately to some very challenging naïve*

scientific concepts. In the classroom we often have to respond quickly and it is this thinking that I'd like to explore together.

A more formal arrangement would have the advantage over the approach taken above of minimising influences on the data collected. I think participants in this study would have been less likely to teach in a similar way to their normal classroom practice, and more reticent in expressing the way they understood portions of the EMT interviews, if this more formal approach had been taken, and that this was a necessary compromise given the complicated social context being studied. The openness of participants in discussing deception (section 4.2.6) within these data is testament to the confidence participants appeared to feel in talking about their practice.

The questioning route was designed to support participant teachers during the EMT interviews (see appendix B) and ensure participants were introduced to the VP and RD interviews in the same way, but all these represent very significant influences of the researcher on these data. The reasoning behind the use of questioning routes is discussed in sections 3.4 and 3.5. The only direct effect on these data that was evident during the analysis was participants looking down at the questioning route and needing time to read it, which was noted by me twenty-one times in the transcript over all 18 interviews.

The reasoning behind using short clips from the EMT videos as prompts for VP interviews was discussed in section 3.11, and represents another significant influence of the researcher on the data collection. Clips were selected using grounded theory methods (theoretical sampling). However the following were clearly influenced by me as the researcher: what to select, where to begin and end a selection, the order in which to show clips (which was chronological, but did not need to be), how many clips to show each participant and the decision to present clips to participants on a laptop where they could choose which clip to play, when to pause it and when to stop and go on to the next clip.

Participants were told that they did not need to use all the clips, but were asked to choose some clips from each of the topics being investigated. Getting participants to control the playing of clips meant they could move on when they wished, and avoided the control of this resource being wholly in the hands of the researcher. Nevertheless I am aware that participants were obliged to use the video clips on the laptop in the way that I had set it up. One participant teacher (**TX**) had some difficulty with this arrangement as the clips jumped to the next clip when he clicked one part of the screen, whereas touching another part made the video pause. Only one other significant problem occurred with the video clips which was when a participant had to wait at the start of their VP interview for a few minutes as a result of a background process on the laptop which could not be stopped (6b:9-10). Neither of these incidents appeared to disturb these participants significantly.

The time interval between the EMT interview and the VP/RD was an unavoidable consequence of the research design as discussed earlier (section 3.4.4), yet represents an undoubted influence on these data. This delay varied from as short as two weeks to as long as one month, and depended to a large extent on when participants were available to do the second interview. Some of the implications of this intermission will now be discussed. The teacher might have forgotten how they understood a particular event which occurred during the EMT interview. Hence verbal protocols may involve a mix of memories of what had occurred at the time, and new interpretations of what is seen on the video clips. Participants frequently pointed out incidents while watching the video which they said they had not noticed during the EMT interview (as discussed in chapter 4). The time delay is not the only reason the VP interpretations might be different to the way participants understood events at the time of the EMT session. For instance experiences happening between the research interviews might influence how participants interpret what they see on the clips. The longer the delay, the more significant this effect might be.

A participant who has longer to reflect on the EMT experience may interpret that interview in a different way to one who must respond more quickly. This can be seen as a positive opportunity for deeper thinking as much as a limitation. Asking a participant to produce a VP immediately after the EMT interview might result in them revealing interpretations they might hesitate to express given more time to think. However there are some potential advantages to a delay between interviews over and above the researcher's need for time to analyse the data and prepare the video clips. For example the EMT process involved intense discussions of challenging ideas, often lasting more than an hour, and is probably tiring for most participants. Time to recover may mean greater willingness to engage again with what had occurred. In addition, according to Schön (1983), time for reflection *on* action gives the opportunity for new insights to be developed by professionals, away from the intensity of direct experience with its associated (and inevitably fleeting) reflection *in* action (see also Eraut, 1995)

There were no direct references made by participants during all 14 hours and 49 minutes of interview to anything said by me outside of the interview transcripts. Indirect influences will be discussed below in section 6.2.2. Almost all of the interventions I made during the interviews were directly related to practical issues with resources (for example 4a:234) or the timing of the interviews (for example 3a:292) and these were coded during the data analysis in the same way as the comments from any other participant. There was a handful of examples where I intervened in the EMT interviews. For example, shortly before the end of the first EMT interview I asked the pupils:

1a:365 JR: *Can I ask a very quick question?*

TU: Yes.

JR: *[Takes the torch] Are you all saying that the light is going out from there? [miming light leaving the torch] What about seeing? Does seeing go out from*

there [indicating something leaving eyes] Does it go that way [out from eyes] or that way [into eyes]?

1a:366 EM: It goes...

JB: It goes...

JR: Would you mind all...

Everyone talking: [unclear]

CS: You can see behind your eyes though.

TU (teacher): Let's have a vote. [CS] [CS] [TU puts hands out towards CS and JK] Lets vote. If you think that you see that way [out from eyes] put your hands up. [CS and JB straight away. JK next. LN next. EM slowly. BN hand held next to her cheek - unclear if she is voting or not]

JK: [To CS] That is only when you go to sleep.

1a:367 **TU: If you think that you see that way [towards eyes] put your hands up. [JK says err and stretches] [BN puts her hand up]**

1a:368 BN: You sort of see both ways. [JK has his hand up too - unclear if this is a vote or asking to speak].

This had a significant effect on the discussion for the next five minutes until 1a:395, when the teacher began to round up the interview (using question 5 from the questioning route – see appendix B). This intervention may also have influenced the subsequent VP interview as this was shown to the teacher in 1b:78. Though I felt at the time of the interview that my intervention had brought out an interesting discussion and the naïve concept expressed in 1a:368, I quickly regretted having spoken and in all subsequent interviews was much more cautious about interfering with the data collection like this (though I succumbed to this temptation again in 3a:406-410). This greater caution can be seen in later interviews where a teacher invites me to intervene. The first example is from an EMT interview:

6a:298 KG: Is the egg hard boiled or is it still like - you know
-

6a:299 **TZ (teacher): Well it is in a cup, so I would imagine [KG laughs] that it's a hard-boiled egg. [TZ looks at JR who shrugs - then TZ shrugs towards KG] I don't know. Egg. It is in a cup. So I would imagine.**

6a:300 JW: It used to be alive.

A second example is from a VP interview:

5b:44 **TY (teacher): [...] I found that really interesting that they'd just assumed it was a cup, therefore it is a coffee cup, therefore it was coffee. Even in the light of me suggesting - It was black wasn't it. [TY looks at JR who shrugs] I think that really threw them and so they were probably too polite and I wasn't going to go for the big argument because it was just interesting.**

Clearly even shrugs like these can still have a significant effect within a complicated social interaction like this, but this demonstrates the desire to minimise my influence during EMT and VP interviews. Another significant intervention by me occurred as one teacher started to sort their own pack of cards onto a living and non-living mat at the same time as the pupils were just starting (2a:91). I asked the teacher in a whisper to wait until the pupils had placed their cards. I spoke quietly to try not to embarrass the teacher in front of the pupils, but am aware that this may have been a difficult experience for this participant. I felt the pupils may have been significantly affected by seeing how the teacher had placed his cards, yet am aware that this intervention meant that I do not know what would have happened if I had remained silent. As the RD interviews involved structured interview questions (section 3.4) more researcher effect on these data is to be expected. I am aware that my being a practising teacher gives me a strong desire to intervene during what I find interesting discussions rather than observe, so as the study progressed I attempted to control this urge more.

Participant teachers and pupils were clearly influenced by being recorded on video. For example:

2b:22 **TV (teacher): [...] had I given them a clue about MRS NERG or used the acronym - and then I think that could have triggered something, they would have remembered - 'Oh, actually there are other things that we need to look at.' But they haven't considered that. OK, so movement, nutrition, ... I can't recall [laughs].**

JR: Excretion and...

TV: Yes, they didn't consider excretion actually. Yes, so these are the first things. Nutrition, and the other stuff. [Laughs] I think it is just because I'm thinking about the camera. [Both smile]

However, though there were several moments when the presence of the video camera appeared to be significant, all participants appeared to be so engrossed during all three types of interview that they appeared unaware of the cameras most of the time. For example the following comment was made 49 minutes after pupils had been asked to read and sign the consent form (appendix A - which reminds participant that they were about to be videoed) and been informed that I was starting the recording. At this point pupils had two video cameras on tripods pointing at them and I was sitting in the room:

1a:253 JB: When are we actually going to be filmed Miss?

1a:254 **TU (teacher): We are being filmed.**

JK: [Simultaneously] We are, look. [indicating backup video camera]

CS and BN: We are. [CS smiles]

1a:255 LN: [To JB] Do you remember the time when you went out. [Smiling]

JB: Oh no.

1a:256 JB: Miss was...

1a:257 **TU: I'm sure you've said more good things than you've said silly things [JB]. [TU is preparing teddy and torch]**

1a:258 JB: I didn't actually even mean to say that.

1a:259 **TU: I'm sure you didn't.**

1a:260 **TU: OK. [Shows teddy to everyone then places it on the table with the torch]**

The mischievous comment by LN above (1a:255) refers to when the teacher sent JB outside to calm down (1a:209). Some pupils were clearly more aware than others of the video cameras.

The seating arrangement was chosen by me and consisted, where possible, of two rectangular tables placed together to make a square. The teacher was asked to sit on one side of the square and the pupils sat round the other sides. The seat next to the teacher was kept clear by placing a coloured folder on the chair and the teachers' place was reserved by placing the print-out of the questioning route on the table next to this chair. This arrangement meant that the teacher could be seen more easily on the video. This view was prioritised because the focus of the first research question was how the teacher promoted conceptual change. On one occasion a pupil sat on the seat next to the one prepared for the teacher, and I asked this pupil to move to the other vacant seat which she did straight away (1 minute 27 seconds from the start of interview 2a). This pupil (ES) may have wished to sit next to the other two girls in the group (SF and LD) who had already sat together, and ES ended up sitting next to a boy (UG – see appendix C for seating plans). In hindsight I could have moved the seat for the teacher and the cameras, but this did not occur to me at the time. Issues to do with gender and these data will be discussed in section 6.2.2. I interrupted once during each interview to ask to take a photo of the table during the card sort activity so that I could see where participants had placed

their cards (for example 6a:481). I also asked pupils during each interview to put their initials on the drawings so I could identify them (for example 6a:541).

6.1.2 Potential researcher effects

Participants were sometimes influenced by my being an educational researcher.

On one occasion a teacher said:

3b:81 **TW (teacher): [Pause] I want to know what your hypothesis is! [TW laughs - question appears to be rhetorical]**

The assumption by this teacher that a hypothesis was being tested will be discussed further in section 6.2.1. There were no other entries in the 14 hours and 49 minutes of transcripts where it was clear that these data had been influenced by my role as an educational researcher, but participants were well aware that I was a visitor in their school with a particular role. It would be unlikely that this did not influence these data in some way, but there were no clear indications as to what these effects might be.

This research was introduced to pupils as about ‘science ideas’, and ‘strategies for conceptual change’ and ‘misconceptions’ were mentioned in the correspondence with teachers (appendix A). In writing these letters I was conscious of wishing to give enough information to potential participants that they would know what they were agreeing to, without saying too much such that participants might change what they would say normally in order to meet what they perceived to be my expectations. Conceptual change literature is unlikely to be well known among the teachers who participated in this study as the term is relatively new in the literature, and because the participant teachers were all experienced, so trained some time ago. The term ‘misconception’ is very well known among UK teachers and it was mentioned in the email inviting teachers to participate so that they would understand something about the focus of this work. The misconception movement was discussed in section 2.2 and the decision to use this term may have

influenced participants. I did not use the term during any of the interviews. All participant teachers used the term at least once, and altogether it was mentioned 38 times.

Care was taken that an equal number of girls and boys participated. The only interview where the numbers were not even was interview 1a, where 4 girls and 2 boys participated. The teacher who chose pupils to take part in that interview (TU) had been asked to choose equal number of boys and girls (see section 3.6), but a change was necessary at the last minute due (I think) to a pupil being absent. Overall 32 boys and 34 girls participated. As regards the teachers, three women and three men participated. There were no overt transcript entries which indicated that my gender influenced these data. As far as I am aware, this issue has not influenced the analysis in this study. As might be expected, during six and a half hours of video recording of interactions between pupils there were a number of times where the gender of the pupils may have been influential. For example boys and girls could choose where they sat around the table and they tended to group together (see 6.1.1). Pupils of this age (11 or 12 years old) are often more comfortable sitting with pupils of their own gender in my experience. The decision to allow pupils to sit where they liked was in order to help them feel more comfortable for the EMT interview. Almost all references to 'boy' or 'girl' in the transcripts appear to be merely a convenient way of referring to a particular pupil or group. However pupils may behave in ways that are influenced by the gender of those they are sitting next to. For example:

1b:13 **TU (teacher): I was just thinking that watching that one I gave it personal attributes saying, 'how does it know which way to go out, when to go out, when to go in.' And very quickly she [CS] said, "It is not thinking, it is just doing it." So she has depersonalised it and I personalised it to try and get them to model and she unpacked that model very quickly.**

JR (researcher): It is amazing isn't it. The things that are happening.

TU: Mm. And the other two boys aren't engaged at all in the debate. Just focussing on those three ideas with the girls.

The exchanges between pupils did appear to be influenced by their gender:

1b:23 **TU (teacher): [...] I notice with the boys there that they were much more involved in that part.**

There was only one occasion in all the interviews where a teacher suggested a direct influence of gender on the way pupils were thinking:

5b:40 **TY (teacher): [TY laughs having just watched 5a:593-601] [...] it just irritates me so much when kids turn up and they say, "Well it is like this 'cause I remember it from the test." [...] she doesn't understand it [...] she will never be able to explain [how it works] using the faulty model that she has. [...] diagrams are important and words are important, but actually knowing stepwise [...] cause and effect [...] is far more important. [...] I have a colleague who calls it 'pretty handwriting syndrome' - because she'll work her socks off, and learn (as she sees it) everything that is written in her book. And it will be pretty and beautiful. [But] unless she changes her model, [she] will never understand it. [...] Whereas AC was [...] trying to be helpful - and giving her a clue [TY mimes something bouncing with his hands - imitating what AC had done in the video clip] that this is how you can remember bounce. That is a boy approach. Because he is an inquisitive [TY smiles] kid who wants to know how things work. And DF's girl approach I think, in this instance, has been proved to be a bit of a fail. [...]**

The teacher (TY) expresses annoyance at 'explanations' from pupils which suggest recall without understanding. TY has watched a pupil (DF) on video describe a classic physics test question which shows a picture of a light source, an object and a person. The pupil is then asked to draw light rays, but they are often not told to use a ruler (indicating the rays

travel in straight lines) or to put arrows on the lines (showing the direction the light travels in). Yet the mark-scheme usually penalises wavy lines or lack of arrows. The following section from the EMT script is what provoked **TY**:

5a:593 DF: Um. Um the tor - there is this thing we did in a science test. Where there was a person, a light, and there was an object. We had to draw arrows on which way it is going to go [DF mimes this with her hand]. So like the person - I think so - is - I think it is from the light to the object - which we can see - and then it goes into a triangle kind of thing.

5a:594 **TY: OK. So are you remembering what it looked like to help you to answer it now? [DF nods] What might be a better way than trying to remember the picture that you almost remember?**

5a:595 DF: Um. [Pause] To do it on this? [DF points at her drawing]

The order in which DF describes the elements of this question (person, light source, object) in 5a:593, and the way she starts her explanation with talking about the person before changing her mind and starting again with the light source, may be significant. It could indicate conceptual change (from seeing being something that comes out of our eyes, to seeing being about light going into our eyes), but this is far from clear. It might even suggest that the memory of the activity of drawing this diagram (the technique of ‘use an activity’ - section 4.2.7) led to conceptual change. But the interpretation from **TY** during the VP interview quoted above seems to be that DF has remembered a picture by rote and that she is using a ‘faulty model’. **TY** says that he hinted to DF that there was a problem, but that this was not accepted. **TY** argues that one of his biggest struggles is to ‘repair the damage’ caused by some teachers who convince pupils that remembering the correct answer is a good learning method. Understanding cause and effect is essential in science according to **TY**. **TY** quotes a colleague who speaks of ‘pretty handwriting

syndrome’, which appears to mean that a pupil presents work well, but understands little. **TY** compares the way DF (a girl) explained vision here with the way AC (a boy) gave a step-by-step account. The first explicit reference to gender occurs five lines from the end of the clip quoted above, where **TY** suggests that explaining something in steps is ‘a boy approach’ and argues that DF’s has used a ‘girl approach’ (see 5b:40). During the analysis (Chapter 4 and 5), which used grounded theory methods (section 3.11), themes emerged from the data. Despite the example above, in the particular context explored in this study it did not appear that gender was a particularly significant factor as regards conceptual change. The topics used (hot and cold, living and non-living, and seeing) are unlikely to lead to discussion where gender is a significant factor. Pupils of this age (11 or 12 years old) are perhaps less likely to be influenced by their own gender, and that of others, as slightly older pupils. Hence my decision to work with pupils of this age may have influenced the importance of this factor.

Participants (both pupils and teachers) came from a wide variety of ethnic groups as would be expected in UK schools. There was no indication in any of the transcripts that the ethnic origin of participants was a significant factor as regards the research questions being explored here. Again, if other scientific topics had been selected this may have been of more importance. English was an additional language for at least two pupils (VH and LM) and one teacher (**TV**). In the following example the teacher who was working with these two pupils (**TW**) can be seen adapting to their needs when a mistake was made with a word:

3a:48 **TW (teacher): [...]** **What would I have to do to this**
[indicating with her hand the bowl of ice cubes in
water] to make it freeze? Is it freezing now?

3a:49 VH: No. You put it in the fridge.

3a:50 **TW: OK, so what kind of change. [Pauses] Hang on
fridge or... [pause] freezer.**

3a:51 VH: Freezer.

Other than this enhanced awareness of the potential difficulties these students might encounter during the interview (discussed as ‘withitness’ in section 4.4), the fact that some pupils struggled a little with English did not seem to affect the way participant teachers taught. Clearly this would be different with pupils who have more significant speech, language and communication difficulties or with other topics.

6.1.3 Non-participant effects

A number of incidents where something, or someone other than the participants in this study, affected or may have influenced these data, will now be described briefly. One participant (JB) spoke about a tree outside the window which did not have leaves, as the interview took place during winter. He argued that after a tree loses its leaves it is non-living (1a:176). The view of the tree through the window was significant, as was the time of year. There was one other mention of a visual aid which was a poster on the wall of a classroom (5a:262). The rest of the events which will now be mentioned did not appear to have a significant effect on these data. During one interview a teacher walked in during the interview and sat at one of the desks in the room (6a:599). They seemed to be unaware that the interview was being video recorded and when this was pointed out by me they left quietly. One potential participant teacher was not given permission by their line-manager, so did not take part. There was sometimes some noise from classes in adjacent classrooms, which made it hard to hear some parts of the transcript (noted as ‘unclear’ when it was not possible to be sure what was said). On a few occasions participant pupils mentioned pupils or teachers who were not part of the study (for example 5a:457). During one interview, some other pupils waiting outside to come in for their lesson, knocked on the door whilst the interview was taking place. I went to speak with them (4a:520) while the interview continued. The physical environment within which the interviews took place was a science classroom in all but two interviews. Interview 3a took place in a portable classroom and 5a in a meeting room. The table was square in all interviews except 5a (where it was rectangular). The same research carried out in a different region of the UK, another country or with teachers working in different types of school might well have influenced this study significantly.

6.2 Are these findings trustworthy?

How the trustworthiness of the findings of this study may be assessed was outlined in section 3.10. This next section uses this framework for evaluating the trustworthiness of interpretivist studies (Lincoln and Guba, 1985, p. 294) to discuss the following questions. Do the research findings represent a credible interpretation of the data? To what extent can the findings be transferred beyond this present study? How well were the integrated processes of data collection, data analysis and generation of theory carried out (dependability audit)? To what extent are the findings supported by the data (confirmability audit)? Each of these criteria will now be discussed.

6.2.1 Credibility

If research is to be credible, prolonged engagement is necessary so that sufficient time is spent to understand the ‘culture’ being studied. Fifteen years teaching science in several schools means that, in one sense, I am very familiar with the culture of secondary school science departments in the UK. However, each science department has its own individual ‘culture’. The methodology used here prioritises observation on a fine scale of the interactions between participants during interviews over an exploration of the broader context within which learning and teaching take place.

[T]he purpose of persistent observation is to identify those characteristics and elements in the situation that are most relevant to the problem or issue being pursued and focusing on them in detail. (Lincoln and Guba, 1985, p.304)

The integration of video data where the playback speed can be slowed down, full transcripts (with timespans) and ‘coding stripes’ (coloured bars which highlight coding next to the transcript) in NVivo (section 3.2.1) helped the detailed exploration of these data. Figure 15 below illustrates the use of coding stripes alongside a section of the transcript.

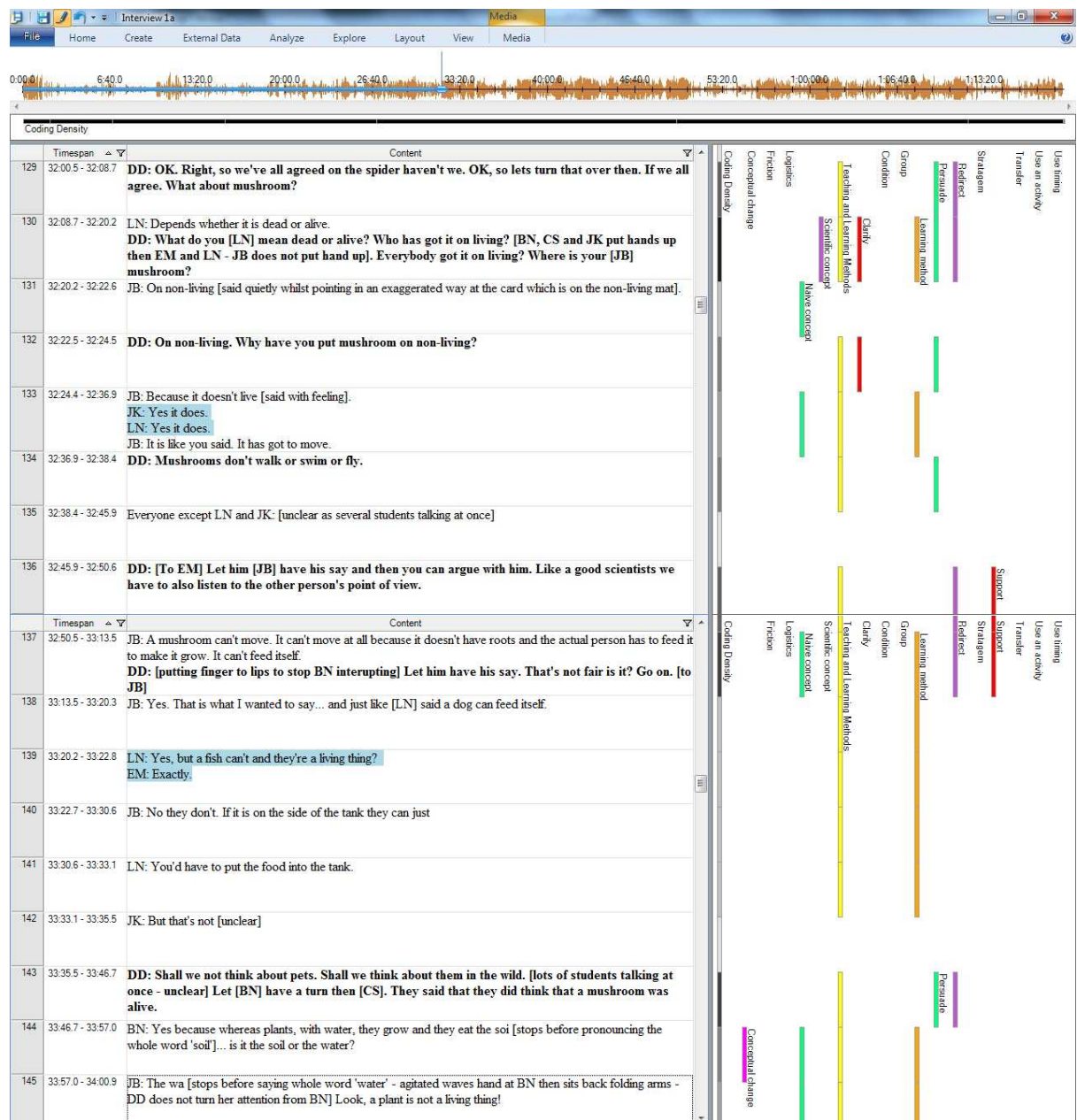


Figure 15: A short section of a transcript illustrating the use of coding stripes (1a:129-145)

In order to code many parts of this rich data set, it was necessary to apply multiple codes to individual phrases or even words. Presentations (for example papers at the national Association for Science Education conference in 2010, 2011 and 2012, the International Conference on Conceptual Change in 2012, and the British Educational Research Association conference in 2013) provided opportunities to see if the grounded theory

emerging from this study was credible from the perspectives of teachers and conceptual change researchers.

Three types of triangulation are appropriate in this study: sources, methods and investigators. Source triangulation here involves using multiple copies of one type of source (for example several different VPs from different teachers) and different sources of the same information (for example EMT, VP and RD interview data from the same participant). Method triangulation is present in this study since different types of data collection are used (observation of a teacher working in an EMT group, VPs and RD interviews). Furthermore 'theoretical integration' (discussed in section 3.11) involves exploring the relations of the emergent grounded theory with results obtained using different methodologies. Investigator triangulation occurred during the VP interviews when both the participant teacher and I were offering interpretations. Hence elements of the interpretations of participants have been incorporated into this study, but the grounded theory is a coherent synthesis.

Peer debriefing provides an external check on the study. Peers in this context include my PhD supervisors, discussions with participating teachers, and presentations at conferences to academic and practitioner audiences. Analysing negative cases refined the grounded theory which emerged, as more data became available. For example there was an incident (1b:10) where a particular clip from an EMT session was shown to the teacher during the VP interview in the expectation that it would represent for them an example of a naïve concept. The reaction of the teacher indicated that they understood the pupil's ideas in a way I did not expect. Surprises like this were noted as annotations (short comments on the transcript) or memos (longer pieces of writing stored within the NVivo software), in order to be used in negative case analysis in the data analysis chapters. Referential adequacy comprises preliminary findings and interpretations being

continually compared with raw data. This is recognisable as the grounded theory method ‘Constant Comparative Analysis’ used in this study. ‘Member checks’ involves the direct evaluation of findings and interpretations by participants. All participant teachers were offered detailed feedback and were invited to comment on this thesis.

As teachers (and pupils) have been found to use deception as a teaching technique in this study (section 4.2.6), this has implications for the credibility of the conclusions.

[Deception is a] distortion of perceived reality. (Whaley, 1982, p.182)

No moral judgement is implied in the use of this word. I considered using a synonym for this term, such as ‘trick’ or ‘pretending’, because deceiving in this educational context might carry negative overtones with some readers. However these alternatives do not describe as well the category which emerged during this study. The use of stratagems occurred on only 208 occasions (out of 21,612 references), so when it was used it was done sparingly. Interpretation of deception is inherently difficult, and misunderstanding is possible in many instances. Furthermore deception emerged as a category during the research from the data, so the coding of this did not start until interview 1b (11.23 am on 28/9/11) and changed during the following interviews as I began to understand the concept better. However, it does appear that teachers in this small sample do sometimes deliberately deceive (section 4.2.6). It should be noted that pupils frequently appeared to be aware that they were being deceived, and to be enjoying this as a game. For example:

1a:321 **TU (teacher): I'm looking around [TU mimes looking in one direction whilst shining the torch in another]. Can I see teddy?**

BN: Use the torch! [smiling]

CS: That's what I'm trying to say.

TU: Oh, I'm moving the torch as well. [as if surprised]

If experienced teachers are adept at not only managing the deception of pupils in their care, but deceiving children in order to promote learning, this should be taken into account when research explores their practice. Indeed it is possible that practitioners might see positivist research methods as a type of deception, and adapt what they do in that light. A blind trial cannot be done with a participant who is capable of guessing the hypothesis and adapting their behaviour accordingly. One teacher expressed interest during an interview as to what the hypothesis was (3b:81). In this grounded theory study no hypothesis was being tested. How might the assumption that there was one, and the perception that this might be being kept from participants, have affected these data? I tried when I first met participant teachers, to make it clear that I was there to try and understand what experienced practitioners do, but it is perhaps natural that participants trained in the natural sciences will assume that the methodology being used is positivist. Positivist researchers in this field should be aware that their perceived methodologies may be being scrutinized by participants for deception, and that participant teachers (and pupils of course) are quite capable of adapting what they do to meet what they think best suits the circumstance. Indeed one teacher spoke about how pupils are often aware that they are being deceived by exam questions (3c:25). Given that teachers sometimes use deception to help children in the classroom, and the fact that deception is an important aspect of childhood (Salekin, Kubak and Lee, 2008, pp. 343-364), the social phenomenon of deception should be acknowledged, and perhaps explored more, in research exploring conceptual change strategy.

6.2.2 Transferability and generalizability

A thick description of tactical and strategic behaviour by participants in this study was given in section 4.4.

[T]he naturalist cannot specify the external validity of an inquiry; he or she can provide only the thick description necessary to enable someone interested in making a transfer to reach a conclusion about whether transfer can be contemplated as a possibility. (Lincoln and Guba, 1985, p.316)

The extent to which the findings can be generalised depends on a number of factors. The similarities and differences between this research and potential settings to which the results may be transferred will be discussed. It will be argued that the teaching and learning techniques participants use (section 4.2) are very similar to those found in studies exploring actual classroom practice. However the Clausewitzian view of strategy which has been used in this study (section 4.4), questions the extent to which tactics and strategies can ever be transferred between even similar contexts.

The methods used in this present study (expert micro-teaching, verbal protocols and retrospective debriefing) took place in a context very different from that experienced by children and teachers during a typical science lesson. Science classes in most UK schools might have about 30 pupils in rather than 6. Normally the teacher would decide what to do during the lesson, and what equipment to use, instead of following a questioning route with supplied equipment. The influences of the researcher were discussed in sections 3.12 and 6.2. It was argued earlier (section 3.5) that these arrangements were a necessary first step in order to establish the grounded theory before this could be tested in a more normal environment. The interactions between participants during micro-teaching are similar in some ways to those in a science classroom, and during the retrospective debriefing participant teachers were invited to comment on this as one way of tackling the issue of the transferability of the theory (appendix B ‘Questioning route for interview 1c’ question 8). Several participants noted similarities between this research context and what happens in normal classrooms. For example:

- 3c:30 JR (researcher): [...] If you'd been doing three topics like that in the sort of normal class, as part of the normal school year, can you tell me a little bit about how it might be similar and how it might be different?
- 3c:31 **TW (teacher): OK. So heat and temperature would all start off being practical. I wouldn't talk about words like freezing, melting, heating - anything until we'd started doing it. And so then they've got - so then you do a lot of observations and they have to describe things, and then once you've built up your bank of words, like melting, freezing, condensation, and so on; then you try and link them all together. So it would, they'd see it and feel it all first before you try to have the words for it. Because I think they are still so complex. So that would be quite different from that point of view - obviously they did get to touch the hot tea and the ice. That might have been quite useful starting point. You might do a discussion, and then do some practical. But I err towards the practical first. Um. The card sort was almost exactly how I would use it in lessons. I probably would have had less cards. [...] No I fully intend to use those in lessons in exactly that way to promote discussion, to promote collaborative learning, and just to get people thinking and justifying. [...] And the last one. Again I think I would have done a lot of experiments with light so they could see it bouncing off mirrors, see it bouncing off - there are quite a lot of animations you can show about light flowing and so on. And that wasn't particularly different, I can imagine that being a standard question. I probably would use it as maybe a plenary part of a lesson. So OK we've done these experiments with ray boxes, we've looked at light, we've looked at this animation. Here's a scenario, draw me what happens. And I often use mini whiteboards and pens in lessons. So that is fairly standard as well.**

This teacher (TW) says she would begin teaching about heat using experiments (the technique of 'use and activity' - section 4.2.7). Vocabulary elements would then be linked to build understanding (Kvanvig, 2003, p. 192 - see section 5.0). She notes that this is different from the EMT interview. She then reflects that the experience of touching hot

and cold things could be a useful alternative starting point and begins to outline a lesson plan which would begin with discussion before doing practical work. **TW** would use fewer cards in the sorting activity, but otherwise would not change it. She then talks about how she will incorporate the activities from the EMT interview into her lessons. As regards the activity involving the torch and teddy bear **TW** speaks about combining this with other experiments and using animations, but using the torch and teddy activity at the end of a teaching session (the technique of ‘use timing’ - section 4.2.11). Hence overall this answer suggests to me that **TW** thinks that the research context is similar to what happens in lessons, but that the way such activities were used would be adjusted (decisions described as tactical in this present study - section 4.4). Participant teachers have been invited to read and comment on this document, so interpretations such as this may be challenged.

Establishing whether the grounded theory, developed using EMT, VPs and RD interviews, is useful for understanding the practice of experienced science teachers in a ‘normal’ classroom is a study in itself and beyond the scope of this present thesis. In such work some influence on the system by the researcher is inevitable (for example, covert videoing of lessons without the knowledge of participants would be unethical, but the knowledge that a lesson is being investigated will influence a social setting like the classroom). There are even some ways in which the micro-teaching context used here may have advantages over attempts to investigate tactical and strategic behaviour in a natural environment. For example, when a normal lesson is explored by researchers, the pressures of teaching and being observed, could combine and influence the behaviour of participants.

Several of the teaching and learning techniques participants appear to use (section 4.2) are similar to those found in studies exploring actual classroom practice. Teacher

clarity ranked 8th in effect size out of 138 meta-analyses synthesised by Hattie (2008, p. 125 and 297). The development of deception in children was discussed by Vasek (1985, p. 271) and Allen (2010a, p. 154) describes ‘bluff activities’ in conceptual change science pedagogy. Persuasion is similar to the “rhetorical strategies” explored by Kress *et al.* (2001, p. 18). Literature investigating within-class grouping was reviewed by Kutnick *et al.* (2005). What is new in this study is the exploration of how participants use such techniques in tactical and strategic ways. Given that the techniques appear to be akin to those found by researchers investigating more natural settings, it can be argued that the conclusions as regards tactical and strategic behaviour in this present study are likely to transfer well to such contexts.

This study challenges current understandings of the meaning of ‘strategy’ in the conceptual change literature, and argues that the prevailing view that a strategy is a plan does not describe well the behaviour of participant teachers in this study. A Clausewitzian view of tactics and strategy (section 4.4) is used here which holds that tactics describe the sophisticated use of teaching and learning techniques and strategy refers to the ability to achieve an objective (here conceptual change). Both teachers and children behave in tactical and strategic ways, hence this aspect of instruction is dynamic and unpredictable. A major theme from the grounded theory was the tendency of tactics and strategy to fail (section 4.6). In education as in war:

everything is uncertain and variable, intertwined with psychological forces and effects, and the product of a continuous interaction of opposites. (Clausewitz, 1832, p. 127-147)

Hence such a study cannot offer a simple solution to how to promote conceptual change to be transferred between different contexts. No teacher ever enters the same classroom twice.

6.2.3 Dependability and Confirmability

For this research to be dependable, the processes used must be used correctly. To establish confirmability, the findings of this research must be supported by these data and be internally coherent (Lincoln and Guba 1985, p. 318). Considerable care was taken to follow grounded theory methods as described in section 3.11. Sixteen NVivo models were made during the coding and converted to ‘static models’ (with time and date stamps) to record the evolution from initial coding to substantive codes (section 3.11). The way substantive codes are grouped within these models shows how the understanding of the categories in the grounded theory emerged during the study. The first model (model A in Figure 5), and a model from the end of the study (model Q in Figure 7), are shown on page 92 and page 94 to illustrate this evolution. Models A to Q describe something of the evolution of the grounded theory during the study and were discussed in section 3.11. Model Q in Figure 7 on page 94 represents the grounded theory which emerged during this study (see Chapter 4).

Incidents within each substantive code (also called indicators by grounded theorists) were used as examples in the data analysis (Chapters 4 and 5). Some substantive codes were more ‘saturated’ than others (see section 3.11). Table 7 below indicates how many references in each type of interview (EMT, VP and RD) were made to each type of substantive code.

Substantial codes	Interview (a = EMT, b = VP and c = RD)														Total				
	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c	5a	5b		5c	6a	6b	6c
Teaching and Learning Methods	399	52	54	570	59	43	449	53	23	465	49	55	665	88	35	1319	143	83	4604
Redirect	52	6	5	94	13	8	136	8	1	209	28	18	166	20	5	156	15	13	953
Clarify	59	0	1	138	5	5	57	4	0	106	2	3	174	12	1	178	15	3	763
Persuade	146	23	15	262	9	9	19	1	3	15	0	0	18	2	1	32	6	8	569
Transfer	0	0	0	0	8	3	65	10	3	20	5	1	87	10	1	193	6	2	414
Learning method	79	14	3	29	2	1	19	0	1	65	5	2	64	11	3	69	7	0	374
Support	60	7	15	36	2	0	30	4	0	15	4	5	51	7	3	23	1	2	265
Stratagem	3	0	0	0	10	6	33	15	6	13	0	11	35	19	9	37	5	6	208
Use an activity	0	1	8	3	6	4	22	3	4	2	2	6	21	1	4	33	15	7	142
Condition	0	1	3	8	2	0	34	0	0	11	1	1	41	2	0	30	3	0	137
Group	0	0	4	0	0	6	21	4	3	4	1	6	5	4	6	7	7	4	82
Use timing	0	0	0	0	2	1	13	4	2	5	1	2	3	0	2	15	2	4	56
Naive concept	69	24	8	71	6	7	54	14	6	51	12	3	97	21	20	94	40	5	602
Scientific concept	62	5	1	196	1	0	80	2	1	108	5	0	81	3	0	93	7	1	646
Conceptual change	11	3	2	27	0	0	19	1	1	14	2	1	28	1	0	28	14	5	157
Friction	2	0	0	0	2	2	10	5	1	10	7	10	30	21	11	36	24	15	186
Conceptual conflict	9	2	0	14	3	0	40	0	0	45	15	4	66	8	2	51	4	6	265

Table 7: Number of references in each type of interview (EMT, VP and RD)

Hence with 602 references I have more confidence that ‘naïve concept’ is saturated than I would with the teaching technique of ‘group’, where there are only 82 references (out of a total of 21,612).

It was argued in section 3.7.3 that an inter-rater reliability check of initial coding (for example Kappa coefficients) might reduce subjective bias, but that transfer of such a technique sensitively into this, or any other qualitative methodology, is by no means straightforward. Armstrong (1997) reported “close agreement” between what Miles and Huberman (1994) termed ‘descriptive coding’ for six researchers exploring group interview transcript data, but differing ‘thematic coding’ as one might expect. Yet during this present study there was no sharp boundary between the grounded theory methods of initial coding and intermediate coding (section 3.11). Therefore it should not be assumed that the study would be improved through inter-rater reliability measures, even if it had been possible to employ a team of researchers to do this work. There is scant evidence of the use of Kappa coefficients in qualitative studies according to Thompson *et al.* (2004).

Categories were sometimes joined together, separated and relabelled, or renamed (called intermediate coding in grounded theory). To preserve a full record of these changes eleven versions of the NVivo file were saved as the study progressed. The length of each interview varied as did the number of references coded within each one. Hence some interviews were used more than others in the development of the theory. To illustrate this point Figure 16 shows the number of references made in each of the 18 interviews:

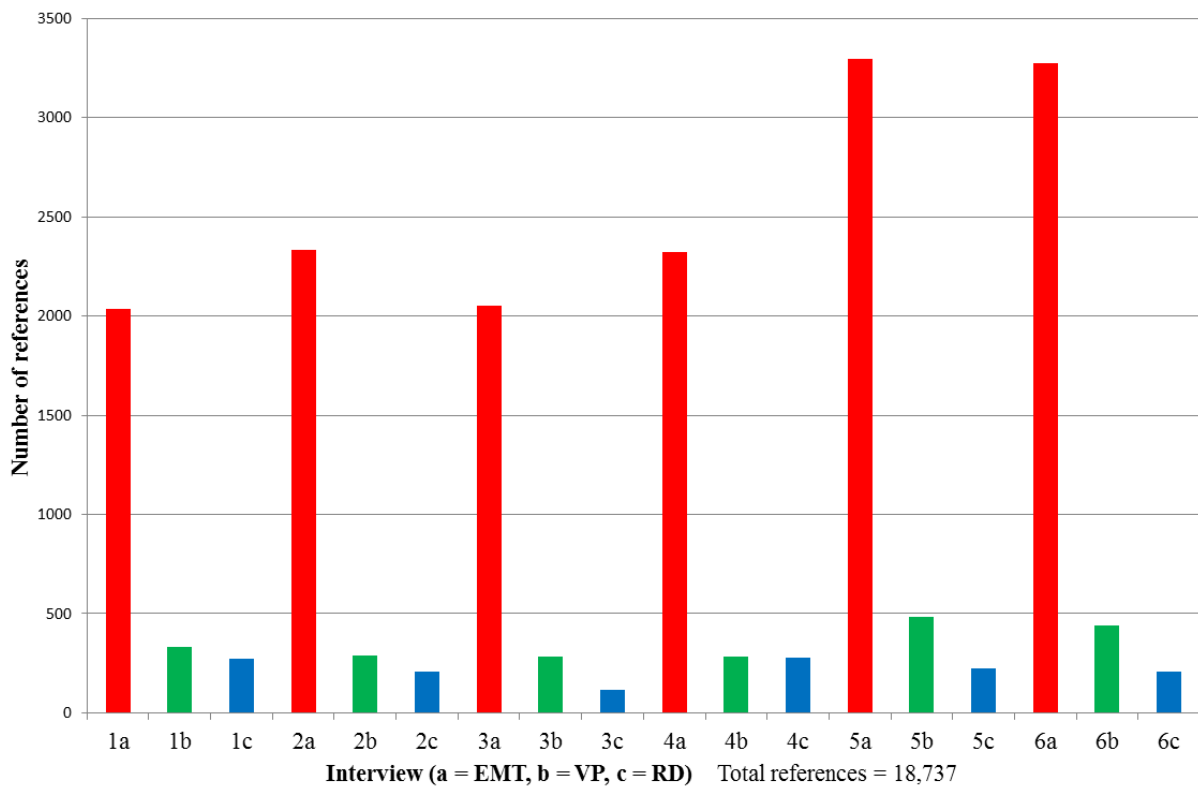


Figure 16: A graph showing the number of references made (i.e. sections of transcript coded) in each of the interviews

Video data for each interview were collected, transcribed and analysed using the techniques described in section 3.11 before the next interview took place. This ‘concurrent data collection and analysis’ allowed the findings from one interview to guide theoretical sampling in the next. Annotations on the transcript and memos provide a record of intermediate coding and how core categories evolved during this study. To illustrate this, a short section of transcript is shown below with an annotation I made as I was coding:

- 5a:56 **TY (teacher): [...] And how do you explain that?**
- 5a:57 AC: ... The hot air rises and it hits the cold surface and turns into water.
- 5a:58 **TY: So the air turns into water.**
- 5a:59 AC: Yes. No, the surface.
- 5a:60 **TY: The surface.**

- 5a:61 AC: The hot air. [AC nods]
- 5a:62 **TY: Does what?**
- 5a:63 AC: Turns into water. [AC is leaning his head on his hand covering his mouth a little - he laughs a little as he says this]
- 5a:64 **TY: So air turns into water.**
- 5a:65 AC: Yes.
- 5a:66 **TY: When it hits a cup.**
- 5a:67 AC: Yes. If it is cold.
- 5a:68 **TY: If the cup is cold then the air hits it -**
- 5a:69 AC: Hot air.
- 5a:70 **TY: If hot air hits a cold cup then the air will turn into water.**
- 5a:71 AC: [Pause - AC looks round at the other students as if for help - MG has her hand up - TY smiles at AC]
- 5a:72 **TY: I'm only checking. Is that what you mean?**
- 5a:73 AC: Yes.
- 5a:74 **TY: OK. Thank you. [TY turns to MG]**

On line 5a:72 on the phrase “I’m only checking.” I made the following annotation in NVivo (annotation number 6 in interview 5a):

21/05/2012 10:10 I think it is clear in the preceding discussion that **TY** is doing far more than 'only checking'. **TY** has guided AC so that his idea is expressed much more clearly. **TY**'s probing did check that this is what AC meant, so this may be how **TY** understands this exchange. **TY** (a physicist) will be well aware that AC's idea is naive. **TY** does not say this to AC, and so I think **TY** is masking his ultimate intention, which may well be to help AC understand this in a different way. Hot air does not turn into water when it hits a cold surface. Water particles in the air (where the water is in a gaseous state) transfer energy to the cup and, as a result, change state to become a liquid. AC does not seem to understand that air is a mixture of

particles. This seems like an excellent example of the need for 'fundamental concept differentiation' (Clement, 2008, p.433).

An example of a memo is given below which was made whilst coding an EMT interview (6a:607-608):

4/07/2012 10:16 See 6a:607-608 JP's first drawing (see appendices) gives no indication that anything enters the eye. His second drawing, before he changes it, appears to be influenced by VG's first drawing (which he was looking at with VG just a moment ago). However JP's second drawing before it is changed is not the same as VG's and suggest two naive concepts (that something comes out of the eye such that it can see the torch, and that nothing goes from the teddy to the eye). Hence I think JP has changed from the naive concept in his first drawing (that seeing does not really involve the eye) to another naive concept in the first draft of his second drawing (seeing involves something that goes out of the eye). In 6a:608 JP appears to undergo another conceptual change to a third where he changes his second drawing to indicate the torch shining half way between eye and teddy. This may suggest that he accepts that light shines on the teddy, whilst maintaining the correct idea that light from the torch is also going to his eye (c.f. **TZ**'s idea earlier that light shines in all directions - even though the torch has a reflector in it that means that the beam is highly directional). JP's second version of his second drawing thus maintains the naive concept that he sees the teddy because something goes from his eye to the teddy. I think the interaction between JP and VG is important here. JP is trying to imitate VG (c.f. the way JP changes the way he draws the eye from his first drawing to his second), but VG is a moving target. VG has changed from a naive concept (which appears to be influencing what JP does) to a 'scientific concept', which does not appear to be influencing JP. This second drawing from VG may of course have been done after JP's drawing was complete.

The seven hundred and eighty five annotations and sixteen longer memos also provide evidence of how the grounded theory presented in Chapter 4 evolved during this study via constant comparative analysis (section 3.11). Many of the annotations and memos were written up as sections of this thesis. The grounded theory represents, I believe, a

“plausible explanatory framework” (Corbin and Strauss, 2008, p.264) for the way the six experienced science teachers promoted conceptual change during the EMT interviews.

Having explored the extent to which the findings in Chapters 4 and 5 are trustworthy (Lincoln and Guba, 1985, p. 294) we turn next to what this study reveals as regards the relationships between practitioners and researchers. Though not directly related to the research questions, this whole study can be considered a reflection on the gap between research and practice in this field.

6.3 Practitioners and researchers

Evidence suggests that the most effective teachers make good use of research findings (Cochran-Smith and Lytle, 1999). Yet fostering research-informed teaching in schools has proved challenging for both researchers and practitioners. For example concern in the UK about the possibility of a decreasing role of research-informed teaching in Initial Teacher Education (ITE) was raised and discussed at a recent Higher Education Academy (HEA) summit (Florian and Pantić, 2013a and 2013b). As regards those already in the profession:

No one involved in real curriculum change... is under any illusion that changing teaching approaches on a large scale is an extraordinarily difficult task. (Shayer and Adey, 2002, p. 8)

As a practicing secondary school science teacher, educational researcher and senior lecturer in primary education, I experience the tensions of trying to translate research findings into my own classroom practice and of supporting new teachers as they attempt to interpret and make use of research. The following discussion will focus on the conceptual change research literature. What do researchers think teachers know about promoting conceptual change? How and why might teachers be resisting a desire on the part of researchers to promote conceptual change, and conceptual change strategies,

among the profession? How might a perceived power differential between researcher and teacher influence work in this field? Each of these questions will now be discussed.

We educational researchers in the field of conceptual change pedagogy do not agree in our understandings of practitioner knowledge and skills. For example, one educational researcher claims that:

[T]he problem of misconceptions ... is largely invisible to teachers during the flow of teaching. (Abd Rahman, 2004, p.30).

The research methods used in that research may have prevented the full picture from being seen (section 2.5). Another researcher noted:

[T]he gap between what is necessary from the researcher perspective and what may be set into practice by ‘normal’ teachers has increased more and more also. In other words, there is the paradox that in order to adequately address teaching and learning processes research alienates the teachers and hence widens the ‘theory-practice’ gap. The views of teaching and learning developed in our research field are far from normal classroom teachers’ ways of thinking about instruction. The instructional strategies developed by us are far from the routines of normal classes. As research has clearly shown, it is rather difficult to change (in the sense of a conceptual change) teachers’ views and teachers’ classroom practice. (Duit, 2003, p.683)

Whilst agreeing with Duit’s point that adequately addressing teaching and learning processes is not straightforward, might such research also be alienating teachers by not being sufficiently aware of the sophisticated ways some teachers currently address conceptual change? As was argued earlier (Chapter 3), the methodology adopted for this present study allows the sometimes subtle ways participants promote conceptual change to be examined. Why work with “normal” teachers and not expert teachers? The evidence presented in this present study (Chapter 4) of the use by a small group of very experienced practitioners of teaching and learning techniques in tactical and strategic ways, presents, I believe, a challenge to the perceptions of this profession by conceptual

change researchers. Teachers and researchers view learning, and the interactions between learners in a classroom, from different perspectives. Practitioners are active participants in conceptual conflict alongside pupils, while researchers (though they may influence classroom behaviour) are not. This study has shown how an interpretivist approach, which moves back and forth between the parts and the whole, can help bridge the “gap” between theory and practice in this field (Duit *et al.*, 2008, p.629). One reason for the emergence of this breach could be the rejection by practitioners of some simple theories of how to promote conceptual change proposed by researchers (for example Clement, 2008, p. 445), which do not correspond with classroom experience. Recognition by educational research of the particular, and often unpredictable, nature of classroom interactions is important if research is to be credible to teachers. Pedagogic fashion may distort the strategic profile of teachers in ways which may not always be appropriate. This might represent a power struggle with the research community, where practitioners could assert their position more effectively if helped to articulate what they do in language that is accessible to the research community. Teachers may not always be able to articulate all that they do intuitively to promote conceptual change (cf. tacit knowledge discussed in section 4.2.12). Teachers do not always say what they do for many different reasons. Sometimes what occurs during interactions between pupils and between pupils and their teacher is so complicated that participants may need the support of the research community in order to adequately describe, or even understand, these events. In the grounded theory presented in Chapter 4, pupils and teachers were seen to use deception (“a distortion of perceived reality” Whaley, 1982, p.182) on many occasions, so understanding the ways that participants deceive each other may be important. As participants may be reluctant to speak of this, methodologies exploring conceptual change strategy must use appropriate instruments for the exploration of subterfuge.

Are teachers really resistant to change as regards how they promote conceptual change (Gregoire, 2003)? Pedagogical inertia among teachers is well known (Shulman, 2005), but the six teachers who participated in this study showed themselves to be adept at guiding children as they experienced some extremely challenging naïve concepts, and at learning from the experience of taking part in this research. These teachers, at least, seemed very open to working in a collaborative way to learn more about how conceptual change can be promoted. There may be many reasons why practitioners are not up-to-date on the latest educational research, including the fact that they are often busy teaching. Given that conceptual change literature is often incoherent (section 2.2), is it reasonable to expect practitioners trained in the natural sciences to understand what they should take from this field where social science, natural science, philosophy and psychology all intertwine? Judging internal consistency and clarity are learning methods used by natural scientists for assessing if a theory is any good, according to Darden (1991, p.245). There are no tested, clear and generally acknowledged theories of conceptual change (diSessa 2006, p.266). Stored knowledge actively affects both perceptions (Gregory, 1987, p.601) and conceptions (Murphy, 2002, p.141). The concepts we have influence the way we construct new ideas. Each participant (whether pupil, teacher or researcher) brings unique prior knowledge which may influence how their ideas change. Hence there is inherent uncertainty in any conceptual change study as to both what brought about learning, and what exactly happened in the mind of participants.

The combination of the imprecise nature of concepts, the difficulty in knowing exactly what someone else knows and the fact that ideas are continuously changing, means that instructional strategy is not an exact science. Humans can be extremely imaginative in synthesizing seemingly contradictory ideas. Researchers will never be able to predict every contortion of a child's mind. The idea that scientists, whether old or

young, use reasoning methods to develop new ideas, assess theories and resolve anomalies is controversial and several philosophers of science have argued that a logic of discovery is not possible according to Darden, 1991 (Lakatos 1970, T. Kuhn 1962 and Laudan 1977 – see Chapter 2).

There is no widely agreed definition of instructional strategy within the teaching profession or educational research (compare for example Forsyth, Jolliffe and Stevens, 1999; with Rowan, 2010). Knowledge-as-theory conceptual change research suggests that modifying a learner's framework theory can change naïve concepts which form part of the framework. Knowledge-as-elements theorists argue that naïve concepts must each be changed in such a way that they can be connected to a framework. Hence elemental perspectives tend to suggest a bottom-up approach rather than a top-down approach. (Özdemir and Clark, 2007, p.356). One researcher (Parnafes, 2007), from a knowledge-as-elements perspective, recommends the use of multiple computational representations in different contexts to allow gradual conceptual reorganisation, which in this present study would be described as the technique of 'use an activity', not a strategy. In contrast Chinn and Brewer (1993, p. 31) from the knowledge-as-theory perspectives support the use of conceptual conflict instructional strategies, which would be described as tactical behaviour in this present study. Hence arguing that teachers should be made more aware of the important discoveries of conceptual change research (Duit *et al.*, 2008, p.629) is all very well, but what exactly are they?

Some practitioners may be choosing not to say to researchers what they actually think. The ubiquity of tactical and strategic failure ('strategic friction') and deception (Whaley, 1982, p.182) led to these being considered as significant themes during this study (sections 4.2.6 and 4.6). The ability to manage the failure of instructional strategy appears from these data to be an essential classroom skill. Disaster in the classroom is

often embarrassing, and a reluctance to talk about it natural. Deception will always be difficult to investigate, especially when it is done well.

The methodology for this present study incorporates the interpretations of these important experiences by participants into the analysis of instruction. Many UK science teachers may be simply unaware of contemporary conceptual change research, especially when their training may have taken place during the misconception movement before conceptual change was even discussed. Given that it may take three years of full time study to build an understanding of this complicated field, perhaps it should not come as a surprise that practitioners are not all *au fait* with the debates among conceptual change researchers. In addition, the resistance of practitioners to change can be understood, at least to some extent, by a struggle where teachers try to express and assert an intuitive understanding of instructional strategy. Intuitive practice, including the consciousness of misunderstanding which develops with experience in the classroom, should not be underestimated by researchers. Indeed better interpretation, according to Schleiermacher (Mangion, 2011, p.151) should assume misunderstanding. Hermeneutics or, “the art of avoiding misunderstandings” (cited in Gadamer, 1975, p.164) should accept that misunderstanding is normal. One should, according to Schleiermacher, address both the shared aspects of language use (grammatical interpretation) and individual habits (technical interpretation), and there is no rule for how to do this. The evolution of the consciousness of misunderstanding during a teaching career could be understood better by researchers. Interpretative educational research works with participants who may already be fine interpreters. But practitioners may not know how to put into words all that they do. In the RD interview participants were asked directly how they helped pupils who expressed naïve concepts:

1c:26 *JR (researcher): ...a naive scientific concept has been defined as non-scientist's everyday understandings of certain bodies of information, it is not meant in any way pejoratively. How do you usually help students who have naive scientific concepts or ideas?*

1c:27 **TU (teacher): [pause] So non-scientific everyday understandings. Well I usually start with, 'What do you understand? What have you heard? Shall we explore it? Shall we do the practicals? Shall we talk about it and see if what these people say, in everyday parlance, is fact or not or can we pr... [stops saying prove?] support those statements or not.' So that's how I would approach that.**

This passage was interpreted as using the techniques of clarify and 'use an activity'. However, when analysing these data this participant appeared to be using a much wider range of techniques than she acknowledges in this answer (section 4.3). Experienced participants in this present study may not know the full range of techniques they use, even after they have been watching clips of themselves using some of these techniques in sophisticated ways. A concert violinist does not need to know the physics of their instrument to play well. Is a teacher's job to teach, or express how they do it?

Might the perceptions by teachers of the research community influence what the former is prepared to tell the latter? Conceptual change researchers, especially with international reputations, can be a little frightening for classroom teachers in my experience. Conceptual change researchers exploring strategy need to be conscious of their perceived status, and the potential impact this may have on the data, when interacting with teachers. Actual and potential researcher effects on the data collection, analysis, and theory generation during this present study were discussed in section 6.2. Might exasperation on the part of researchers mask a feeling of powerlessness to change classroom practice as they would like? It is clearly difficult to promote conceptual change among pupils, and within the teaching profession. The desire, and necessity, by

researchers in the UK at least, to have “impact” (HEFCE, 2011) may influence how we present our findings. The wish among teachers, researchers and policy makers for simple answers to the question of how to promote conceptual change may be strong, and could be partly responsible for the tendency of researchers to argue that a strategy is just a plan (section 2.5). As a teacher and conceptual change researcher, I agree with Duit (2003 - quoted above) that practitioners, and thence pupils, could benefit from knowing more about research in this field (though some ideas could do with being translated into language more accessible to non-specialists). However, close collaboration between teachers and researchers using methodologies which acknowledge the relationships between conceptual change, learning methods and instructional strategy, might be more effective in bringing about change in the classroom than more publications.

As mentioned earlier (section 2.2) Piaget began the interest in children’s ideas which is now known as ‘conceptual change’ research. Traditional epistemology saw knowledge as ‘justified, true belief’ (from Plato’s *Theaetetus*). Piaget argued that concepts evolve and that studying the growth of human understanding may be more useful than attempting to establish unchanging principles (Gruber and Vonèche, 1977). He called this ‘genetic epistemology’, and it engendered the misconception movement and conceptual change research within science education, developmental psychology and experimental psychology. In a similar way, perhaps research into strategies for conceptual change can be made more meaningful to teachers if researchers refocused on the growth of pedagogic understanding, rather than seeking simple answers to the question of how to deal with children’s naïve scientific concepts.

6.4 How were differences in interpretation between participants managed?

Pupils, teachers and myself as researcher took part in this study, and these participants frequently appeared to agree with each other's interpretations. Through the use of Grounded Theory Methods (section 3.11) some of these ideas became eventually part of the grounded theory (chapter 4). I agreed with the vast majority of what the teachers said in the VP and RD interviews. For example in the following passage from a VP interview the teacher comments that:

4b:14 TX: [...] they're interchanging temperature and heat.
Which is a common misconception - all the way up to
Years 10 and 11.

Research supports this view that heat and temperature are difficult for children to distinguish (Driver, 1994, p. 139). Where researcher, teacher and pupil apparently agree that some idea expressed by the pupil is 'correct', the passage was coded as a 'scientific concept' (this was used 646 times during the coding of all the interviews - see section 4.0). Finally pupils frequently agreed with each other:

5a:89 DF: I kind of agree with what AC said.

Sometimes a point was made by only one of the six teachers, more often a group of the teachers would have the same idea, and frequently all six teachers expressed the same thought. For example 'unclarified' was coded only once in one interview (and so was not used in the grounded theory), 'timing' was coded 56 times and emerged as a technique in 13 out of the 18 interviews, whereas the technique 'redirect' was coded 953 times from all 18 interviews. Hence the teachers often appeared to express similar views to each other.

Of course participants frequently disagreed with each other. So teachers clashed with pupils, and pupils argued with each other. Such disputes were termed ‘conceptual conflict’ (section 4.1):

6a:442 KG: I'm not sure about water. I don't think water is [living] because - the organisms in water might be living -

JP: Yes [JP is disagreeing with KG]. Because every life form begins with water.

6a:443 KG: But that -

6a:444 **TZ: The fact that [TZ holds up the card for water] - the fact that every life form gets - or has some connection with water. Does that make water living?**

6a:445 KG: No.

JP: No.

Here one pupil (JP) disagrees with another (KG), whilst the teacher (**TZ**) agrees with KG that water itself is non-living and disagrees with JP’s naïve concept. Teachers were asked in the RD interviews what they would do if a student disagrees with them (for example 3c:36). The responses often became part of the grounded theory. For example:

2c:25 JR: [...] If a student disagrees with you, how do you persuade them?

2c:26 **TV: Oh, that's a good one. If a student disagrees with me then I get other people to voice out their opinions. [...] there have been situations like that where actually that happened. And there was one student who actually was convinced that - because he knows he is very bright - but he got the basics wrong. And he was talking from personal experience. And I said, 'OK, do we have other people who agree with this?' So I tried to get the classroom involved.**

This example was interpreted as the technique of ‘persuasion’ (the use of the audience - see section 4.2.9). The methodology was not designed to investigate conceptual conflict between teachers and researchers. As the researcher, on just one or two occasions, I disagreed with something one of the teachers said. For example one teacher said:

2a:143 **TV: [...] Is there anything that you would change then as we are going through?**

2a:144 SF: I've changed the clock! [she laughs as she says this]

2a:145 **TV: OK, you've changed the clock. It moves, but it doesn't respire. It doesn't produce energy.**

Because of the principle of conservation of energy, I am uncomfortable with the idea that respiration means that energy is ‘produced’ (see also 2a:139). The inevitability of misinterpretation and misunderstanding in a study like this were discussed earlier (sections 2.2), and I am very conscious that other science teachers might have no problem with this definition. There is an inherent asymmetry between researcher and other participants in the methodology for this study, as the teacher and pupils did not have access to my interpretations until near the end of the study in order to agree or disagree with me. Very occasionally there were suggestions of where participant teachers might not be agreeing with my interpretations. For example in the following example I attempted to redirect the teacher during a VP interview into considering the idea, expressed by EM in 1a:89, that “the coldness of the ice will go into your body”.

1b:10 **TU: [Whilst clip 2 is playing TU says "will make you feel warmer."] But she is talking about feelings not actual temperatures. So she is muddling up two things, two concepts and I didn't notice it at all the first time I watched that clip. Interesting isn't it.**

JR: There is a bit at the end of that one where she talks about the coldness of the ice cubes going into her.

TU: But it is the feeling of it. I didn't even hear that last bit. I think I'm concentrating more on what she is saying earlier and the conflict between how she says it makes her feel warmer inside, not necessarily that the body temperature has risen.

Here the teacher TU and I appear to be concentrating on different aspects of the same passage, and the teacher resists my attempted 'clarification'. There might well be elements of this huge data set which I missed when doing the analysis, which the participating teachers had seen during the VP interview. For example in hindsight, in the light of insights from the sociocultural approach discussed earlier (section 2.2; Smardon, 2008, p. 364), I wish I had considered gestures, proxemics, gaze direction and rhythm more thoroughly in this study as the following example illustrates:

1b:17 **TU: [...] [CS] is using her hands to say [the air] is moving [...] Using a lot of body posturing to reinforce and support her thinking.**

Therefore, whilst it seems reasonable to assume that participating teachers and I would agree with most of each other's interpretations of this rich data set, it is highly likely that some of my interpretations were different from those which other participants would have given. Some ways in which participating teachers and pupils attempted to influence each other were investigated in this study, but a different methodology would be necessary to explore how researchers and teachers attempt to influence or change each other's concepts. This thesis argues that the grounded theory methodology, combined with the research methods developed for this study, offer a way to incorporate critically a number of interpretations into one grounded theory.

6.5 Summary

This chapter explored how the researcher affected the data collection, data analysis and theory generation during this study (section 6.1). The trustworthiness of the

findings was investigated in section 6.2 before the issue of how researchers and teachers perceive each other was considered (section 6.3). How differences in interpretation between participants was managed was discussed in section 6.4. This thesis concludes by evaluating the understanding which it aimed to build from careful observation and by using the interpretations of participants.

Chapter 7: Conclusions

7.0 Introduction

The key findings of this study will be outlined and the contribution of the thesis to the conceptual change research community and classroom teachers described (section 7.1). A summary of the limitations follows in section 7.2. The extent to which this study answers the research questions will be discussed (section 7.3) and the thesis will be evaluated (section 7.4). The military metaphor, which emerged during this study (section 4.1) may be controversial for some readers, and this view will be explored in section 7.5. How this present study relates to other approaches to investigating classroom talk will be discussed in section 7.6 and a wider political context will be mentioned briefly in section 7.7. The study finishes with suggestions for future work in section 7.8.

7.1 Originality of the thesis and summary of key findings

Ways in which doctoral work can be original were identified by Wellington (2012, p. 7). Her framework will now be used to describe the originality of this present study before the key findings are summarised. Firstly, a grounded theory study of conceptual change pedagogy in school science from an interpretivist theoretical perspective (symbolic interactionism), and using a constructionist epistemology (social constructionism), would appear from my investigations to be unique. Secondly, expert micro-teaching (EMT) was developed as a research method for this present study. In

addition Taylor and Dionne (2000) claim that combining verbal protocols (VPs) and retrospective debriefing (RD) is “uncommon” in the research literature. Therefore the research method of combined EMT with VPs and RD constitutes an original approach. Thirdly the synthesis of a Clausewitzian understanding of strategy with the integrated approach to conceptual change is new. The grounded theory which emerged from this methodology, though consistent with the integrated approach to conceptual change (see sections 2.6 and 5.1), does not support the idea of instructional strategy being merely a plan for a teacher to implement. That view of strategy is prevalent in conceptual change literature (section 2.5). Finally the “gap” (Duit *et al.*, 2008, p.629) between theory and practice is a recurrent issue in the literature (for example Driver and Erickson, 1983; Scott, Asoko and Driver, 1991; Sinatra, 2005). This thesis contributes a new grounded theory for conceptual change pedagogy to this debate, which emerged through collaboration between pupils, a group of experienced science teachers, and myself as both an educational researcher and practising science teacher.

The key findings are that techniques, tactics and strategy are interrelated and together can be understood to constitute conceptual change pedagogy (Chapters 4 and 5). These three elements represent different levels at which practice may be analysed. Hence in this study, tactics are demonstrated in the way that eleven instructional techniques were used during ‘conceptual conflict’ (chapter 4 - part 1), and strategy describes how conceptual conflicts are managed so as to try and achieve conceptual change (chapter 4 - part 2). Similarities between some of the techniques identified and the findings of other studies exploring classroom practice were acknowledged in section 6.2.2. The pedagogical aim investigated in this thesis is conceptual change, but teachers and pupils had many other aims which they expressed on occasion, or which were interpreted as underpinning their behaviour.

Strategic friction can occur at each of the levels of technique, tactic and strategy (section 4.6). The enacted curriculum rarely corresponds to that intended (Gehrke, Knapp and Sirotnik, 1992, p. 55), so tactics and strategy must be dynamic; responding to circumstance. In social interactions like the EMT, VP and RD interviews participants do not always get what they want. Hence strategic friction sometimes resulted in a change of strategy leading to different tactics being employed. Poor strategy, such as stubborn resistance to necessary change or unnecessary accommodation of an unreasonable belligerent, can itself cause strategic friction. Pedagogy involves the techniques, tactics and strategy of the leader and the led. The complicated interacting intentions of participants which constitutes strategy will always be harder to identify than techniques, or their tactical use.

No suggestion is made that participants themselves would consciously separate out what they do using the typology of techniques, tactics and strategy as they teach, even if they had time. However this framework could help dialogue between conceptual change researchers and teachers (section 6.3), could help experienced practitioners understand their own practice better, and also could be useful in initial teacher education.

7.2 A summary of the limitations of this study

The following is a summary of the major limitations of this present study which have all been discussed in depth earlier in the text (in particular in sections 3.10, 6.1 and 6.2):

1. The expert microteaching (EMT) research method used for this study was a necessary compromise (section 3.4), but is a different context to a 'typical' science lesson, and this is acknowledged as a limitation. Only six teachers and thirty-six pupils

participated in the study, which influences the generalizability of findings (see section 6.2.2).

2. Combining expert microteaching (EMT) with verbal protocol (VP) and retrospective debriefing (RD) interviews, provides some insight into the way participants understand their own practice, but obviously cannot tell us what someone is actually thinking.
3. Because of the focus of this study, and inherent time constraints in such a project, VP and RD interviews were not conducted with pupils. This represents a significant limitation as interpretations of pupil talk could not be triangulated in the same way as the teacher talk (sections 3.10 and 6.2.1).
4. As the VP and RD interview with each teacher took place between two and four weeks after the EMT interview this may be a limiting factor on the trustworthiness of the data. Participant teachers may have forgotten how they understood an incident at the time, may remember incorrectly, could be combining new interpretations with memories, might be offering a completely new understanding, may not wish to share a memory or a new understanding etc. During VP and RD interviews participants said many times that they had not noticed particular events at the time of the EMT interview. Clearly they may have forgotten, but other interpretations of such comments are possible. Experiences in the intervening time, and time to reflect, might influence how someone interprets EMT incidents. This may be beneficial in enabling new insights to be developed (Schön, 1983). It was argued in section 6.1.1, when this issue was discussed, that there may be some advantages with the delay beyond the researcher having time to analyse the EMT data. The positive opportunities for deep learning through reflection are advocated by Schön (1983) and Eraut (1995).

Altogether, I do recognise the time delay as having a notable influence on the data and interpretation of events.

5. Though this study holds that the findings represent a credible interpretation of these data (section 6.2.1), it is not possible to know that the interpretation of any event during such complicated, possibly even complex, social interactions is precise, accurate and complete. Deception (as defined by Whaley, 1982) emerged as a category within the grounded theory (section 4.2.6), which necessarily has implications for the credibility of the findings of this, or any other, study of conceptual change pedagogy (section 6.2.1).
6. Some transfer of the findings of this present study to other contexts is possible (see section 6.2.2 for a full discussion), but strategy involves the collision of often competing aims, and the thesis has challenged vigorously those who offer simple solutions to the pedagogical challenges exemplified in these data.
7. The many ways in which I have, or may have, influenced these data were discussed in depth in section 6.1. A researcher having no effect on such complicated social interactions would be impossible, but it might be possible to have less impact.
8. Grounded theory methods were used carefully, but with about fifteen hours of video analysed I acknowledge that some mistakes in coding are likely (section 6.2.3).
9. Evidence was presented to show how these data support the findings (called ‘confirmability’ by Lincoln and Guba, 1985) and a complete ‘audit trail’ is available in the NVivo file. Some findings were supported by more data than others (see section 4.2.9 and 6.2.3).

In spite of these limitations, the thesis argues that the grounded theory presented in chapter 4 is a “plausible explanatory framework” (Corbin and Strauss, 2008, p. 264) for the conceptual change pedagogy which the six participating science teachers

demonstrated during the expert microteaching sessions. Teaching children who express naïve scientific concepts, and investigating conceptual change pedagogy, are never going to be simple matters.

7.3 Does this study answer the research questions?

To what extent do the grounded theory (Chapter 4), and the exploration of the interrelations between conceptual change, teaching techniques and learning methods (Chapter 5), answer the research questions? This study argues that there are no simple answers to the question of how to promote conceptual change in school science. Patterns which emerge on a small scale which indicate relations between particular teaching techniques and conceptual change, or certain learning methods and conceptual change, (section 5.2) must be understood in the context of the tactical and strategic behaviour of participants (section 4.4). What works in one lesson or with one pupil will not necessarily work in another. It will not always be possible to predict this in advance (section 4.6). Hence the answer to the first research question of how experienced science teachers interact with small groups of children, when the pupils express and discuss naïve scientific concepts is, “It often depends on the particular context”. However, observation of the practice of the experienced practitioners involved in this study suggests that they adapt to this unpredictable environment by using certain techniques more or less than others (section 4.3) in tactical and strategic ways (section 4.4). They are well aware that what they intend to do will sometimes fail and have become resilient to this reality (section 4.6). This middle way between teaching as a recipe and teaching as instructional despair has been termed ‘Clausewitzian strategy’ in this study. It echoes a similar debate which has long raged among military strategists (section 2.5). This study attempts to incorporate the interpretations by participant teachers of complicated classroom

interactions into the analysis such that, it is hoped, the grounded theory which emerged in Chapter 4 may reflect something of their experiences in real classrooms. Meanwhile this study also tries to engage with the conceptual change research community. Here it is argued that care needs to be taken within the research community about how the word strategy is used if the gap between theory and practice is to be addressed (Duit *et al.*, 2008). The word strategy is used by both teachers and researchers to refer to a plan, but bearing in mind the etymology of the word, good generals are not just people who make plans. The following quotation would be equally apposite if the word war were replaced by the word education:

War is not an exercise of the will directed at inanimate matter, as is the case with the mechanical arts, or at matter which is animate but passive and yielding, as is the case with the human mind and emotions in the fine arts. In war [and education], the will is directed at an animate object that reacts. It must be obvious that the intellectual codification used in the arts and sciences is inappropriate to such an activity. At the same time it is clear that continual striving after laws analogous to those appropriate to the realm of inanimate matter was bound to lead to one mistake after another. (Clausewitz, 1832, p.149)

In a similar way this thesis argues that current research into instructional strategy for conceptual change does not sufficiently acknowledge the sophisticated ways in which teachers and pupils react to what each other does. A suitable interpretivist methodology was used (Chapter 3), and it has been argued that a positivist theoretical perspective is not appropriate for the investigation of instructional tactics and strategy as these terms are understood in this study (sections 2.5 and 4.4).

This Clausewitzian interpretation of strategy leads to the question of whether strategists are taught or born. Again this issue has been much discussed among military strategists:

Strategic genius is rare, strategic talent is more common, though still unusual. The latter can be improved by formal education, the former most probably cannot. However, there is merit in the educational aspiration to help educate instinct for a better performance ... [B]ecause strategy is a pragmatic creative activity, the strategist – well-educated or not in a formal sense – ideally has to know what to do, how to do it, and, last but not least, he/she needs to be able to do it. Obviously, biology and psychology shaped by the opportunities granted by experience loom large here. Professors of Strategy cannot so teach their military students that they are truly fit for purpose as strategists-in-action. But professors can help educate the strategic judgement of those soldiers and civilians who are educable (Gray, 2009, v).

How to nurture strategic genius is beyond the scope of this thesis. However, I think a partnership in education between ‘strategists-in-action’ and ‘professors of strategy’ is necessary. But I find it telling that there are no results in a Google search for ‘Professor of Instructional Strategy’ or ‘Professor of Educational Strategy’.

Does Chapter 4 represent a substantive theory or formal theory (section 3.3)? If a substantive theory reaches ‘theoretical saturation’ (see section 3.11) it is called a formal theory by grounded theorists. A formal theory explains a phenomenon in a wider context (Glaser and Strauss, 1967, p. 31). It was argued earlier (section 3.1), that the research methods in this current study are a necessary compromise between naturalistic observation and laboratory study. The detailed observations needed to address the research questions could be masked by whole class effects, but observing a teacher at work with a pupil in laboratory conditions would remove the complicated social context within which learning takes place. Evidence of children experiencing conceptual change would be rare during a normal science lesson, whereas the research methods used here led to 157 instances being identified with 602 naïve concepts expressed and discussed (over all 18 interviews). The compromises in this study, necessary because of the focus of this research, mean that it must not be assumed that this grounded theory transfers in a simple

way to a normal science classroom. A further study could test the grounded theory in a more natural environment. Hence conclusions here remain at the level of substantive theory rather than formal theory. Transferability of the results was discussed in section 6.2.

7.4 Is understanding techniques, tactics and strategy for conceptual change of value?

Participants in this research (pupils, teachers and researcher) have different understandings of the part of the data set they experienced. In addition, the understandings of participants changed as the study progressed, so even for an individual participant it may be necessary to distinguish different understandings. This study attempts to articulate the different understandings of conceptual change strategy that six experts appear to have, and explores patterns across these understandings.

Whereas it is awkward to speak of degrees of knowledge or of some knowledge being better or worse than other knowledge, understanding comes in these forms. Some people have a better understanding of a subject matter than others, and others have a greater degree of understanding. (Kvanvig, 2003, p.196)

There are two bases on which to explain this relative understanding:

First, justification itself comes in degrees, so two bodies of information regarding the same subject matter might differ in the degree of coherence they display. Second, the two bodies of information might differ in terms of the amount of information contained regarding the subject matter. In both of these ways, understanding can be a matter of degree, and in that way understanding is different from knowledge and from truth. (Kvanvig, 2003, p.196)

Hence the understanding of one participant demonstrated in the EMT interview and described in the VP and RD interviews, may be more coherent for one teacher than for another. In addition some participants will be using a larger pool of instructional information (techniques) than others. The convenient title of ‘Advanced Skill Teacher’

hides a huge diversity of experience among these participants. A smaller body of information may of course be used more effectively than a larger body, but the converse could also be true. As science teachers must teach biology, chemistry and physics, they teach sometimes outside their subject specialism, so are often more confident in one subject than another:

1c:28 **TU (teacher): ... I don't think it is just non-scientists [who have naive scientific concepts], ... if you're not a specialist in that particular field of science ... I think there are lots of physics concepts that I would describe myself as ... a non-scientist. And yet, you know, chemistry things I'm quite happy with.**

Four options are available: a large body of coherent information, a small but coherent content, a large body with less coherence and finally a large incoherent body of information. The strategic profile of the teachers in this study gives a glimpse of the range of teaching techniques each uses in this context and how they use them. Verbal protocol and retrospective debriefing interviews gave some insights into the amount of strategic 'informational items' each participant was aware they used and how coherent the understanding might be in their minds. For example:

1c:22 **TU (teacher): JB was so adamant that it wasn't a living thing. That it was a dead thing. I don't think I really anticipated that. I think I had an unwritten assumption that he would know that the vast majority of foodstuffs would have been alive at one stage or other [TU shrugs - JP does as well afterwards]. And it just hadn't really occurred to me that he wouldn't get it eventually.**

The changing understandings of participants (pupils, teachers and researcher) occurred on three levels. The first is during each interview (expert micro-teaching, verbal protocol and retrospective debriefing). Most of the time teachers, pupils and researchers are probably not aware of what learning has actually occurred in the minds of other participants, or

perhaps even in our own minds. A second level where changing understanding can be seen in these data was during the repetition of the set of interviews (EMT, VP and RD) six times with different teachers and pupils. Though the same procedure was used in each set of interviews, I became more confident in what I was doing as the study progressed and began to use the prior knowledge built up during the first interviews to modify elements of the later ones. This is recognisable as the grounded theory method of theoretical sensitivity (see section 3.11). I did not, and believe I could not, analyse the last interview in exactly the same way as the first was scrutinized. Some of the changes to the way the grounded theory methods were used were recorded in the software which helped manage this huge data set (NVivo 9), but only the tip of the iceberg can be glimpsed of the changing conceptions of all participants inherent in a complicated context like this. Finally, this study builds on a long tradition of research into children's ideas in science, reasoning methods in the natural sciences, naïve reasoning methods and pedagogy. Preparatory work, data collection, data analysis, writing up and even the reading of this thesis, extend this history to the present. This historical context influences the complicated interactions between participants captured in these data. Knowledge and understanding are both valuable (Kvanvig, 2003, p.204), but:

[U]nderstanding requires, and knowledge does not, an internal grasping or appreciation of how the various elements of a body of information are related to each in terms of explanatory, logical, probabilistic and other kinds of relations... (Kvanvig, 2003, p.192)

Different types of relations (such as competing explanations and logical arguments) can be seen in these data (see for example 1a:159-173 and 1a:196). Understanding is the grasping of coherence-making relationships and involves piecing together informational items (see section 5.0). The topics discussed (heating and cooling, living and non-living, and seeing) represent three large and comprehensive bodies of information. The

pedagogical findings (Chapters 4 and 5) constitute yet another information set.

Understanding is valuable:

it is constituted in subjectively justified true belief across an appropriately individuated body of information that is systematized and organized in the process of achieving understanding, and subjectively justified true belief that is systematized in this way is valuable. (Kvanvig, 2003, p. 202)

Children and their teachers react to each other, so the understandings of teacher and pupil change as concepts, and the relations between these concepts, are modified during this interaction. The understandings of participants in this study of conceptual change strategy are sometimes different, and vary in both coherence and depth. The methodology, designed for this study, allows these differences to be described. The understandings of participants, including myself, change on a number of different levels such as within each interview, between interviews and throughout the study. Expressing the understandings of experienced practitioners, and the meta-understanding which the grounded theory (Chapters 4 and 5) represents, may be helpful for trainee teachers, in the Continued Professional Development of experienced practitioners and in the dialogue with other conceptual change researchers. Simple deterministic rules for relationships between conceptual change, learning and teaching techniques are inadequate.

7.5 Is it appropriate to use a military metaphor for pedagogy?

The military metaphor for conceptual change strategy was first used by participants in this study (section 4.1) and then incorporated into the analysis; a process described as theoretical integration by grounded theorists (section 3.11). Other metaphors for communication are possible according to Krippendorff (1993), but he argues that a war metaphor works best when there is something to gain or lose in an exchange (see also Lakoff and Johnson, 1980, p. 4). One aim in teaching is to promote conceptual change,

and pupils sometimes do lose naïve concepts and gain scientific ones (and vice versa). So this military language may occasionally be appropriate. Obviously the military metaphor must not be taken too far (see section 2.5).

[Metaphors] carry explanatory structures from a familiar domain of experiences into another domain in need of understanding or restructuring. (Krippendorff, 1993)

Each section of the grounded theory began with data to try to illustrate these ideas for the reader before using the metaphor to aid understanding and to promote restructuring of this complicated domain of experiences.

[Metaphors] must be made use of to illustrate ideas that we already have, not to paint those which we yet have not. (Locke, 1801)

Some would suggest that conceptual change is largely a matter of reaching consensus (Meyer and Woodruff, 1997) and I acknowledge that pupils and teachers sometimes do seek agreement. But this does not describe well the ‘conceptual conflicts’ which occurred very frequently when pupils and a teacher talked about naïve concepts in this present study (section 4.1).

The military strategy metaphor for conceptual change has therefore been used strategically in this work to attempt to promote conceptual change. I quite consciously aim to influence how conceptual change is understood by teachers and the conceptual change research community through this work. Even if the reader is unconvinced by the value of this metaphor in this context (strategic friction – section 4.6), the categories within the grounded theory of techniques, tactics and strategy can stand alone. Explanatory structures from alternative domains like business strategy or game theory could have been used in this study, but I felt the former has learnt so much from debates within military strategy that it was better to use the original arguments, and the latter is

dominated by an objectivist epistemology which we have argued is unsuitable here (Chapter 3).

7.6 How does this thesis relate to other ways of examining classroom talk?

Classroom talk in secondary school science lessons has already been explored extensively (for example see Mortimer and Scott, 2003 or Evagorou and Osborne, 2010, p. 135). This thesis argues that the scale of analysis at which a solution to a problem may be found, varies according to the question being explored. In her analysis of the reasoning methods used by professional scientists, Darden (1991, p. 244) notes that a “move to another level of organisation” can help produce new ideas. For example, to answer how the Earth and Sun influence the movement of each other, physicists have discovered that all one needs to know is the mass of each body, the distance between their centres and a number. What constitutes each celestial body is irrelevant. However, to know why the sun shines, the interactions on a tiny scale between nuclei within the sun must be understood (nuclear fusion). In a similar way, in this study it is acknowledged that fine scale discourse analysis of teacher-pupil talk is necessary to answer some pedagogical questions (for example Lemke’s, 1990, thematic pattern diagrams), but argues that the question of how teachers promote conceptual change can only be resolved at the interacting scales of techniques, tactics and strategies.

7.7 Politicians, educational researchers and teachers

What physicists call the ‘three body problem’ has been used, by someone from the world of politics, to model the relationships between politicians, researchers and practitioners (Coles, 2009). Coles argues that these ‘worlds’ are in constant motion such that effective communication is rare, but occasionally the planets align. The gulf between

research and practice (Duit *et al.*, 2008, p.629 - section 3.0) may be understood as one of three gaps in education. The other two are between research and policy, and between policy and practice. It has been argued that politicians in charge of educational policy in the UK do not always listen to educational researchers (Alexander, 2004). In addition practitioners and their political leaders here sometimes have a frosty relationship (Ball, 2005, p. 17). This present study has had much to say about the gap between research and practice, but now turns briefly to these 'other gaps' and to what, if anything, this present study might contribute on the scale of what Clausewitz called grand strategy. Clausewitz famously defined war as the continuation of politics by other means (Clausewitz, 1832, p.119), so the metaphor for conceptual conflict (section 4.1) which emerged during this study might suggest an intimate relation between the politics of education and instructional strategy.

This present study argues that the grounded theory for instructional strategy which emerged from what experienced teachers actually appear to do in classrooms may be more useful for teachers, and for educational researchers, than one which is used because it has some ostensibly logical structure. The theory also has implications for policy makers as it may provide a framework for dialogue. Policy could encourage teachers to use techniques which researchers have established as being the most effective (for example Hattie, 2008), but the ways in which practitioners use techniques tactically and strategically cannot be proscribed by researchers or politicians. Politicians might note that this study suggests that it is unrealistic to think that trainee teachers can analyse and understand complicated classroom dynamics, such as those explored in this thesis, without the support and guidance of educational researchers. This has implications for current UK government policy of reducing the input from researchers into Initial Teacher Training (for example School Direct, 2013). Even the experienced Advanced Skills

Teachers who participated in this present study, whilst watching video clips of their own practice, did not always describe all that they were doing (section 6.3).

7.8 Suggestions for future work

What is the most appropriate methodology for the investigation of instructional strategy? Several aspects of this question have been discussed at length already in this thesis. For example it was argued that a constructionist rather than an objectivist epistemology was more appropriate, an interpretivist theoretical perspective was necessary to rebalance dominance by positivist literature and that a grounded theory methodology can be more fruitful in a field where the scientific background of many researchers might account for the preponderance of the use of experimental methods (sections 3.1 and 3.2). As regards where to go next methodologically, the research questions in this present study led to the teacher and researcher interpretations receiving more weighting than those of participant pupils. In other work I explore a variation on the methodology used in this study where both teacher and researcher give verbal protocols, and the retrospective debriefing of a teacher by a researcher becomes a retrospective conversation between researcher and teacher. A future study could involve pupils, teacher and researcher all producing verbal protocols, followed by a group interview. This may necessitate an even smaller sample size than was used in this present study, but could provide even richer data about the interplay of the tactics and strategies of participants.

Methodological constraints meant the grounded theory which emerged during this study remained a substantive rather than a formal theory (sections 3.3, 3.11 and 7.3). A formal theory for conceptual change strategy could be developed if a team of researchers worked with a group of teachers using the methodology developed here. Researchers would analyse each other's EMT, VP and RD interviews allowing inter-coder checks

which would improve the trustworthiness of the data (section 6.2). A smaller scale, but less satisfactory option would be for a team of researchers to re-analyse the video data collected for this present study. The relationship between researchers and participants, and the opportunity for the researcher to participate in the EMT interviews, would be missing with this approach.

It was argued here that this detailed qualitative methodology was necessary in order to build understanding of the nature of instructional strategy. Elements of the grounded theory which emerged (for example particular techniques) could now be tested, using other methods, to explore how effective they are in promoting conceptual change. Indeed a mixed methods approach to the investigation of instructional strategy could increase the trustworthiness of the qualitative data. However, the tactical and strategic ways in which instructional techniques are used, and the unpredictability inherent in teaching (described here using the concept of strategic friction) mean any finding that one technique appears to be more effective than another, though useful to know, can never be definitive.

The present study only looked at instructional strategy used when naïve concepts about heat, living and non-living, and vision were discussed. There are many other areas of science where children have naïve ideas, and these could be investigated using this research design. Conceptual change researchers have found that thinking appears to be substantially different in scientific domains like biology, physics and chemistry (section 2.2). This present study acknowledged this by selecting a topic to discuss from each traditional domain, and by working with practitioners who specialised in all three areas. However findings about instructional strategy in one particular topic (for example living and non-living) may not generalise over other topics within a domain. Hence further work could investigate a range of topics within a particular domain.

The field of conceptual change research includes the work of psychologists, practitioners, philosophers, educational researchers etc. I am very conscious that in writing this thesis I have had to speak about many things in which I am not a specialist. For example the discoveries of children's naïve learning methods were made by psychologists (for example Zimmerman, 2005; see sections 2.3 and 4.2.4). Future work on instructional strategy would ideally involve an interdisciplinary team.

Pupils of age 11 or 12 participated in this study. Future work could ask if instructional strategy varies with the age of pupils. This present study offered a snap-shot describing the practice of a group of experienced science teachers. A longitudinal study could track the evolution of the strategic profiles of a group of teachers from Initial Teacher Training to retirement.

The strategic profiles of participants in this study may be useful to novice and expert practitioners (section 4.3). Now that the teaching and learning techniques in section 4.2 have been outlined, it would be possible to recode all these data in order to provide a more accurate strategic profile. Ideally this would be done by a team of researchers as discussed above. These profiles illustrate subtle differences in the pedagogy used by a group of experienced teachers while they promote conceptual change. Though techniques used in the classroom would probably depend on the subject matter taught, the school context and much else, comparing such profiles could still be instructive.

On occasion I have used published comments by some colleagues to represent theoretical positions I wished to discuss. I am conscious that such quotations can rarely sum up understanding in such a complicated field, and I would like to apologise to anyone offended by my generalisations. I look forward to engaging with colleagues over comments and criticisms of this present study.

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Appendices

Appendix A: Correspondence with teachers, pupils, parents or guardians, and the school

From: John-Paul Riordan [mailto:j.riordan173@canterbury.ac.uk]

Sent: 09 February 2011 09:42

To: [Name of the teacher]

Subject: Research Opportunity

Dear [Surname],

I'm writing to ask if you would be interested in working with me on some educational research. I'm doing a full-time PhD in science education at Canterbury Christ Church University. I taught science in mainstream schools for ten years and now teach science part-time in a special school (St Nicholas School in Canterbury). My research interest is in strategies for conceptual change in school science.

This research would involve two video recorded sessions of one hour each separated by a month, with no need of any preparation on your part. The first session would involve you running a one hour group interview with six pupils from Year 7 talking about three familiar science topics. I will make all necessary arrangements. For the second session I would like to interview you for one hour. Your responses and those of the students involved would be anonymous.

This work explores what used to be called 'misconceptions' in science and what students and teachers do about this. [Name of one of the participating teachers who has already completed all the interviews], who is a science AST at [School] has already done both interviews. She has kindly agreed to be contacted to share her experience if you'd like to hear what this involves from a participating science AST [email address of this teacher].

If you might be interested in taking part in this research, please contact me on either [mobile number] or jr173@canterbury.ac.uk. I'd be happy to come to your school for a short meeting to talk with you about the project in more depth and answer your questions if that would be helpful.

Yours sincerely,

John-Paul Riordan

jr173@canterbury.ac.uk

[mobile number]



Project: Science Ideas



Letter for participants

Hello,

My name is Mr Riordan. I'm studying for a PhD in Education at Canterbury Christ Church University. I want to learn more about science ideas and I'm writing to ask your help.

I would really like to interview you with TU in a group on video about

your science ideas. You don't have to prepare anything. You don't even have to be

good at science. Our talk would be private. I am working with some university

lecturers. I will not tell other people what you say. I may show

excerpts from the video to other academics and science teachers. I will change

your name in my report. You can ask the interview to stop at any time. It will

take no longer than one hour. You can say yes or no, it is up to you

whether you take part. If you would like to talk with us, I would be very



grateful if you would sign this letter and give it to me. If you would like to



know more about the project please just ask me (telephone 01227 472577



or email jr173@canterbury.ac.uk) or TU . Thanks for taking the

time to read this letter and for your help.

Yours sincerely,

Mr Riordan



I understand the interview will be **video recorded**.



I understand that the interview will be **private**.



I understand that **excerpts from the video** may be shown to other people.



I understand that I can **stop** the **interview** any time.

If you understand the statements above, you now need to decide whether you would like to take part in the project. Please tick **yes** or **no**.



No



Yes

Signed: Please print your **name:**

Please give this letter to us at the start of the interview.

School address
Date

Dear Parent/Guardian

Re: Project – Science Ideas

My name is Mr Riordan and I am a PhD research student at Canterbury Christ Church University. I also teach science at St. Nicholas School in Canterbury. I have been a science teacher for 13 years. I am doing a project about how science teachers support young people as they change their scientific ideas. I would really appreciate your help with this project by allowing Mrs D and me together to talk to your daughter or son about her/his ideas in science. Students don't need to prepare anything and I hope it will be interesting and useful for them.

We have planned to talk with a group of six students for up to an hour. I will video record the interview to help me remember what they have said and to help me write a report. However, the interview will be confidential and the only people who listen to the interview will be myself, Mrs D who is working with me on the project, my supervisors and my examiner, who will be checking my work. Short excerpts from the interview may be used in presentations to other academics and science teachers. No-one will be named in the report.

If you are happy for your son or daughter to take part, I would be very grateful if you could sign the attached form and return it to Mrs D or to the school office.

If you would like to know more about the project, please contact either me, Mrs D or the Head Teacher at the above addresses or at x .

Many thanks for taking the time to read this letter and for your help.

Yours sincerely,

Mr Riordan

I am happy to let my son/daughter* (print name).....take part in the project "Science Ideas".

- I agree that the interview can be video recorded.
- I understand that the interview will be confidential.
- I understand that short excerpts from the interviews may be used in presentations to academic and science teacher audiences.
- I understand that my daughter/son can stop the interview at any time.
- I understand that if my son/daughter does not want to take part, it will not affect him/her if help is needed in the future.

Signed..... (Parent/Guardian). Please print your name

Please return this form to Mrs D as soon as possible

Home Address

Telephone: x

Mobile: x

Email: x

School Address

Date

Dear [name of Head Teacher],

Re: Educational Research Project – Science Ideas

My name is Mr Riordan and I am a PhD research student at Canterbury Christ Church University. I also teach science at St. Nicholas School in Canterbury. I have been a science teacher for 13 years. I am doing a project about how science teachers support young people as they change their scientific ideas. I'm writing to ask your permission to do some educational research with Mrs D and a group of six Year 7 students from your school. Students don't need to prepare anything and I hope it will be interesting and useful for them.

We would like to talk with a group of six students for up to an hour. I will video record the interview to help me remember what they have said and to help me write a report. However, the interview will be confidential and the only people who listen to the interview will be myself, Mrs D who is working with me on the project, my supervisors and my examiner, who will be checking my work. Short excerpts from the interview may be used in presentations to other academics and science teachers. No-one will be named in the report. With your permission this first interview could take place on Friday 3rd December 2010. Early next year I would be coming to your school for a second time in order to interview Mrs D herself for one hour (this does not involve students). I have offered to return later to give either individual feedback to Mrs D on the results of my work, or to run an INSET session for any teachers who might be interested in this research.

If you are happy for this research to go ahead, I would be very grateful if you could let me know. If you would like to know more about the project, please feel free to contact me at the above addresses or at x . Letters to parents and to the students have been prepared and Mrs D has copies of these. If you would like me to forward you copies of these please just say.

Many thanks for taking the time to read this letter and for your help.

Yours sincerely,

Mr John-Paul Riordan

Appendix B: Questioning Routes for EMT, VP and RD interviews

Questioning Route for Interview 1a – EMT

This list of questions has been written to help you during the group interview. They are only meant to be a guide. Please feel free to follow the student's ideas within each question. Many thanks.

- Please try and get the students to talk about their science ideas. Also please feel free to teach them whenever you feel this is appropriate.
- The times are only a rough guide. But please make sure you get through questions 1 to 3 quickly.
- Please go round the table for answers to question 1 so that everybody speaks early on. Subsequent questions are open to anyone to answer.
- The most important questions are 4a, 4b and 4c.
- Questions 2 & 4d are optional extra questions to use if you have time.

Time	Question	Question
< 1 min	Intro.	e.g. "Thanks for doing this. We're going to talk together about ideas in science. This is not about getting 'the right' answer, but about exploring how we change our ideas. If you change your mind about any of the things we're talking about here that is fine. Please tell us during the interview about that experience."
< 3 min	1	Please tell us who you are and how you feel about science. [Go round the table so that each student answers this question please]
< 3 min	2	[Optional] What is the first thing that comes to mind when you hear the word 'science'?
< 3 min	3	Please tell us about any experiences you've had where you, or someone else, changed their mind about a science idea.
10 – 15 min	4a	[Put hot cup of tea and bowl of ice cubes on the table] Please tell me what is happening to the hot tea and the cold ice cube in as much detail as you can.
10 – 15 min	4b	[Give pack of 'cards' to each student with two mats – one for 'living' and one for 'non-living' – please also take one yourself but wait for students to do theirs first] Please sort these cards onto the spaces on the two mats quickly: one for living things and the other for non-living things. Try not to look at what your neighbours do as the idea is to explore the different ways in which we might understand the word 'living'. It is OK to have your own ideas on this and you can change your mind later if you want.
10 – 15 min	4c	[Put teddy bear and torch on the table. Give whiteboard and pen to each student and take one yourself] Please imagine you walk into a completely dark room with that torch on and you see teddy. Please make a quick sketch showing the torch, teddy and your eye which explains how you can see the bear. Stick people are fine. We'll talk about our ideas afterwards.

(< 10 min)	(4d)	Optional extra question: [Put sapling and block of wood onto the table] Where does the stuff (or particles) in this wood come from?
< 3 min	5a	Of all the things we've discussed, what has been the most useful for you?
< 4 min	5b	[Please give a very quick summary of the ideas which have struck you most during the interview] How well does that capture what was said here?
< 3 min	5c	Is there anything that we should have talked about but didn't?

Resources in the blue box: hot cup of tea, bowl of ice cubes (in the thermos – please pour them into the bowl), 'living' and 'non-living' cards to sort and mats to place the cards on, teddy bear and torch, whiteboards and pens, sapling and block of wood.

Questioning Route for Interview 1b – CVP

- Please watch each video clip and then 'think aloud'. By that I mean talk freely about anything that comes to mind about the video. I'm interested in how you might 'solve' these problems. What you'd actually do to help the children when they think like this. Please just report your thinking as accurately as you can in your own words. You don't have to edit, explain or justify your thoughts. We'll leave how you understand the issues raised to the second part of the interview. Everything you say will be anonymous.
- There are 17 clips, but we don't have to use them all. Try and do some from each of the three topics. We'll spend a maximum of 30 minutes on this. I'll keep an eye on the time, so you don't need to worry about that. After that I'd like to ask you a few questions which will take about another 30 minutes. Please feel free to say when you've had enough or if you need a break. I'll try not to interrupt you while you're watching and responding to the video clips.
- Please don't worry if you can't make sense of what the children say in some of these clips. Some of the ideas which came up are very challenging even for trained scientists. Since I started exploring children's naïve concepts I've discovered several of my own! Please just say if you'd like to 'unpack' an idea together. I'm aware that you're being asked to do something which is difficult, namely to respond immediately to some very challenging naïve scientific concepts. In the classroom we often have to respond quickly and it is this thinking that I'd like to explore together.
- Is there anything you'd like to check about this before we start? Many thanks for doing this.
- ["Keep talking", "What are you thinking?", iff silence >10 – 15 s]

Time	Clip	Questions
<1½ min	Intro.	
1	1	Surroundings

	2	Cold
	3	Air
	4	Colder
10	5	River
	6	Mushroom
	7	Die
	8	Wind
	9	Plant
	10	Tree
	11	Heart
	12	Milk
20	13	Light
	14	Darkness
	15	Seeing
	16	Eye
	17	Both

Questioning route for interview 1c – RD

Video Clips:

1. Can you recall what you were thinking about during the clip x?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
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2. Please tell me about what it was like ‘thinking aloud’ after watching the videos. Do you think like this in the classroom? How does the experience of watching these videos compare with what happens in the classroom?

3. Which questions did you anticipate coming up, was there anything which you hadn’t anticipated? Which ideas expressed by the children do you find the most challenging to deal with?

General:

4. A naive scientific concept has been defined as, “nonscientists’ everyday understandings of certain bodies of information” (Wellman and Gelman 1992 p. 338) – it is not meant in any way pejoratively. How do you usually help students who have naive scientific ideas? Please tell me about any experiences you’ve had with children who had or have naive scientific ideas.

5. Are you conscious of applying specific teaching practices in your everyday work? How do you understand the phrase ‘teaching strategy’? What teaching strategies do you use? [Pedagogies or behaviour management techniques?]

6. Please tell me about any experiences you’ve had with children solving scientific problems themselves. In what ways do you try to influence children’s problem solving?

7. Would you tell me about any experiences you’ve had where your own scientific and/or teaching ideas changed?

8. If you’d been teaching the three topics to a class, rather than the small group, please describe how it might be different?

9. Is there anything else that you’d like to say? How did you feel about this research? Could I mention your name in emails inviting other teachers to take part in this research?

Modelling (optional):

10. Here is a model for the relationships between naive concepts, 'scientific' concepts, learning strategies and teaching strategies. Please have a look and tell me what you think.

Questioning route 2c

Video Clips:

1. Can you recall what you were thinking about during any of the clips?

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
---	---	---	---	---	---	---	---	---	----	----	----	----	----	----	----	----

2. Please tell me about what it was like ‘thinking aloud’ after watching the videos. Do you think like this in the classroom? How does the experience of watching these videos compare with what happens in the classroom?

3. Which questions and ideas from the pupils did you anticipate coming up, was there anything which you hadn’t anticipated? Which ideas expressed by the children do you find the most challenging to deal with?

General:

4. A naive scientific concept has been defined as, “nonscientists’ everyday understandings of certain bodies of information” (Wellman and Gelman 1992 p. 338) – it is not meant in any way pejoratively. How do you usually help students who have naive scientific ideas? Please tell me about any experiences you’ve had with children who had or have naive scientific ideas.

5. Are you conscious of applying specific teaching practices in your everyday work? How do you understand the phrase ‘teaching strategy’? What teaching strategies do you use? [Pedagogies or behaviour management techniques?]

6. Please tell me about any experiences you’ve had with children solving scientific problems themselves. In what ways do you try to influence children’s problem solving?

7. (Would you tell me about any experiences you’ve had where your own scientific and/or teaching ideas changed?)

8. If you’d been teaching the three topics to a class, rather than the small group, please describe how it might be different?

9. How do you ensure you’ve understood what pupils say? (clarification)

10. How do you direct conversations with pupils? (redirection)

11. If a student disagrees with you, how do you persuade them? (persuasion)

12. How do you use activities in the classroom? (task)

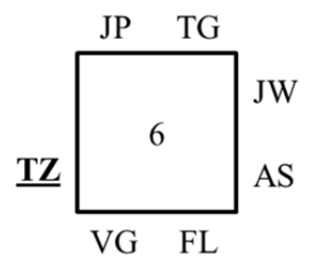
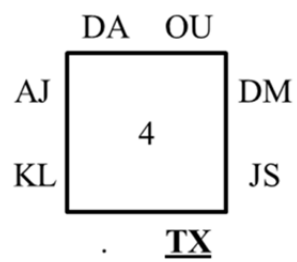
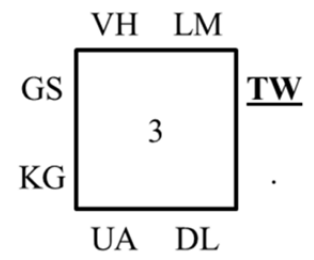
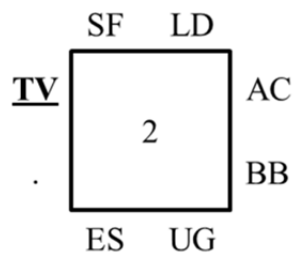
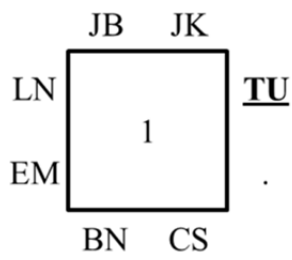
13. How do you use different ways of grouping students? (group)

14. How do you use different way of supporting pupils? (support)

15. In what ways might the timing of what you do influence learning? (timing)

16. Is there anything else that you’d like to say? Feelings? Name in emails?

Appendix C: Seating plans



Teachers are in bold and underlined.

Appendix D: Reasoning methods used by professional scientists

(adapted from tables 15-1, 15-2 and 15-3 in Darden, 1991)

No.	Type	Reasoning method	Explanation
1	Method for developing new ideas	Analogy	Retrieval (find appropriate analogue), elaboration (make features relevant to target explicit), mapping (put into correspondence features of target and analogue) and justification (new hypothesis must be justified). Darden 1991 p. 245
2		Use a Theory Type	“Once... an abstract structure of a type of theory has been formed, it can then play a role in additional instances of theory construction without invoking the detailed analogs.” Darden 1991 p. 248
3		Interrelations	“postulate a new interrelation between two bodies of knowledge in two different fields” Darden 1991 p. 243.
4		Move to another level of organisation	Frequently in science understanding phenomena at one scale requires some knowledge of smaller or larger scales.
5		Use a symbolic representation	“Any use of a model falls under this general strategy, either mental models, diagrammatic representations, scale models, computer simulations, or formal systems of equations. The important feature uniting these is that they all stand in a relation of representation to the natural system being investigated. Furthermore, the activity of manipulation is a part of using this strategy. The symbolic representation serves as a substitute for the natural system.” p. 255
6		Simplify then complicate	“Dalton (1808) assumed a simple relation between atoms and elements: in compounds, assume one atom for each combining element.” Darden 1991 p. 256
7		Refine a vague idea	“theories may begin as vague ideas that are developed in stages.” Darden 1991 p. 256
8	Method for theory assessment	Internally consistent and non-tautologous	“[Theories must] contain no internal contradictions among their components... [and not be] a trivially true statement with no empirical consequences.” Darden 1991 p. 258
9		Systematicity and Modularity	“all components [should be] systematically interconnected [and] components [should be] modular to facilitate anomaly resolution.” D. 1991 p. 259
10		Clarity	“Theoretical claims should be stated clearly, and the nature of theoretical entities and processes

			specified in detail.” Darden 1991 p. 259
11		Explanatory Adequacy	“A theory is expected to explain a domain of phenomena. The Philosophy of Science literature contains a number of analyses of explanation...” Darden 1991 p. 260
12		Predictive Adequacy	“The ability to make successful predictions can function as a strong constraint in theory assessment.” Darden 1991 p. 261
13		Scope and Generality	“theories of a larger scope are to be preferred; in other words, a theory that adequately explains a large domain is to be preferred over one that explains only a subset of the domain... Although scope and generality are related, they are not the same criterion.” Darden 1991 p. 262
14		Lack of ad hocness	“Simplicity in the sense of lack of numerous ad hoc hypothesis is often claimed to be a mark of good theories.” Darden 1991 p. 264
15		Extendability and Fruitfulness	“[An extendable theory] can easily accommodate changes and extensions to explain new domain items... Fruitfulness is a measure of the theory’s fertility in suggesting new experiments or new ideas for its further development.” Darden 1991 p. 264.
16		Relations with other accepted theories	“Minimally, the new theory does not contradict any claim in any other theory, that is, the new theory is consistent with other accepted theories.” Darden 1991 p. 265.
17		Metaphysical and Methodological Constraints	“a broad category encompassing many kinds of issues in theory assessment. ... [e.g.] the demand that a theory be experimentally testable. ... a theory should be simple. Whether a theory is compatible with a ‘world view.’ ... general assumptions that may influence data collection [theory-ladenness]. ... science should be unified because it is a body of knowledge about a single natural world.” Darden 1991 p. 266
18		Relations to rivals	“an important issue in assessing a theory is whether it has rivals and whether it is better than they are.” Darden 1991 p. 267
19	Method for anomaly resolution	Confirm that an anomaly exists - reproduce anomalous data	“Repeating experiments is one way to verify the existence of an anomaly.” Darden 1991 p. 271
20		Confirm that an anomaly exists - reanalyse problem	If a problem is looked at in a different way this can sometimes remove the anomaly.
21		Localize the problem outside the theory -	"remove the anomaly from being a problem for the theory. ... two kinds of monsters are

		monster barring	possible, unique ones and ones that belong to classes.” Darden 1991
22		Outside the scope of theory's domain	“the anomaly is removed from being a problem for the theory; some other theory must account for it.” Darden 1991 p. 271
23		Delete the anomaly	“One component of Darwin’s hypothesis was the claim that hereditary units circulated throughout the body. The circulation component was used to explain inheritance of acquired characters (gemmules from the longer neck of the giraffe circulate to the reproductive areas and are passed on to the baby giraffe).” Darden 1991
24		Generalize	“Generalization expands the scope of a hypothesis; specialization narrows the scope. If generalization occurs by dropping a condition, then it is like simplification” (Darden 1987).
25		Specialization	“Generalization expands the scope of a hypothesis; specialization narrows the scope. If generalization occurs by dropping a condition, then it is like simplification” (Darden 1987).
26		Delineate and change one but not other	
27		Tweak	“changing a component slightly to account for an anomaly or a new instance.” Darden 1991 p. 274
28		Propose opposite	“[In genetics] Purity was changed to nonpurity; random fertilization was changed to selective fertilization; equal numbers of types of gametes was changed to unequal numbers; independent assortment was changed to linkage.” Darden 1991 p. 274

Appendix E: Interview transcripts

Interview 1a

- 1a:1 [Introduction]
1a:2 [Question 1: Please tell us who you are and how you feel about science].
1a:3 [Question 2: ADAPTED What is science?]
1a:4 **TU: OK, right. Now you don't all have to take turns to ask the questions here. OK. Cup of tea. Ice cubes. [laugh from one student]. You can describe what is going on in the cup of tea...** [CS puts hand up. JB calls out answer. TU looking at JB].
1a:5 JB: Cold and heat.
1a:6 **TU: Something to do with cold and heat. OK.** [Turns to CS]
1a:7 CS: [unclear] The ice cubes are really cold because they've just come out of a freezer. And then it is just like melting, because there is like heat.
1a:8 **TU: Where is the heat?**
1a:9 CS: Like in the room. Perhaps that like all of a sudden just makes it start melting. Because it is really hot and it starts to get colder
1a:10 **TU: Why is it getting cold? You just told me that there was heat in the room.**
1a:11 CS: Because with that one, the tea, it will get colder because when it gets hot, when it has just been boiled. It can all of a sudden, where it is really hot, it can just get colder.
1a:12 JB: Because of the air.
1a:13 **TU: What about the air?**
1a:14 JB: Because the air might... If you've had like a cold drink or something, the air might be cold and damp - but quite warm as well - and it would go into the cup (mug) and it would cool it down. But if you actually have a flask, it has got a special thing round it that keeps the heat in so that it last for quite a long time.
1a:15 **TU: So the air is in there?** [pointing to the cup]
1a:16 JB: The air goes in there
1a:17 **TU: How does it get in?**
1a:18 JB: The air we breathe. Like the oxygen. And that can be quite cold sometimes. It goes into the cup.
1a:19 **TU: Where is it going in? Can you show me?**
1a:20 JB: It goes in from the top.
1a:21 **TU: So the air is going in down from the top.**
1a:22 JB: Yes, and then it gets colder. You know, but the minute. But it is quite hot. [Seems to be embarrassed by what he has said. JK is looking at him - might be trying to embarrass him].
1a:23 **TU: Do you [indicating with eyes and hand EM] think something different then?**
1a:24 BN: I think. [JB tries to come back in.] **TU: Let BN have a go.** Because it is really hot if you put it in a room, the cup of tea drops down to the level - the temperature of the room. So if it was really hot it would go really cold.
1a:25 **TU: OK, so what would happen if I turned off all the heating in this room?**
1a:26 EM: It would still be... it would still be... it would still drop because even if the heating was completely off it would still drop because the body... the temperature of this room relies on what is out... what the temperature is out there. **TU: OK.** EM: Because the room... because there are loads of bricks and everything is covering us it may be a half or a quarter of what it is out there [indicating the outside seen through the window]. **TU: OK.** EM: But another thing, when because when you make tea, when you boil a kettle, steam comes out, so when you're having brand new tea it is red hot and steam comes out so if you put the bowl of ice next to it the steam will come out and it will affect the ice so the heat will sort of... so basically if you put the ice there [indicating next to mug]...

- 1a:27 **TU: Are you [EM] thinking of these two things together or are you thinking of just the cup of tea at the moment?**
- 1a:28 EM: I'm thinking of both. So if you put the ice... if you got the bowl of ice and put it here [next to the mug] the steam from the new cup of tea would affect the ice thing
- 1a:29 BN: It would melt it.
EM: It would affect it.
- 1a:30 **TU: So the steam would be... [indicating with hand steam moving from mug to bowl of ice]**
- 1a:31 EM: It would affect it.
JB: And also it would...
TU: How is it going to affect it? [directed at EM and BN]
- 1a:32 BN: If the tea was right next to it and boiling hot because ice it would melt the ice.
- 1a:33 EM: And even if it was here it would still affect it.
JB: Plus it could be the other way round. [TU glances at JB then attention returns to EM and BN]
- 1a:34 EM: Even if it [the mug] was here [further from the bowl], the steam would still affect it [the bowl].
- 1a:35 **TU: That [the mug] would still get colder?**
- 1a:36 EM: Yes, but the steam would go up.
- 1a:37 BN: Yes that...
- 1a:38 JB: Because of the ice.
- 1a:39 **TU: Why would that still get colder?**
- 1a:40 CS: The steam comes out, the steam comes out and the temperature in the room is the same as what the tea is...
- 1a:41 **TU: You [LN] can chip in. [LN has indicated she would like to speak]**
- 1a:42 LN: I don't think that it would. If this was a freezing cold room the tea would drop to that [temperature].
- 1a:43 BN: Not straight away.
JB: If you put...
EM: If you put it in a freezing cold room it wouldn't drop straight away because the steam is coming out.
JB: No... but if you put the ice in...
TU: Can we just listen to [indicates EM and BN with finger]
- 1a:44 CS: When I had a cup of tea, my Dad was sitting in the garden and it was pretty chilly so and he needed to get some air. He put his cup of tea on the decking. No matter what the temperature was outside it would slowly drop no matter... I don't think the temperature of the room would change it. Because even if this room was like freezing cold I don't think it would change it.
- 1a:45 JB: And also if you put the ice in there [the mug] it would melt. If you put the tea in there in the ice water if you only put a little bit in there then that [the ice] won't melt and if you put one of two of them [ice cubes] in there [the mug] then that would turn cold. And if you put a few drops of that [tea] in there [bowl] then that would still stay cold and then that would go cold.
- 1a:46 JB: And also if you put the ice in there it would melt.
- 1a:47 EM and LN: [Seem to be disagreeing - shaking heads]
TU: Are you [EM and LN] disagreeing?
- 1a:48 **TU: So I think we're talking about two things. One we're talking about the room and the cup of tea and then we're talking about putting the ice with the cup of tea. You need to stick with one idea to make sure we know what we're talking about. So can we just stick with that [putting the mug into the middle of the table and bringing the bowl of ice closer to TU] for the moment. Just the cup of tea, ignore the ice cubes and talk about this [the mug].**
- 1a:49 CS: I...

- TU: So you're [looking at LN] still of the opinion... can you just say what you said again?**
- 1a:50 CS: If the room is freezing [BN] is saying that it would get colder faster.
BN: No. It would go down slowly but it would eventually drop to the temperature in the room.
- 1a:51 **TU: So whatever the temperature of the room is that is going to be the temperature of the cup of tea?**
- 1a:52 BN: Not precisely but...
TU: But close.
- 1a:53 BN: Yes.
TU: OK. What did you [LN] say?
- 1a:54 LN: I don't think that it goes to the temperature of the room.
JB: Because...
TU: Do you [LN] think this is going to get colder?
LN: Eventually.
TU: How cold will it get?
LN: [Not sure]
TU: You're not sure. [indicating with finger for BN to come in]
- 1a:55 **TU: What do you [BN] think?**
BN: If you wait about an hour it will get really cold [laughs and smiles with LN].
JB: [Starts to say something - unclear]
TU: What about you [JK]? You're being very quiet amongst all this. [EM tries to speak] Hang on [to EM - TU keeps facing JK].
- 1a:56 LN: You're keeping... You're [BN - but looking at TU] changing your mind.
EM: Yes but... because [BN] earlier you said if when...
TU: It is OK to change your mind though isn't it after listening to other people's arguments?
- 1a:57 EM: When the tea gets colder it gets to room temperature but when I have a cup of tea, my Mum always makes me a cup of tea in the morning, I drink quite a lot of it, but there is always a bit left - by the time I go it [the tea] is freezing cold even though my living room is quite hot. So the difference is...
- 1a:58 **TU: So you feel that it [the tea] is getting even colder than the room?**
EM: Yes.
- 1a:59 JB: Because I've had a cup of tea before that was burning hot, and I left it for... I drank half of it and then I had left it for a long time like one and a half hours and then when I went back to drink some of it it was quite, it was mepid [sic]. It was mepid, but it was quite cold.
- 1a:60 **TU: When you say 'mepid', do you mean 'tepid'? [JK laughs then other students laugh] Tepid is the word you mean. Not too hot and not too cold. [JB seems to be embarrassed - puts his head on his arms on the table then sits up and covers his face with his hands]. Come on then [JK], I haven't heard from you. You tell us about the ice cubes. What is going on there? [JB turns to him] We've heard about the cup of tea.**
- 1a:61 JK: They melt into water which makes the water colder than the room [slight question in the tone of his voice].
- 1a:62 **TU: So you think the water is colder than the room temperature.**
- 1a:63 JK: The room is not even cold.
- 1a:64 **TU: OK. So what if we left it until perhaps this afternoon.**
- 1a:65 JK: They would all melt...
TU: it would all melt... [tone encourages JK to go on]
JK: ...and there would be water that would be very cold.
- 1a:66 **TU: And it will be cold water in there?**
- 1a:67 JK: [slowly] I think it will get warmer.

- 1a:68 **TU: What, the water would?**
- 1a:69 JK: Yes
- 1a:70 **TU: Why would that?**
- 1a:71 JK: Because the heat. **TU: The heat from where?** The heat of the room is going into the water and heats it up.
- 1a:72 **TU: You keep talking about the heat each time don't you. So on this one [indicating the cup of tea] the heat is going where?**
- 1a:73 BN: Into the cup.
CS: Out. [shows movement with her hands of 'out of the cup']
BN: Oh, out, out of the cup. Yes, out.
- 1a:74 CS: The heat is coming... the heat is coming out which can like...
- 1a:75 **TU: So on this one the heat is coming out... into the room... [indicates with her hands energy coming out of the cup - pauses inviting students to elaborate]**
- 1a:76 BN: And that one is coming in. [indicating bowl]
- 1a:77 **TU: And you're saying the heat is going in. [indicating the bowl to BN]**
- 1a:78 **TU: How does it [heat] know when to go in and when to go out? [As TU speaks she sits back in her chair and crosses her arms - as if indicating exasperation with the nature of the flow of heat energy]**
- 1a:79 CS: Because it [heat] is air.
BN: Just air. [appears to be agreeing]
CS: Just air. It goes all over the place. It doesn't really know what to do it just goes all over the place say like if we were all spread out and acting as if we were the air and we're like moving around far apart from each other without knowing what we're doing.
BN: Eventually we all...
- 1a:80 **TU: So what you're saying is air is moving about without a particular order. But how does it [the air? heat?] know when it gets near here [indicating the cup]...**
- 1a:81 JB: The best thing the best thing to eat ice in tea is probably when...
- 1a:82 **TU: Iced tea! [smiles, looks round, sits up - several students laugh]**
JB: [unclear]
TU: I like iced tea.
- 1a:83 JB: If you have some juice and you put some ice in it [CS, BN, EM and LN talking - TU holds up a finger whilst still listening to JB]. Don't you [addressing JK] ever put juice in with ice when it is very hot [CS, BN, EM and LN continue to talk. JB glances over at CS, BN, EM and LN quickly]. If you put ice and juice and let it cool down and sometimes when it is really cold like now outside you'd have a cup of tea or like coffee. It is best to have something hot on a [when it is] cold and something coldey... or cold you know on a more hot day.
- 1a:84 **TU: Why do you think that?**
- 1a:85 JB: It will cool you down and...
CS: It will cool you down. [said at the same time as JB - TU looks at CS] It will cool you down if you're hot and heat you up if you're cold.
- 1a:86 **TU: So heat is moving again.**
- 1a:87 JB: In your body...
EM: Because in your body you have a certain temperature, called body temperature basically, so when it is freezing cold outside the warmth of the tea...
TU: So this [indicating the cup of tea]
EM: I don't know how to put it. ...will make you feel warmer.
- 1a:88 **TU: So it [heat energy?] is going into your body.**
- 1a:89 EM: ...and make you be warmer because the heat is actually going inside your body. So on a boiling hot day in August or the summer if you have a, if you have like ice in orange juice let's say and drink it, the cold, the coldness of the ice will go into your body and make your body temperature even colder [TU continues to listen whilst removing the cup and bowl from the table.

- 1a:90 **TU: So are you still thinking that the heat is moving?** [TU is meanwhile removing the cup and bowl from the table]
- 1a:91 EM: Yes.
JB: Like [EM] said about her body temperature.
TU: Yes.
JB: Say you were going to go swimming and it is pouring down with rain and it is raining and the sea is really rough and that, it would actually matter to your temperature of your body. Say you were really cold and you went into the sea and it was freezing, it would feel really warm. But if you're really warm and you go into the sea it is going to be really cold. [CS puts hand up]
- 1a:92 JK: That is like when you have a shower before you go in the water it feels really cold.
TU: Definitely. [listening whilst getting card sort activity out]. Terrible isn't it. The one good thing about having a freezing cold shower before you go for a swim is the pool feels warmer!
- 1a:93 JB: Yes but when...
CS: [unclear]
- 1a:94 **TU: What I'm going to ask you to do now, sorry to interrupt you, is inside here are some pictures. You've got two grids and I want you, as quick as you can, so this one is the first thought.**
- 1a:95 BN: What if you get it wrong?
- 1a:96 **TU: Doesn't matter.**
- 1a:97 JB: What have we got to do?
- 1a:98 **TU: There is no right and wrong. It is your opinion.**
- 1a:99 **TU: I want you to put your pictures on which sort of bingo board you think it belongs on. [A student repeats 'bingo board'] Bingo board. [laughs] [Students sort cards] Just go as quick as you can. First thoughts no talking. Try not to get involved... Shall I move out of your [JK] way?**
- 1a:100 CS: What is an embryo?
EM: Not sure about the seed...
- 1a:101 **TU: Not sure what an embryo is? Can anybody help her out? What is an embryo?**
- 1a:102 JK: [unclear]
TU: You think it is a brain?
JK: A brick. [showing the brick card up]
TU: Oh a brick. Sorry, I misheard you.
- 1a:103 LN: We done the car in science.
- 1a:104 **TU: Can anybody help me? What is an embryo? If you're not sure look at the picture and see if that gives you a clue.**
- 1a:105 EM: What is an embryo again miss?
- 1a:106 **TU: Well that is what we've just asked around the table. If you're not sure look at the picture and make a decision based on what you've seen.**
- 1a:107 CS: I've got two bicycles miss.
EM: It looks like a mini frog. [looking at the embryo card]
- 1a:108 **TU: You've got two bikes. Lucky you. Look at the bikes carefully.**
- 1a:109 EM: I'm going to say it is living because it looks like a frog.
BN: Have we all got different ones?
?: One's [of the bikes has] got a person sitting on it.
- 1a:110 CS: Oh, yes.
JK: It is not that hard.
LN: Is the leaf on the floor or on the tree?
- 1a:111 **TU: You decide. ...**
BN: Is a river living?
CS: No.
TU: You put it in the one you think.

- 1a:112 JB: Oh no. A person is not living! [said with irony - LN and JB laugh]
- 1a:113 LN: What's that? [showing a card up - unclear which one]
 JB: I don't know... it looks like a...
TU: Don't tell her. Let her do her own. [loud whisper]
- 1a:114 LN: What is it?
- 1a:115 **TU: Look at the picture and decide.**
- 1a:116 JK: [shows a card to JB] [unclear]
 JB: Oh my God. Yes it is.
 JK: I was joking.
- 1a:117 EM: A ball falling is [alive]. Because there is a person in it and there is the ball.
 LN: No, it says the ball falling. [emphasising the word ball]
- 1a:118 JB: Everything that has to live has to have seven things to live.
- 1a:119 JK: I've got two bicycles.
TU: Look at the pictures carefully.
CS: They're both bicycles, it's just one's got a person on it.
- 1a:120 **TU: Do it quickly. [standing away from the table - miming running with her hands. Then shows her watch holding it with the other hand] Right, ten, nine,**
- 1a:121 **TU: [JK] Can I move this so you have space. [moves cards on table]**
- 1a:122 **TU: I'm going to be quite strict on this. Ten, nine, eight, ... seven, (counting more slowly), six, five [collecting bags in] [helps JB lay out his cards more neatly]. Right, those on that pile go on that picture and those on that pile go on that picture. So shall I help you... three, two**
JB: I swear you was on six. [JK and TU laugh]
- 1a:123 LN: Miss do you live on [a particular] road?
TU: That is the school address love not my address. Well I might live here. I've got a cardboard box under my table and I sleep there. [laughs]
LN: But Miss you're a Mrs. You've got children. [TU is helping JB lay out his cards. TU does not answer LN's question.]
- 1a:124 **TU: Right, so what I want you... you know when we did the activity similar to this when we did about solids, liquids and gases. I want you to tell me why we've put them in those particular piles. OK. So if we just go through a few of them. If we choose [JK's] one here 'the spider'. Has everybody got it on living?**
- 1a:125 Everyone: Yes.
TU: Why?
EM: Because it can grow.
 JB: Because it can move, it can walk, it can eat, it can grow, it can live.
 LN: It can eat.
 JB: It can mate.
- 1a:126 **TU: It can mate. [nodding]**
- 1a:127 JK: It can [unclear - but a joke - TU laughs]
 JB: They do don't they.
- 1a:128 EM: It can mate, it eats, it sleeps, it feeds, it basically does loads of things, it eats, it sleeps, it grows, it moves.
- 1a:129 **TU: OK. Right, so we've all agreed on the spider haven't we. OK, so let's turn that over then. If we all agree. What about mushroom?**
- 1a:130 LN: Depends whether it is dead or alive.
TU: What do you [LN] mean dead or alive? Who has got it on living? [BN, CS and JK put hands up then EM and LN - JB does not put hand up]. Everybody got it on living? Where is your [JB] mushroom?
- 1a:131 JB: On non-living [said quietly whilst pointing in an exaggerated way at the card which is on the non-living mat].
- 1a:132 **TU: On non-living. Why have you put mushroom on non-living?**
- 1a:133 JB: Because it doesn't live [said with feeling].

- JK: Yes it does.
 LN: Yes it does.
 JB: It is like you said. It has got to move.
- 1a:134 **TU: Mushrooms don't walk or swim or fly.**
- 1a:135 Everyone except LN and JK: [unclear as several students talking at once]
- 1a:136 **TU: [To EM] Let him [JB] have his say and then you can argue with him. Like a good scientists we have to also listen to the other person's point of view.**
- 1a:137 JB: A mushroom can't move. It can't move at all because it doesn't have roots and the actual person has to feed it to make it grow. It can't feed itself.
TU: [putting finger to lips to stop BN interrupting] Let him have his say. That's not fair is it? Go on. [to JB]
- 1a:138 JB: Yes. That is what I wanted to say... and just like [LN] said a dog can feed itself.
- 1a:139 LN: Yes, but a fish can't and they're a living thing?
 EM: Exactly.
- 1a:140 JB: No they don't. If it is on the side of the tank they can just
- 1a:141 LN: You'd have to put the food into the tank.
- 1a:142 JK: But that's not [unclear]
- 1a:143 **TU: Shall we not think about pets. Shall we think about them in the wild. [lots of students talking at once - unclear] Let [BN] have a turn then [CS]. They said that they did think that a mushroom was alive.**
- 1a:144 BN: Yes because whereas plants, with water, they grow and they eat the soi [stops before pronouncing the whole word 'soil']... is it the soil or the water?
- 1a:145 JB: The wa [stops before saying whole word 'water' - agitated waves hand at BN then sits back folding arms - TU does not turn her attention from BN] Look, a plant is not a living thing!
- 1a:146 BN: [To TU] And they [plants] grow and they eat and they're living [meanwhile JK suggests to JB that plants are living - JB disagrees] because they breathe as well. And a leaf is [alive] and so is a tree.
- 1a:147 JB: Miss [pointing at BN's cards] a plant is not a living thing because you need to feed it.
- 1a:148 CS: It is! It can die.
 JB: You need to give it water [unclear - but continuing to argue with CS]
- 1a:149 **TU: Let [JK] have a say. Come on.**
- 1a:150 JK: A plant is a living thing because it can die when you don't feed it or like give it water... because it rots.
 JB: [unclear]
- 1a:151 **TU: So what makes something alive then? [to JK]**
- 1a:152 JK: When it can die. [JK smiles - seems unsure. CS smiles as well]
- 1a:153 JB: A tree is a living thing.
- 1a:154 **TU: What if I said to you [looks at JK's cards then at JB's - points to JB's car card] 'My car'. My husband might come in and say to me, "Oh, the car died on me today."**
- 1a:155 JB: You told us the other day that it has to have seven things in it...
- 1a:156 EM: It has to be MRS GREN [Mnemonic used to remember the seven characteristics of life].
- 1a:157 JB: Yes, and he says, "My car's died on me." because he hasn't got no fuel in it or something. [CS puts hand up]
- 1a:158 **TU: OK, so it is somebody using [CS puts hand up] the expression my car died on me but it is not actually alive.**
JB: They need to put some petrol in it. [JB says this whilst TU is still speaking]
TU: OK, so...
- 1a:159 EM: Miss can I... I just think that a plant and a mushroom is a living thing because when you think of a plant it moves because it grows and can sway in the wind...
- 1a:160 **TU: But isn't that the wind moving it? It is not the plant moving it.**
- 1a:161 EM: Yes, but it can move and it can grow.

- BN: [Quietly whilst EM continues to speak] The wind is a living thing. [She holds up her 'wind' card. She smiles in an embarrassed way as CS, LN and JB begin to laugh].
- EM: The plant has leaves and its leaves will grow. Its leaves can move [indicating leaves shaking in the wind using her hands]. Like a tree. [JB laughs, puts his head on his hands on the desk. LN is laughing as well. EM glances at LN] And if say, I don't know, ...
- 1a:162 **TU: [to JB - stops EM, speaks quietly and leans forward on the desk towards JB] Is there something the matter?**
- 1a:163 JB: [BN] said that the wind is a living thing. [JK laughing].
- 1a:164 **TU: We'll come back to that. [Hand held palm downwards towards JB]. And I don't think we should laugh at anybody's answers. [Shaking head slightly]. You didn't like it when somebody said something to you just now did we? You said a word wrong, so we're not going to do it to somebody else. OK, [EM] I'm sorry to interrupt you**
- 1a:165 EM: A plant can move because its leaves will grow and then they'll flap about and then and it can grow. It [the plant] eats the soil. Because the soil goes up into its roots...
- 1a:166 BN: No water. [goes up into the roots]
- 1a:167 **TU: You [BN] think it is water going up into its roots. You see you [EM] said soil goes in the root. [BN] didn't like that answer, she said it is water going into the roots.**
- 1a:168 CS: Soil is like nutrients and water helps it grow.
 JB: Miss... **[TU holds up a finger to JB glances at him briefly and then continues to listen to CS]**
 CS: I've got a little seed. Say I've just planted a sunflower or something, I plant it in my garden. I have to like grow it or plant it in soil. If I just plonked it onto my pavement, 'Oh be careful don't stand on my seed'. It won't grow because it hasn't got nutrients from the soil. But if it is in the soil and all that all the nutrients will go into the seed and help it grow and all the roots need nutrients to make it and so make it work.
- 1a:169 **TU: [To JK] That is a really good answer isn't it.**
JK: Yes.
- 1a:170 BN: You do need water.
 CS: Yes, you do need water to grow it and help the soil to...
- 1a:171 **TU: So you need soil, and you need water.**
JB: [Simultaneously] Plants don't have roots. [JK reacts - JB realises he has said the wrong word]
TU: I thought you said mushrooms didn't have roots?
JB: I mean I mean plants do have roots, plants do have roots. But I mean, they [plants] can't move their leaves. They don't because...they have... [unclear]
- 1a:172 JK: Miss was talking about they turn to the sun [mimes turning plant with his hands].
- 1a:173 JB: Yes, that is what trees do. Tree is not a plant.
 Everyone except JB: Yes it is!
 LN: What is a tree then?
 JB: It is a tree. A tree is a tree.
- 1a:174 JB: It is not a living thing when there are no leaves on it. [points at tree through the window which has lost its leaves].
- 1a:175 **TU: So when the leaves drop off. Those ones [trees] out there they're not alive.**
- 1a:176 JB: Not really no. But when...
 BN and CS: [Both disagreeing - unclear]
 JB: They grow back.
- 1a:177 **TU: Are they dead those trees?**
- 1a:178 JB: No, there are little things that fall off them. They're like circular seed things aren't they.
- 1a:179 **TU: How can just a bit of the tree be alive and the rest of it be dead?**
- 1a:180 Several students at once: [unclear]
TU: [shows palm downwards to CS and turns to face her]
 CS: It is either dead or alive. You can't really choose.

1a:181 JK: You can get an axe.

1a:182 **TU: Are you [JK] dead or alive?**

1a:183 JK: I'm alive. [smiles]

1a:184 **TU: You can't be a bit dead or a bit alive. You're either dead or alive.**
JB: Yes, but miss...
 JK: You can be half alive.

1a:185 **TU: So do you [JK] think plants can be the same? [Before he can answer CS comes in]**

1a:186 CS: My aunt died, but she didn't even know that it was coming because she had cancer she didn't really know that she was going to die. She thought that the doctor was going to treat her and make her better, but they didn't actually know that she was going to die. So you can't really predict whether a thing is dead or is going to die or whether it is alive.

1a:187 JK: If you get an axe and chop it and it is like all sort of...

1a:188 CS: Yes

1a:189 JK: ...inside [unclear - could be dead wood inside indicates half alive half dead?]

1a:190 CS: There is this tree on my family's drive and it was cut down last year and no... but it didn't grow. It hasn't grown since. And it hasn't got taller and it hasn't developed leaves. It hasn't even got twigs or anything. It is just like a stump. [JB is moving one of the cards on his mat and showing it to JK] It won't really grow from that.

1a:191 **TU: So if it is not growing you're saying it is dead. But when it is growing, and that is something you keep coming back to all of you, you've got this idea that if it grows then it is alive, if it doesn't grow... or am I not saying what you're saying...**

1a:192 EM: Not technically miss. Because an old lady, take old ladies for instance, they don't... once you stop growing, let's say eighty, seventy, [JB has put his hand up] **[TU: Shush, shush]** [EM puts her hand up - then starts to use it to show the height of the old woman] say you were this height when you're old you sort of shrink [showing height getting less with hand].

1a:193 **TU: OK. Did everyone hear what she said? An old lady is not alive because she is not growing anymore.**

1a:194 EM: Yes. So...
 JB: Old ladies are alive! [laughs]

?: [unclear]
 JB: As long as she has a heart she is alive, isn't she!

1a:195 JB: As long as she has a heart she is alive. A lady that is walking along the street and her heart stops she is dead. [touches his heart whilst miming walking]

1a:196 EM: I'm not saying that.
TU: [JB... JB...]Listen to what she says.
EM: I'm basically saying that what you're saying is that if it doesn't grow it is not alive. So basically if it not growing it is not alive. So you're saying an old lady is not alive.

1a:197 CS: What I was trying to say was that it was cut last year. It doesn't take like two years for a tree to grow into like a beautiful and fantastic

1a:198 JB: It takes up to fifty or sixty years to grow I think.

1a:199 CS: No, because I planted a little tree in my backyard and...
 JB: A little one? A little one?
TU: [JB]
CS: No, it wasn't exactly tiny, but it was growing. But I knew it was alive because trees were... no... all the leaves were all green and...
 BN: People are different to plants.

1a:200 **TU: People are different to plants. You're right. But I also accept what [EM] is saying. An old lady doesn't necessarily get taller [showing this with her hand] she might even be getting shorter as she gets older. But she is still alive because there are still bits of her growing. So if she perhaps cut herself, [JB puts hand up] there would be new skin growing. Her hair would still be growing. So she is still growing, but not**

necessarily in height. So you're absolutely right to have that argument. Right, let's just...

1a:201 JB: Miss, you know milk. It is a living thing...

1a:202 **TU: Right we'll do one more.**

1a:203 JB: And they all laughed when I put it on living.
Everyone: [unclear - but protesting]

1a:204 **TU: Let [JB] prove it. A scientific theory. [TU sits further back in the chair]. Why is milk alive?**

1a:205 JB: Because it comes from a cow...

1a:206 **TU: Please don't laugh [towards EM and LN] [CS has also been laughing - she stops as soon as EM and LN have been reprimanded]**

1a:207 JB: A cow is a living thing isn't it?

TU: Yes

JB: and then milk comes from a cow so it basically is alive...

1a:208 CS: No. No. [Shaking her head]. You're [JB] saying that a tree isn't a living thing [JK talking with JB behind his hand]...

JB: A tree is a living thing.

CS: What did you say earlier then?

JK: A mushroom wasn't alive.

CS: And also that mushrooms don't like live...

JB: Mushrooms don't come out your bum or something. [Laughs and puts his face in his hands on the desk]. Oh no, I've just said that wrong haven't I.

1a:209 **TU: Where does the milk come from? OK. Take yourself outside for one minute and calm down and then you can come back in a minute when you can explain yourself properly [pointing to the door - JB moves immediately].**

1a:210 LN: Anything that comes out of us is alive.

1a:211 LN: Anything that comes out of us is alive? [Said with incredulity]

TU: So blood would be alive?

LN: Yes, so that is what he is saying.

1a:212 **TU: OK. So do you disagree with that then?**

1a:213 LN: Yes. Because you're saying that when blood comes out of you it is alive...

JK: That is like bread. Bread is not [unclear - probably says 'alive']... That's [i.e. bread] not alive.

1a:214 CS: No, no, not everything that comes out of you is alive.

LN: That's what I said.

CS: No, but what I think he was trying to say was that not everything that comes out of you is alive. Your blood isn't alive, it is just liquid really...

JK: That we need.

CS: Exactly. We need it, but it is still not alive. It works in its different ways to keep us alive. If we lose too much blood then we would die because you've lost too much blood. If we want all our blood inside us. It [blood] is not exactly dead type of thing it is alive because...

1a:215 **TU: Just part of us.**

1a:216 CS: It is part of your body. It helps you grow. Like sorts out bits and bobs in your body and all that. But when a baby comes out of you [JB comes back in - TU nods to him] it is... it is... when a baby comes out of you at some point it can be, or it can be dead, you don't really know.

1a:217 **TU: That is a difficult one isn't it because we've just said that things that come out of you like the milk, like the blood is not alive and then you said a baby comes out of you but that is alive.**

1a:218 CS: But it can be dead.

1a:219 CS and JK: [Heated exchange talking at the same time - unclear]

CS: It can be alive and it can be dead. You don't really know.

- JK: You can predict!
 CS: No you can't predict!
TU: [To JB] So is that something else that [unclear - could be 'doctors'?] have to do?
JK: Yes. [Meanwhile CS is continuing to speak loudly - she appears to be making the same point that you can't predict - unclear].
 CS: You can't really predict that it is dead.
 JK: Yes you can. If it stops kicking [mimes a baby wriggling in the womb] and everything.
 CS: [Responds, but unclear what she says because of so many students all speaking at once].
- 1a:220 JB: A baby can actually die. A baby can... if you're pregnant and a woman smokes and drinks alcohol the baby can die.
 JK: You don't say.
 JB: Because it can get the cafetine [sic] out, not cafetine, you know the bad stuff out of the alcohol and the baby drinks it and when they smoke the thing comes out doesn't it. But the baby... when they feed it they have to eat something and the lady swallows it and the baby actually eats it.
- 1a:221 **TU: I think what you're saying is when the mother is pregnant there are things that she does that can pass onto the baby.**
- 1a:222 JB: If she actually drinks water [BN and CS have their hands up]...
- 1a:223 **TU: She should avoid alcohol and smoking and stuff like that.**
- 1a:224 JB: And eat fruit and look after herself.
- 1a:225 **TU: Right OK. Right so can we wrap this one up a little bit then?**
- 1a:226 EM: When [JB] said that everything that comes out is alive. [CS] made a good point that babies can be dead, but...
 CS: If it is in your stomach you can't really tell if it is alive.
 JK: You can.
 CS: No you can't.
- 1a:227 **TU: Ultrasound**
- 1a:228 CS: If you have a scan but if it is just a regular week and you haven't been to a scan in like months or something you can't really predict [unclear - but from the context possibly 'if the baby is still alive']...
- 1a:229 **TU: We're getting a bit side-tracked really.**
- 1a:230 EM: That everything that comes out of you is alive.
- 1a:231 **TU: So what we're disagreeing about is that maybe things... OK...**
EH: Sick! [holds out her hands palm down]
- 1a:232 BN: Miss, Miss...
- 1a:233 **TU: Let's just have a quick decision then. Are things that come out of living things alive?**
- 1a:234 LN: No.
 EM: No.
 CS: Not all the time.
 JB: Sometimes.
- 1a:235 BN: Miss, Miss...
- 1a:236 **TU: Do you [JB] mean sometimes?**
- 1a:237 JB: Not anything else, like you know...
- 1a:238 CS: Your blood isn't like alive, it just like helps you. It is not like...
- 1a:239 **TU: So you're [CS] very very strongly 'it is not alive'.**
- 1a:240 JB: A heart is a living thing. A heart is a living thing because if it wasn't living then we wouldn't be a living thing.
 CS: [Simultaneously with what JB has just said] It [the heart] can't mate. It can't mate.
- 1a:241 **TU: So now [JB] is saying that the heart is a living thing.**
- 1a:242 JB: Yes. If we don't have a heart the we wouldn't be here...

LN: That is true.
 JB: ...nobody would be here.

1a:243 **TU: Could I ask a question. Where is the heart in the tree?**

1a:244 JB: In the middle of it.

1a:245 Several students at once: [unclear]
 BN: No Miss. In a tree there is actually when you cut it like stuff coming out...
 EM: Sap
 BN: Yes, it is like blood.

1a:246 **TU: So you think plants have their own kind of blood?**

1a:247 CS: They have their own type of living because they might not even have our bl... they might not even have blood. They might just have...
 EM: Sap.

1a:248 CS: Yes, whatever. Whatever they might....
 JB: But...
 CS: It could be anything. It could be stones as their blood. Crunched up stones. [Indicates many options by tapping the fingers on one of her hands]

1a:249 JB: Because there are kind people in the world where they have to make toilet paper and [JK laughs] It is not funny [to JK] where they make toilet paper and paper and they... when they cut trees down to make that they're actually nice people because they plant more trees for us and let them grow and be not like us and so we can actually stay alive because we need trees to live.

1a:250 CS: Why do we need trees to live?
TU: It is a good question, why do we need trees to live? [starts putting cards into plastic bags] You answer her while we pack these...
JR: Could we perhaps just take those off like that [moves around the table taking away the card sort activity]
TU: OK, right, OK. Right so if we can just
JR: Can I just grab them like that. If you'd just put one on top of the other just like that and I'll take them away. I can sort them out later.
TU: Pop them all in piles and try not to let them spill.

1a:251 BN: With the milk miss.
TU: Yes, with the milk... [TU continues to tidy cards]
BN: When babies are born they need it [milk] for... to get nutrients [unclear - but could be 'that could be a lot of help to them to get nutrients']
TU: That's true, it could be that the milk is providing nutrients.

1a:252 LN: [To JK] Does something need to die before [unclear]
TU: Does it?
CS: No, but not everything

1a:253 JB: When are we actually going to be filmed Miss?

1a:254 **TU: We are being filmed.**
JK: [Simultaneously] We are, look. [indicating backup video camera]
 CS and BN: We are. [CS smiles]

1a:255 LN: [To JB] Do you remember the time when you went out. [Smiling]
 JB: Oh no.

1a:256 JB: Miss was...

1a:257 **TU: I'm sure you've said more good things than you've said silly things [JB]. [TU is preparing teddy and torch]**

1a:258 JB: I didn't actually even mean to say that.

1a:259 **TU: I'm sure you didn't.**

1a:260 **TU: OK. [Shows teddy to everyone then places it on the table with the torch]**
LN: Ahh, teddy bear!

- JB: I know what you mean by... we're going to have to take. Somebody is going to have to take it... Miss this looks scary - it looks like it is dead by its eyes [mimes closing eyes like a corpse]
- 1a:261 **TU: Well is he [teddy bear] a living thing?**
Several students: No!
TU: Why not?
CS: Because he is full of stuffing. [several people laugh including TU]
TU: Because he can't move and he can give you a kiss.
JB: But if you get batteries miss [mimes teddy walking along the desk] he can actually walk.
TU: He can walk up to me and give me a kiss couldn't he!
JR: [*Questioning route had been left on the side bench. JR moves it onto the table next to TU*]
EM: Yes but [JB] everything needs to be able to grow. Can it grow?
JK: Yes it can.
BN: Even a dolls hair? It can't grow back.
- 1a:262 **TU: What we're going to do is... grab one of these each. OK, now we're moving on to a new topic now. So new ideas on the next one you've got a marker pen and a whiteboard.**
JK: This marker pen don't work.
TU: So I want you to imagine that all the lights are out and it is really dark and...
- 1a:263 **TU: ...you've just walked into the room with the torch and you've found teddy in the torch light.**
JB: That would be quite scary.
TU: I want you to draw how come you can see him.
- 1a:264 **BN:** Because the torch light is on him.
TU: [Puts finger to lips and sits back in chair] Draw. Don't say.
EM: This one isn't working very well.
TU: Try this one. [Tries to give BN a new pen].
BN: I've tried those.
TU: Just do your best.
JB: You haven't tried this one. [Indicating the pen he is using]
JK: Yes, that is a good one.
- 1a:265 **TU: So it is dark, you've walked in the door with the torch and you've just found teddy. How come you can see teddy?**
JK: Mine is rubbing out what I've drawn.
BN: Mine is not very good.
- 1a:266 **LN:** Can we write Miss?
- 1a:267 **TU: You want words - put words if you want.**
- 1a:268 **TU: You've gone into a dark room. You've got the torch on and you can see teddy. With a picture...**
JB: Miss, mine doesn't really look like a teddy.
TU: It doesn't matter. I think we can work that out.
LN: Mine is a really bad drawing.
CS: It is not a drawing competition. Mine looks like he is doing the splits [several people laugh].
- 1a:269 **BN:** [unclear - could be 'That is a hand' to TU]
TU: What, your hand on the torch?
- 1a:270 **JB:** Look, this [picking up the teddy] doesn't have ears. Now it looks like something [unclear].
- 1a:271 **TU: OK, so we're going to start with somebody different this time - [JB and CS put up their hands] [JK] is going to start us off. Telling us - how come you can see teddy?**

1a:272 JK: Because the torch...
TU: With your picture, let's have it in the middle.
JK: I forgot to draw the torch.
TU: Oh, don't let me stop you, if you haven't finished your picture.

1a:273 CS: Miss, can I start?

1a:274 **TU: I would prefer [JK] started this time if that is alright with you and then you can go second perhaps.**
EM: Miss, I haven't started yet.
JK: Miss, do I have to write?
TU: You don't have to write anything. You're going to explain it. If you don't want to write anything. ... So this is the dark room is it?
JK: Hush.

1a:275 **JR: Would you mind putting your initials on the - in the corner please. Thanks.**

1a:276 CS: I can't pick it [the whiteboard] up.
TU: [laughs]
CS: I've forgotten my initials.
TU: [laughs]
JB: CS

1a:277 **TU: OK, so do you want to get us started then [JK]? How come we can see the teddy bear?**

1a:278 JK: Um. It is because like when this - the torch is powered up by a batteries, it makes a light and if you were in a dark room you kind of like see - it makes lots of light - and you could see a teddy bear.

1a:279 **TU: Why do you see the teddy bear?**

1a:280 JK: Because you're obviously [unclear - could be 'looking at?'] at the teddy bear.

1a:281 **TU: OK. So the light comes out of there [indicating the torch], it hits the teddy bear, how come you standing at the door get to see?**

1a:282 CS: Because...
TU: [Raises finger slightly on desk in the direction of CS - doesn't stop looking at JK]

1a:283 JK: Because of the torch.
TU: What is the torch doing?
JK: The torch is making a light to see.
TU: Yes, so we can't see without light?
JK: Yes. Because it is dark.

1a:284 **TU: OK, so if you don't have a light, what are you saying?**

1a:285 JK: You can see without a light.
TU: You can see without a light. So what is the point of the torch?

1a:286 JK: Make it [unclear - could be 'more powerful?'] Like a [unclear]

1a:287 **TU: So we've gone into a dark room.**
JK: Yes
TU: Can you see the teddy bear?

1a:288 JK: No, not without a torch.

1a:289 EM: Not technically without a torch because some people, some people like my Dad are really good at seeing in the dark because they stay up all the time, they never go to bed. Um, so basically

1a:290 **TU: So do we mean a dark room in our houses where there is a little bit of light coming in through the curtains or are we talking about a really [with emphasis and hand gesture] pitch black, like if you go into one of these rides at the fairs where it is totally black. Let's just make sure we know what type of room we're going in.**
JB: Thorpe Park [an amusement park]

1a:291 EM: I think we're talking about, if we turn all these lights off. Get loads of [indicating with her hand the windows] - put some blinds there. Make sure they're properly shut and we can't get

1a:292 **TU: OK, so a really really dark room. And we walk in through the door and teddy is in the middle of the room.**
EM: Got to make sure the TV is off.
TU: OK no TV on. Are we going to shut the door behind us in this dark room?

1a:293 EM: Yes.
BN: No.
TU: Oh, we'd better agree.
BN: No.
TU: I think we're going to shut the door the door.
JB: Why?
TU: I think we're going to go in the room we're going to shut the door. Can we see teddy?

1a:294 EM: Yes. [Still working on her drawing]
LN: Yes. [Still working on her drawing]
CS: No.
BN: No.

1a:295 CS: Not until you turn on the torch, because...
JB: Yes but you would if you left the door open...
TU: We've shut the door.

1a:296 CS: But if we shut the door...
JB: But say if we had blinds, some of the light can still get through...
TU: No, we've sealed it all up [indicating with her hand sealing the blinds]. Totally dark - no light shining through the windows.

1a:297 JB: Wouldn't you just go over to the window and undo the blinds?

1a:298 **TU: No. We've got a torch.**

1a:299 BN: The nails [indicating with her hand hammering in nails - she appears to be suggesting that the blinds have been sealed with nails so cannot be unsealed]

1a:300 JB: I know what I would do...
TU: OK, so now turn the torch on [JB].
JB: I would get the torch, turn it on, go over to the blinds, open the blinds and see more easier.

1a:301 **TU: ['JB' then a pause - then with slightly changed tone of voice] that is not what we're going to do. I said, we're in the really really dark room and we've shut the door.**
JK: Could be in the attic.
TU: OK, we're in the attic, and

1a:302 BN: It depends...
JB: [unclear - saying something to JK]
TU: ['JB' - with a finger held out to him]
BN: If the teddy was right over there in the far corner and your light only shines a little bit then you can't see it. But if you went over there and you actually shined it right on it then you would.

1a:303 **TU: So if I shine my torch over there [shining torch in a direction other than that which the teddy is in] [EM who is sitting in the path of the light reacts as if the torch is blinding her] My teddy bear is over there you see. [Joking that EM is the teddy bear?]. If I shine it over there and teddy is over here**

1a:304 BN: You're not going to be able to see him.

1a:305 **TU: You're not going to see him. Why not?**

1a:306 EM: Because you're pointing in the wrong direction. The light can only go from where the torch is because light is not a living thing, it can't turn round. It can only turn when you move the torch

1a:307 **TU: OK, because light is not a living thing... sorry EM [having shone the light in her eyes again by accident]. It will only move...**
EM: When you move it.
TU: In the direction that it starts out. And if I move it...
BN: It will move where you want it.

1a:308 **TU: Then the light beam will move.**

1a:309 EM: Like sometimes you can get...
TU: ... like a search light.
EM: ... lights that are pointing different ways so those lights [pointing to lights in the ceiling]. So if you've got one pointing that way [towards one side of the room] and one pointing that way [towards the opposite side of the room] in this pitch dark black room, the only light you will see is the light from there pointing that way and the light from there pointing that way. Because you won't see light there [indicating another part of the room not in either beam of light] and you won't see light there. It is only where the light is coming out

1a:310 **TU: OK, what are you saying about light. Light has to be... [pauses]**

1a:311 BN: Moved
TU: and
EM: Controlled.
TU: So we've moved it. When do you want me to... when will we see teddy?

1a:312 EM: You will see teddy once you point it at teddy.

1a:313 **TU: So this has to be...**

1a:314 CS: But if you don't know where teddy is. The power has gone in your house. You don't know what to do. So you find a torch and you walk into the room. Say it is your bedroom or something. You walk into your bedroom and it is absolutely pitch black. You can't see a thing. There are probably clothes on the floor. Toys. You don't know what you're doing. You don't know whether you're going to slide over a car or something.
TU: OK.
CS: And then you walk in there and you turn the torch on so you can look around. Say you are getting ready to go to bed. You don't actually know where your teddy is. So you're like panicking looking round the room going, "Oh, I want my teddy. I don't know where he is."

1a:315 EM: Yes but you look.

1a:316 JB: You know what [CS] said. Of all the toys on the floor. Because I've lived at the bedroom at the house for six years now I know exactly the same line to my bed...

1a:317 **TU: The question is, the question is ladies and gents. How do we get to see teddy?**

1a:318 CS: You see teddy by [shining? - unclear] the torch.

1a:319 CS: You've got the torch. You're looking round the room. You go, "Where's my teddy?" I've got to find my teddy. I've never like gone to bed without it.

1a:320 **TU: That's good.**
CS: You're looking around - you're looking around the room and you...
TU: I'm looking round [mimes looking left and right without moving the torch].
CS: ...and you find it with the torch.
TU: I'm looking around [as before].

1a:321 **TU: I'm looking around. Can I see teddy?**
BN: Use the torch! [smiling]
CS: That's what I'm trying to say.
TU: Oh, I'm moving the torch as well. [as if surprised]

- 1a:322 **TU: So I'm not just looking, I'm looking and moving the torch. [mimes looking left whilst shining the torch to the right, then looking right whilst shining the torch to the left].**
- 1a:323 JB: [Laughs]
 BN: Wait!
 JB: You have the torch and your eyes. [miming using his pen as the torch showing torch being shone in the direction he is looking in].
 JK: Why are you [BN] doing it like that? [miming the way BN is holding the torch at arm's length].
- 1a:324 **TU: So I have to keep my eyes with with the light. Why? [Pulling a face as if TU doesn't see the need for this].**
- 1a:325 JB: Look. The light is like that. [Stands up and uses his pen as the torch] You walk round the room, you have the light - looking where the light is shining [walks round the room miming using the torch correctly].
- 1a:326 **TU: OK, so look where the light beam goes.**
JB: Walking round and, "Say, there is a picture." ['Shining' his pen at a picture on the wall of the room].
- 1a:327 **TU: So you are doing the two together. [continues to mime shining the torch and looking in the direction the torch is shine in].**
- 1a:328 **TU: You [BN] want to demonstrate OK. [passes torch to BN]**
BN: [Picks up teddy from the table and takes torch from TU. Sticks tongue out at CS as she rises to her feet. Unclear why as several people talking at once.]
- 1a:329 CS: Can I have a go after? [To TU]
 JK: No, what would be the point? [LN is also looking at CS in what appears to be a challenging way]
- 1a:330 BN: If you point it there [into a corner] and you're looking round the whole entire room like down and up, wherever you left it [shines the torch down and up to the ceiling].
- 1a:331 JB: Why is the teddy bear going to be up there? [several students laugh]
TU: Shhh. [TU leans towards JB and reaches out with palm downwards]
- 1a:332 BN: Someone might have stuck it up on the roof. And you look around. If you point the torch over there you have to look to see if it is there. And if you - and once you have pointed it to the teddy...
 JB: It would fall down.
- 1a:333 **TU: So have all your pictures got the light pointing at teddy?**
Several students: Yes.
TU: Have all of you got that? Right [JK], yours is a very good picture. Talk us through this. Light beam. You're holding it. You've controlled it so that it is now pointing at teddy and your head is towards teddy. Now tell me, why do you see teddy?
- 1a:334 JK: Because...
TU: You're here, and teddy is over there. How come you get to see him?
JK: Because the light...
TU: [BN saying something - unclear] Shh [reaching over with hand towards BN whilst still listening to JK. JK looks up at TU]
JK: Because you're following the light you can see - you need to see your way so you flash it.
- 1a:335 **TU: But how does the image of teddy - how does teddy get to your eye? [pointing to JK's drawing of teddy and then to her eye] Because you're over here [pointing to the corner of the room] and teddy is over there [on the table].**
 BN and JB: [try to come in]
TU: Let [JK] answer.
- 1a:336 JK: You need to move the torch. When you need to move closer.
TU: I need to move closer to teddy to see him?

1a:337 JK: Yes, because like when you flash is over there, it might like fade away.

1a:338 **TU: OK, so the brightness might be different. That would help. [CS has hand up. JB is playing with a pen. LN picks up the teddy. EM tries to take the torch from CS who doesn't let her take it].**

1a:339 **TU: How come we get to see teddy? [looking at questioning route]**

1a:340 BN: The light is reflecting onto teddy.
JB: Yes.

1a:341 **TU: What do you mean reflecting?**

1a:342 **TU: Lets listen to [BN].**

1a:343 **TU: She said the light is what off teddy?**
BN: Reflecting.
TU: What does that mean?

1a:344 BN: [Slight pause]
TU: Can you show me on your picture?

1a:345 JB: If there is... [stops]
TU: Show me on your picture what reflecting is.

1a:346 BN: The light beams onto it [showing the light hitting teddy] and then maybe it has a shadow. I think.
TU: OK.

1a:347 CS: Miss can I?
TU: OK, you tell me.
CS: What I think is that where the torch - can I borrow the torch quickly? [EM passes her the torch] - thanks. Well say I'm really upset, I'm walking around [stands up and starts to walk holding torch - TU holds teddy up over the table] wondering where teddy is. And I'm looking all over the place, I can't find it. I'm looking down on the floor because it might have fallen or something. And all of a sudden I find it.

1a:348 **TU: How come it gets to your eyes then?**

1a:349 CS: Because when I'm looking I'm looking kind of where the torch is going. Where ever the torch goes I'm looking...
TU: OK, it has landed on teddy.
CS: It has landed on teddy. I see him.
TU: How come you see him?
CS: Because the light...
JB: [Interrupts] Because light is reflecting off it.

1a:350 **TU: What do you mean by reflecting again. You said that earlier.**

1a:351 CS: Reflected is where... You're standing in front of the mirror, you're standing in front of the mirror and you see stuff. That is called reflecting and you can see it like rebounding.
TU: Rebounding. So what is rebounding?

1a:352 CS: [Still on her feet] the light is going...
TU: So the light is hitting teddy, and then it is rebounding off teddy [mimes with her hand light going from the torch, hitting the teddy and then bounding off towards CS's eyes].

1a:353 BN: No.
CS: No, not literally like rebounding. It is shining onto him so it light up.

1a:354 **TU: OK, so it is shining on.**
CS: It is shining on
TU: You hold it [the torch]. So it goes on.
CS: So it goes straight to teddy.
TU: But how does it get to your eyes?
CS: Because I'm looking, where I'm looking, where ever the torch light is I see it [shows what could be something coming from her eyes to the teddy - unclear]. So I can see the teddy and it all depends whether the light of the battery - whether the batteries are like half dead. You can't really see much.

1a:355 CS: So I can probably only see to your [TU's] jacket. But then if I - if it was a full battery probably like see quite a way. You can like see teddy from quite a far distance.

1a:356 JB: [Puts hand up] Miss I've got something to...
TU: You've [JB] got one more thing to finish off. Because then I've got one more question at the end.

1a:357 EM: Miss, can I just say one thing?
TU: Yes, go on then. [TU looks at JB who is saying something quietly to JK]. [JK] can you just listen to [EM's] answer.
JB: I've got something... [EM is already talking - TU's attention is with EM - she holds up a finger towards JB]

1a:358 EM: So basically, because the light is reflected on teddy [unclear] [JB puts his head on his arm on the desk] because the light is reflected on teddy [showing her drawing] so tech... so the light has gone on teddy so you can see teddy then just next to teddy - thanks [BN passes EM the torch] - there would be like a little black thing. It is called shadow, so basically you can see teddy and next to teddy would be like a shadow.

1a:359 JB: Depends on the light. [TU looks at JB. JB puts up his hand]
EM: If it is a strong light then you would be able to see like a silhouette of teddy. Like teddy, but you can't see any detail. It is just black.

1a:360 **TU: I'm still confused about how you get to see it. How does teddy's picture get to your eye?**

1a:361 JB: Miss I've got something to...

1a:362 EM: Say teddy is there. You're looking around for teddy. Because there is no point in doing this [pointing the torch in another direction away from where teddy is] because if you don't catch teddy with the light you won't see him.
JK: Why don't you pick him up?
TU: So your head has got to be in line.

1a:363 EM: Yes.
TU: Yes I get that bit.
EM: Then if you catch teddy, if say teddy is there you go, "Where is teddy? Where is teddy?" And then you see him. You go up to him, you go up to teddy and get teddy. You can see him because the torch, because the light from the torch is seeing teddy.

1a:364 **TU: So he has got to be in the same line.**
EM: Yes.
TU: And your head has got to be in the same line. OK. I think I'm getting there now.

1a:365 **JR: Can I ask a very quick question?**
TU: Yes.
JR: [Takes the torch] Are you all saying that the light is going out from there? [miming light leaving the torch] What about seeing? Does seeing go out from there [indicating something leaving eyes] Does it go that way [out from eyes] or that way [into eyes]?

1a:366 EM: It goes...
JB: It goes...
JR: *Would you mind all...*
Everyone talking: [unclear]
CS: You can see behind your eyes though.
TU: Let's have a vote. [CS] [CS] [TU puts hands out towards CS and JK] Lets vote. If you think that you see that way [out from eyes] put your hands up. [CS and JB straight away. JK next. LN next. EM slowly. BN hand held next to her cheek - unclear if she is voting or not]
JK: [To CS] That is only when you go to sleep.

1a:367 **TU: If you think that you see that way [towards eyes] put your hands up. [JK says er and stretches] [BN puts her hand up]**

1a:368 BN: You sort of see both ways. [JK has his hand up too - unclear if this is a vote or asking to speak].

1a:369 EM: Because when you look, this is my opinion, I think that when you look you see. So I'm looking around I see [TU]. I can see her. The picture sort of comes back to me [mining something going towards her eyes] in my brain... [unclear]

1a:370 **TU: So you're saying the picture is coming back to you.**

1a:371 EM: Yes, I can see it. [CS has her hand up] Everything around me coming back to me. [unclear - something about width of the field of vision] [JB stands up and spreads his arms demonstrating the width of vision. TU does the same mime]

1a:372 **TU: OK, [JK] says he can see [unclear]**
JB: And also like I said...
TU: Shh [to JB]

1a:373 JK: When you see something it has actually come from your eye.

1a:374 JB: You've got the corner of your eye haven't you. So you can see that way so like if something... [indicating with his arms the extent of his field of vision].

1a:375 **TU: So it is not about seeing that way [indicating something going out from her eyes] it is about [showing light coming into the corners of her eyes]**

1a:376 CS: I can see everything in front of me.

1a:377 **TU: But is it that way [coming in] or that way [going out]?**

1a:378 JK: Going in.
TU: Going in.

1a:379 CS: What I think is you can't right exactly look behind your eyes [points at her eyes]. Your eyes are like... I can't really explain it. Say you rolled your eyes right the way back. So they wasn't that way but like behind. I'm not saying you could do that. So you can't say it is behind you because you haven't got eyes at the back of your head. With which you can look and all that. Because you've either got one way or you've got nothing. Because you can't really like decide whether you are... [JB and JK are talking at the same time - unclear what they're saying - possibly JK is rolling his eyes? - see backup video angle - TU looks at JB who has his head on the table]

1a:380 CS: If I'm just like looking at [JK] I can see everything around him. I can see that there is like 'respect' [the word written] on the board, 'Friday', or 'Fri the 17th of December'.

1a:381 **TU: So you can see... [unclear]**

1a:382 CS: I can't really see anything else because his head is in the way but I can see that there is a TV, there is a poster, there's a door...

1a:383 **TU: There is lots of information coming in.**

1a:384 CS: I can see everything. I can't look behind me. I can't beyond here [showing field of vision with her hands].

1a:385 **TU: OK. So you've got that range.**

1a:386 CS: I can see here [showing range with her arms]. I can't see behind me. Unless I turn round like that

1a:387 **TU: OK, so without having your eyes facing whatever you're looking at...**

1a:388 JB: But also going back to the torch bit. The battery and torch make you see stuff you want to see. Sometimes if you have a bigger torch and better batteries you can see to a really further distance. If you have a really small cheap one like the one we had there, that would probably only reach to over there [indicating a nearby wall].

1a:389 **TU: OK then. Can I ask you to...**
JB: I don't mean as in cheap. I mean as in not so...
TU: I know what you mean. [Said gently - TU starts to take whiteboards in]

1a:390 **TU: Not a searchlight like they have at... [unclear]**

1a:391 **TU: OK. Sit down still for a minute. I'm going to ask you... [JB and JK are still talking about searchlights - unclear] that would be like a searchlight [to JK], or maybe like when you go to the sports centre and you're playing hockey outside or go to a rugby match and you've got searchlights. Big big lights.**

1a:392 JB: And say you're playing like track or something in the night. You'd have a torch wouldn't you. When we went to [unclear] we were all quite smart because we were

- thinking. If we turn the lights off then they won't be able to find us [TU is clearing the table and listening].
- 1a:393 **TU: You do need light to see things.**
- 1a:394 JB: That is a good thing about torches as well. When you need them you can turn them on, if you don't need them you can turn them off.
JK: This is a good idea if there is a light on the floor and you run away there... [unclear]
- 1a:395 **TU: Right. So [JK], from what we've done there. We've done three different activities. Do you remember the first one? Cup of tea and the ice. Then the second one was when you had the sorting cards. And then the third one was the torch and the teddy. From those activities did you learn anything new today?**
- 1a:396 EM: [Has hand up] Yes...
TU: Lets go round and take it in turn.
- 1a:397 JK: We could start there. [Pointing towards CS at the other end of the table]
TU: Go on then. [smiles]
- 1a:398 CS: What I've learnt about torches, more about, I know stuff about torches, I've learnt more reflecting and eyesight and ...
- 1a:399 **TU: Do you think you have answers or more questions?**
- 1a:400 CS: Because I think like when we was going to like put the pieces on the board I think I've learnt more bits with the sheets and the trees and all the
- 1a:401 **TU: About living things and...**
- 1a:402 CS: I've learnt stuff about that. Hearing other people's opinions about what is dead, what is alive has helped me. I don't think everybody is alive or dead or anything like that [last sentence unclear]. I learned quite a lot about it. Because
- 1a:403 **TU: Has it made your ideas clearer?**
- 1a:404 CS: I think it has made my ideas, yes, clearer and more, say put it this way, thinkable. I can think about things better than what I did when I first... When I go out of this room I'm going to think, "Well, I never knew that before. I've learnt something today in this interview and I'm really proud of what I've done.
- 1a:405 **TU: Well done. What about you BN?**
- 1a:406 BN: Exactly the same.
- 1a:407 **TU: What is the one thing that you'd say that you learnt today during this session?**
- 1a:408 BN: When I saw the cup of tea I thought it would drop to the temperature, but when I heard everyone else's opinions it doesn't sound as if it would drop to the temperature straight away. Maybe a couple of hours later maybe. It would be colder than the temperature
- 1a:409 **TU: Well I think that you had some very very good ideas and sometimes you shouldn't be persuaded by one person or another. So how would we find out for sure if you were right or [LN] was right?**
- 1a:410 BN: By testing it.
- 1a:411 **TU: Yes. So maybe that is an investigation we could do back in the classroom. So we could start off with a hot cup of tea and put it in a really cold place and see if it gets to the temperature of the cold place or if it gets colder.**
- 1a:412 JB: We could see if ice can melt as well. Put ice in like...
TU: ...a warm room and see if the water is actually warmer or colder than the room. Or the same as the room.
- 1a:413 BN: And I'm very proud that I learnt lots of things as well.
JB: [Starts to say something]
TU: [EM]
- 1a:414 EM: I think that I've got more answers - got more questions as well because I've learnt now about things that I didn't know and things that I want to [find out about?]. So I've got loads of answers, loads of questions. So I can be, I can know now that I'm, if it makes sense, cleverer than I was before in science. Because I know more. But I've got more answers because there's questions that I thought I knew the answer to, but hearing

- everyone else thought [BN and JB?] and all the other people I know... I now know that... basically I now have more questions so I... because people - loads of people have got different answers that I think that I sort of want the proper answer to the question.
- 1a:415 **TU: But maybe you'll never get the proper answer. Maybe there are always more questions and that is what keeps people like me in business. Keeps me in a job. Because if you've got lots of questions and I've got lots of questions that is what makes us human beings because we're inquisitive is one word or nosey is another word.**
- 1a:416 BN: No one is perfect.
- 1a:417 **TU: No. None of us can know everything.**
- 1a:418 CS: None of us will ever know every single thing.
TU: That's right. OK, [LN] next.
- 1a:419 LN: I learnt that it is hard to explain how to see something.
- 1a:420 **TU: OK. So you had some ideas in your head, but you found it really tough to say?**
- 1a:421 LN: Yes, because I didn't know that it would be that hard to explain because it sounds really easy but I learnt that it is quite hard.
- 1a:422 **TU: I agree.**
- 1a:423 JB: The same as we found out on Friday with [Mr W].
TU: OK, go on.
JB: He said we had to put how to put a jumper on.
TU: How to put a jumper on? [amused]
JB: Yes, how to put a jumper on and I went, "Pick the jumper from the chair, pick the jumper up from the chair, then put your head through, and then put your arms through and then...
- 1a:424 **TU: And it didn't work.**
- 1a:425 JB: He put his head through. And then he put his arms, you know the ends of them, he went - he didn't go through like that [as one would put on a jumper normally] he went like that [miming putting his hands through the sleeves from the outside of the jumper]. So his arms were like that... [JK and CS both talk for a second - unclear]
- 1a:426 **TU: So what you're learning from that is that when you're trying to explain things it is difficult.**
- 1a:427 JK: [JB] said put your head through your sleeves.
JB: No I didn't.
JK: Who said that?
TU: I think you're distracted [to JK]. Let him say what he learnt from today.
- 1a:428 JB: Yes, I really enjoyed it as well. And it was quite fun arguing and stuff. [LN smiles - can't see other faces from this angle]
- 1a:429 **TU: You liked the arguing about the ideas.**
- 1a:430 BN: Debate.
TU: Called debate. [smiles at BN] I prefer debate too.
JB: And I just like watching people arg... debating and all that.
TU: Interesting isn't it.
JB: Yes, and when you finally get the answer you might start another argument.
- 1a:431 **TU: [Unclear - but probably 'What about you JK?'] You like the debating side of things too?**
JK: [Nods]
TU: Do you think that you like arguing just for the sake of arguing and you'll ask the awkward question even if you believe it.
JK: It is funny arguing. [Looks at JB then laughs]
TU: Do you like to win an argument?
JB: Yes, definitely.
JK: I like an argument to carry on.
JB: I can never win an argument with my mum or step dad.

JK: I can!

1a:432 **TU: But that is different. We're talking about an argument or a discussion aren't we [JK and JB are talking together - unclear] [JK with a short pause after]. We're talking about an argument or a discussion about some information not about an argument because we've fallen out with somebody. OK.**

1a:433 **TU: Well thank you ever so much for giving up your time. And I've certainly enjoyed having a chat with you.**

JB: This was a lot better than all that mentoring.

TU: Maybe we could all go downstairs and have a hot chocolate afterwards. You've really joined in brilliantly. Thank you very much.

[End 1a]

Interview 1b

1b:1 JR: Thanks ever so much. Please watch each video clip and then 'think aloud'. By that I mean talk freely about anything that comes to mind about the video. I'm interested in how you might 'solve' these problems. What you'd actually do to help the children when they think like this. Please just report your thinking as accurately as you can in your own words. You don't have to edit, explain or justify your thoughts. We'll leave how you understand the issues raised to the second part of the interview. Everything you say will be anonymous.

There are 17 clips, but we don't have to use them all. Try and do some from each of the three topics. We'll spend a maximum of 30 minutes on this. I'll keep an eye on the time, so you don't need to worry about that. After that I'd like to ask you a few questions which will take about another 30 minutes. Please feel free to say when you've had enough or if you need a break. I'll try not to interrupt you while you're watching and responding to the video clips.

Please don't worry if you can't make sense of what the children say in some of these clips. Some of the ideas which came up are very challenging even for trained scientists. Since I started exploring children's naïve concepts I've discovered several of my own! Please just say if you'd like to 'unpack' an idea together. I'm aware that you're being asked to do something which is difficult, namely to respond immediately to some very challenging naïve scientific concepts. In the classroom we often have to respond quickly and it is this thinking that I'd like to explore together.

Is there anything you'd like to check about this before we start? Many thanks for doing this.

1b:2 **TU: No. I think I'm clear.**

1b:3 JR: Great. Many thanks for doing this.

1b:4 *CLIP 1: surroundings [ID: 1a-44] CS: When I had a cup of tea, my Dad was sitting in the garden and it was pretty chilly so and he needed to get some air. He put his cup of tea on the decking. No matter what the temperature was outside it would slowly drop no matter... I don't think the temperature of the room would change it. Because even if this room was like freezing cold I don't think it would change it.*

1b:5 **TU: I find that quite strange that she has explained the situation of the cup of tea going cold and yet she still believes that it is not going to make an effect on the cup of tea. And you want to immediately jump in and correct it and tell her what the facts are rather than let her keep try and talk herself round it to see if she will eventually - the penny will drop for herself so then it will be permanently in their mind as**

- opposed to something that I plant she'll learn it for that short period of time and then forget it again. [pause] Can I watch that one again?
- JR: Of course. If you press on the screen it will play again.
- TU: I just want to listen to her a bit.**
- JR: It pauses if you press again [demonstrating this].
- 1b:6 *CLIP 1: surroundings ID: 1a-44 (played a second time - see 1b-4)*
TU: [Whilst clip is still running] So the tea is definitely getting colder. But she is still saying that the air temperature is not making a difference to the cup of tea. She is arguing against herself. Seems a bit strange. [pause] The house [indicating house icon for returning to the menu].
- 1b:7 *CLIP 2: cold [ID: 1a-89] EM: Because in your body you have a certain temperature, called body temperature basically, so when it is freezing cold outside the warmth of the tea...*
TU: So this [indicating the cup of tea]
EM: I don't know how to put it. ...will make you feel warmer.
TU: So it [heat energy?] is going into your body.
EM: ...and make you be warmer because the heat is actually going inside your body. So on a [TU talks over the clip at this point] boiling hot day in August or the summer if you have a, if you have like ice in orange juice let's say and drink it, the cold, the coldness of the ice will go into your body and make your body temperature even colder [TU continues to listen whilst removing the cup and bowl from the table.
- 1b:8 **TU: Because of the misconception of the first child I'm interrupting and correcting as I go along reinforcing. So the first child I just let her be. The second one I'm prompting and encouraging. That is interesting to think that you're guiding the learning of one and challenging the thoughts of another. And I'd just trying to think to myself whether it is because one child in my mind is of higher order in all the assessments I've given her so I'm leaving her be and the other one doesn't have such high assessments so therefore I've nodded I've encouraged I've prompted and reinforced.**
- 1b:9 *CLIP 2: cold [ID: 1a-89] (Played a second time - see 1b-7).*
- 1b:10 *CLIP 2: cold [ID: 1a-89] (Played a second time - see 1b-7).*
TU: [Whilst clip 2 is playing "will make you feel warmer."] But she is talking about feelings not actual temperatures. So she is muddling up two things, two concepts and I didn't notice it at all the first time I watched that clip. Interesting isn't it.
JR: There is a bit at the end of that one where she talks about the coldness of the ice cubes going into her.
TU: But it is the feeling of it. I didn't even hear that last bit. I think I'm concentrating more on what she is saying earlier and the conflict between how she says it makes her feel warmer inside, not necessarily that the body temperature has risen.
- 1b:11 *CLIP 3: air [ID: 1a-72] TU: You keep talking about the heat each time don't you. So on this one [indicating the cup of tea] the heat is going where?*
BN: Into the cup.
CS: Out. [shows movement with her hands of 'out of the cup']
BN: Oh, out, out of the cup. Yes, out.
CS: The heat is coming... the heat is coming out which can like...
TU: So on this one the heat is coming out... into the room... [indicates with her hands energy coming out of the cup - pauses inviting students to elaborate]
BN: And that one is coming in. [indicating bowl]
TU: And you're saying the heat is going in. [indicating the bowl to BN]
TU: How does it [heat] know when to go in and when to go out? [As TU speaks she sits back in her chair and crosses her arms - as if indicating exasperation with the nature of the flow of heat energy]

- CS: Because it [heat] is air.
 BN: Just air. [appears to be agreeing]
 CS: Just air. It goes all over the place. It doesn't really know what to do it just goes all over the place say like if we were all spread out and acting as if we were the air and we're like moving around far apart from each other without knowing what we're doing.
 BN: Eventually we all...
- TU: So what you're saying is air is moving about without a particular order. But how does it [the air? heat?] know when it gets near here [indicating the cup]...
- 1b:12 TU: I think she is quite good because she has taken away the sort of idea of it being [pause - JR pauses the video]
- 1b:13 TU: I was just thinking that watching that one I gave it personal attributes saying, 'how does it know which way to go out, when to go out, when to go in.' And very quickly she said, "It is not thinking, it is just doing it." So she has depersonalised it and I personalised it to try and get them to model and she unpacked that model very quickly.
 JR: It is amazing isn't it. The things that are happening.
 TU: Mm. And the other two boys aren't engaged at all in the debate. Just focussing on those three ideas with the girls.
- 1b:14 TU: Just click on that again?
 JR: If you click on it it will continue playing I think.
 TU: It's gone back to the beginning.
- 1b:15 JR: Sorry, I think we've gone onto the next one by accident. Did you want to or...
 TU: I'll go back and watch that one again. It was three wasn't it.
- 1b:16 CLIP 3: air [ID: 1a-72] (Played a second time - see 1b-11)
- 1b:17 TU: So she has a really strong concept of the fact that - she is using her hands to say it is moving [pause whilst listens to the end of the clip 1a-79] A lot of [pause] Using a lot of body posturing to reinforce and support her thinking. I wonder how many times you give positive body language because you want to encourage the child to talk and then they misinterpret that into, 'Yes, I'm giving the right answer.' And therefore it reinforces a negative answer. So I need to think more carefully about how I - what kinds of gestures I use when I'm approving of them contributing and when it is about the science being correct. I think that is something for me to really think about. That would take a big big change in me. I think. Yes.
- 1b:18 TU: One more on that topic.
 JR: That's right.
- 1b:19 JR: I'm sorry, they're not wanting to play automatically.
 TU: That's alright.
- 1b:20 CLIP 4: colder [ID: 1a-408] BN: When I saw the cup of tea I thought it would drop to the temperature, but when I heard everyone else's opinions it doesn't sound as if it would drop to the temperature straight away. Maybe a couple of hours later maybe. It would be colder than the temperature
- 1b:21 TU: She is quite a deep thinking little girl. She obviously spends a long time listening to other people, assimilating information and she is weeding out the unnecessary stuff and that child is one that doesn't always score very highly in written assessments. So for her the verbal feedback is going to be really very powerful. Maybe I need to video more of my lessons! [both laugh]. Maybe I need to video more of my lessons before I make a judgement. I think there is a big opportunity really. As long as you don't see it as 'spy in the classroom'. A big opportunity there.
- 1b:22 JR: I think from the context of that little snippet, she is wanting to get an idea that a cup of tea left out becomes colder than the environment. I think it is possible that is what she - which others in the group had claimed as an idea. Which she'd earlier rejected, and now seems to be promoting.
- 1b:23 TU: As in totally different - as in it was actually going to get colder than the room?

JR: Colder than the room.

TU: Right.

JR: My cup of tea there [indicating cup of tea in the room] if I went and had a drink from it it would be colder than the room.

TU: So she is not only distilling what was said, but taking it too far. Isn't she. Do you think that I would - I was just thinking to myself, do we cut the kids off once we've got the answer - or what we think is the right answer. We then move on. I don't think we ever have enough time to really talk to them to find out what they're really thinking.

JR: There are so many ideas I think that come out in the classroom. This is only just a small group, with thirty children in the classroom it is bouncing around all over the place.

TU: It is amazing they learn anything really.

JR: I think it is fascinating that they do learn a lot.

TU: Or even if they don't learn what the intended learning outcome is - even just the process of thinking it through, of listening to other people and picking up on their ideas. I notice with the boys there that they were much more involved in that part. I don't recall that being the sequence of the conversation.

1b:24 JR: They are little snippets.

TU: They're out of sequence.

JR: And that does make this a strange task. I'm taking you back just to those initial point. Because of course with the video which we've done before we've got how that discussion developed in reality. I suppose I'm just interested in [talking in] this much more relaxed environment where we can really talk about these issues looking at some of these... we could call them naive concepts, not in a pejorative sense, but as just...

TU: Well they're basic fundamentals aren't they.

JR: Yes, and...

TU: And if we keep getting these wrong it is no wonder they find more complicated things difficult.

JR: And I suppose I'm really interested in the ways in which you as a teacher, you as an experienced Advanced Skills Teacher, nudge them in different directions or attempt to change their minds on things. Or even use the group.

1b:25 **TU: I definitely would through practical work on that task definitely would be using more practical work where they are actually taking measurements. You know, whether the feelings are the same as the actual measurements. You know, there are all sorts of experiments where you put your hand in really cold water and then put your hand in really warm water and how much hotter it feels than the actual temperature. Those kinds of things I would do with them. And then we'd talk about those kinds of concepts. But I think at the end I would definitely stop and give them a definitive answer. I wouldn't just keep letting them go round the houses. The scenario there is lovely to explore their thinking and see where they're at, but at some point I think you have to tell them as it is. And give them the facts as we know them.**

JR: Thank you very much. How are you feeling?

TU: Yes I'm alright.

JR: It is a weird thing to do. I'm aware that it is a difficult thing to do. But I'm really grateful you're trying this.

1b:26 **TU: Let's give it the next one. So this is the living and the non-living.**

1b:27 *CLIP 5: river [ID: 1a-111] BN: Is a river living?*

CS: No.

1b:28 JR: "Is a river living?" I think she says.

1b:29 **TU: Ah. And that's all there is.**

JR: As a question. Very quick one that.

TU: The fact that she even asks it? I can understand why she asks it because they've been given the definition of MRS GREN: Move, Respire, Sense, etc. I think it is more that it has got living things in it and it is moving and in lots of poetry and stories and things they talk about the living, you know the sort of [thing] nature as a living thing. And I think if she has seen somebody putting it towards one of those piles she is asking a question. She is not sure. She is not sure. I think the tone with which it was asked means it was quite incredulous. Like, 'I don't really believe that that is what it is.' but she has seen somebody else putting it in that pile so the seed of doubt is there. She is not absolutely sure on the definition. I can see perhaps where she might get that from.

1b:30 JR: I'm just going to check the camera.

1b:31 **TU:** It is that one. [TU is starting the next video clip] Quite a long one about mushroom then? [both laugh]

1b:32 *CLIP 6: mushroom [ID: 1a-130] TU: What about mushroom?*

LN: Depends whether it is dead or alive.

TU: What do you [LN] mean dead or alive? Who has got it on living? [BN, CS and JK put hands up then EM and LN - JB does not put hand up]. Everybody got it on living? Where is your [JB] mushroom?

JB: On non-living [said quietly whilst pointing in an exaggerated way].

TU: On non-living. Why have you put mushroom on non-living?

JB: Because it doesn't live [said with feeling].

JK: Yes it does.

LN: Yes it does.

JB: It is like you said. It has got to move.

TU: Mushrooms don't walk or swim or fly.

Everyone except LN and JK: [unclear as several students talking at once]

TU: [To EM] Let him [JB] have his say and then you can argue with him. Like a good scientist we have to also listen to the other person's point of view.

JB: A mushroom can't move. It can't move at all because it doesn't have roots and the actual person has to feed it to make it grow. It can't feed itself. [TU starts talking over the clip at this point. Please see transcript 1a-137 for the rest of the transcript for this clip]

1b:33 **TU:** What he's doing there is he's really reinforcing. We're taught them the basic set of ground rules about why it is living and not living and in his experience it supports the fact that it is not living. And yet the others intuitively know that it is a living thing... and I can feel myself getting quite irritated that they won't even let him express his opinion... and I think that is my frustration at not being able to support him... he's quite adamant isn't he... ["a plant is not alive"] So he is under the impression that human beings are actively involved in doing that [feeding] for them. That they can't do it for themselves. We've got to feed them, we've got to water them. So his experiences of plants are very much about farming and gardening rather than a living organism that can survive and compete.

1b:34 **TU:** Good on him JB. Good for you boy. He stuck his ground and he had good reason to I think and with the definitions we've given him then I think there is merit in where he has categorised it. It's still wrong. [both laugh] I think that is something I'd really like to think about later. How we get round that. The plant one is easier. Because even in their own experiences they can talk about leaves moving and flowers and sunflowers - and you can even show them an animation of a sunflower moving round through the day. And I suppose one of the other things I would do, if he persisted in that opinion, is I'd probably go away and I'd look for evidence and video clips of mushrooms and the hyphae, that kind of thing. Searching out the minerals. In the same way that a root does. So yes, I think that that is something that I would now perhaps include in my lessons when I'm teaching it. More about how do plants

- display those characteristics. We do focus very much on animals, and therefore reinforce that stereotype.
- 1b:35 **TU: I think JB, he's only operating on the level that he can operate which is very factual. I've given him these facts and he's very loyal and will do as he's told and want to please me and therefore he's giving the answer and sticking his ground. Because he can't think beyond that. Yes.**
- 1b:36 **TU: It was going this time. [both laugh]**
- 1b:37 JR: Sorry, not sure what's going on [clip won't start]
- 1b:38 *CLIP 7: die [ID: 1a-151] TU: So what makes something alive then? [to JK]*
JK: When it can die. [JK smiles - seems unsure. CS smiles as well]
- 1b:39 **TU: You see JK is one of those children that always comes out with what he thinks is the witty remark. And ninety-five per cent of the time his witty remark is actually the truth. [pause] But he says it as if he's telling a joke because he's not sure. He's not sure if he is saying it because it is a fact, and a plausible one, or whether he is saying it for effect. [pause] But he is right. You can't be alive if you don't die. But it is not a definition of living. Not sure what I think about that one. I don't have any instant thoughts about it in my mind at all.**
- 1b:40 **TU: In some ways it is a flippant comment. In other ways it is a statement of fact. Living things die.**
- 1b:41 *CLIP 8: wind [ID: 1a-159] EM: Miss can I... I just think that a plant and a mushroom is a living thing because when you think of a plant it moves because it grows and can sway in the wind...*
- 1b:42 **TU: [laughs] So she is saying they are moving themselves when actually it is something moving them. So there is a massive misconception there. [pause] And it is quite a typical one that children use all the time. So we need to I think, when I'm teaching it is the emphasis on that it is able to create the movement itself and not have movement - the forces acting on it causing it to move. [pause]**
- 1b:43 *CLIP 9: plant [ID: 1a-145] JB: Look, a plant is not a living thing!*
- 1b:44 **TU: What does he say? Plants not...**
 JR: Plants are not a living thing.
TU: Plants are not a living thing. He's gone back to that same thing with the mushroom. He's convinced that if you have to feed it and you provide for it and it is not doing it by itself. And they don't move - they don't move around in his mind. They don't move location. And because they don't move location, that's his definition of movement. So he's stuck in that moment really. But I notice the other children are getting quite frustrated with him now. They're getting quite angry that he doesn't get it. And that is quite a problem in a classroom where a child's got a misconception and rather than supporting that child get through that misconception what you do is you move on quickly and you tell them the right answers so that he's not ridiculed and he's then not exposed to all of that anger and venom from the others and sometimes they can be quite spiteful and then you kill his need to learn. He's exactly the kind of kid who by Year 9 who will be naughty disaffected and saying, "What's the point?" Because he's not been allowed to develop in his own time and at his own speed and he's not been allowed to make the mistakes in a ridicule free environment. And they're nice children. They're not spiteful children. They just know that he's wrong, or in their opinion he's wrong.
- 1b:45 **TU: That is amazing dynamics going on. [indicates with her hands interaction] Because it is not even science. It is the way he is being allowed to learn.**
- 1b:46 **TU: That's quite sad actually.**
- 1b:47 *CLIP 10: tree [ID: 1a-174] JB: It is not a living thing when there are no leaves on it. [points at tree through the window which has lost its leaves].*

- 1b:48 JR: It is a difficult one to hear. He's pointing out the window at a tree during Winter which hasn't got leaves on it and he says, 'It is not a living thing when it hasn't got leaves on it.'
- 1b:49 **TU: Because the other little girl had given the definition leaves are moving [indicating moving leaves with her hand]. So she'd said the leaves are moving in the wind and he's arguing against her and saying, but when it hasn't got its leaves. [pause] He's still hanging out in there isn't he. And they haven't actually got a better explanation for him. They're not helping him learn. They're just saying, no, you're wrong.**
- 1b:50 **TU: But you can see how children like him get told off a lot in class. I love listening to JB.**
- 1b:51 *CLIP 11: heart [ID: 1a-240] JB: A heart is a living thing. A heart is a living thing because if it wasn't living then we wouldn't be a living thing.
CS: [Simultaneously with what JB has just said] It [the heart] can't mate. It can't mate.
TU: So now [JB] is saying that the heart is a living thing.
JB: Yes. If we don't have a heart the we wouldn't be here...
LN: That is true.
JB: ...nobody would be here.
TU: Could I ask a question. Where is the heart in the tree?
JB: In the middle of it.*
- 1b:52 **TU: So now he thinks that the heart, that independently the heart is a living thing. Is that what he is saying? [playing the clip 11 again] So they're agreeing with him without the heart that we as an individual can't be alive, but it is back to that misconception of live and dead and being a living organism. If I'm understanding it right. And that he's now saying that the heart itself is a living entity. [pause]**
JR: And you come in and say about the tree. And he's then saying...
TU: He's convinced that the tree has got a heart in the middle of it, because we call it the heart of the tree don't we. [pause] I think our language creates huge problems for children like him where there are multiple meanings for a word. I've experienced it more overtly in things like when you talk about condensation and things like that where people misuse the term and when you are weighing something, you know, we get all wound up about the technicalities of whether it is finding the mass or finding the weight and you know I think we do get very wound up in that. But actually I think we're doing it a lot more subtly all the time. In so many of our phrases: he's got a heart of gold, you know. What does that really mean? When we start using metaphors like that then it is not a surprise that these children are confused. And he has obviously heard more than most. He is very much in that lower order of thinking skills. But I think he is capable of, with explanation, I think he is capable of moving through quite quickly. But he is immature and he is excitable which is making it difficult for him to process his thinking I think.
- 1b:53 **TU: I think he is asking all the right questions, but he is not listening to any of the answers. [Both laugh] Do you know what I mean? A bit of a mismatch. It is a bit like when babies are kicking their legs and they're just kicking you to see what happens and eventually they find what the pattern means: a kick here means that that leg is moving. And he is a little bit of that. Shouts out lots of different thoughts and ideas as they come to him, but he never does that finding the pattern. He does it when he sits down. And he can't sit still. He just has to blurt out, he has to turn round. He doesn't understand that when - in doing that there are consequences for doing that. Because he hasn't sat down long enough to process or think it through. And he is doing it with his thinking. Or that's what it appears on here to be.**
- 1b:54 JR: Can I check, are you OK?
TU: Yes, yes.

- 1b:55 JR: In about ten minutes we'll be coming onto the half hour. I'm absolutely fine with the time...
TU: If we move on to the teddy bears then?
 JR: If that is OK.
TU: Yes.
- 1b:56 *CLIP 13: light [ID: 1a-277]* **TU: How come we can see the teddy bear?**
JK: Um. It is because like when this - the torch is powered up by a batteries, it makes a light and if you were in a dark room you kind of like see - it makes lots of light - and you could see a teddy bear.
- 1b:57 **TU: JK has expressed himself quite well so far. He seems to have the concept that you need the light in order to be able to see. And that he has got the idea of the torch being the source of the light. So in terms of conventional thinking he has absorbed it. He has processed it. He seems to have learnt that quite well. And it is the first time he has really been confident in his explanation.**
 JR: I suppose, it is so tricky snippets like this taken out of context. I suppose the reason I'm putting that in there seems to be some thinking among some of the children that that was sufficient as an explanation. That you see because the torch makes light. And then you can see. I suppose it is that sort of thinking that I'm exploring in that one.
- 1b:58 **TU: I think there is an assumption that, 'and therefore it goes into your eyes and therefore it goes into your brain.' But it is not explicit in their explanations. Well in fact, later on it is not clear and we talked to them about it, how it got from the bear to their eyes. In my lessons at the primary school that is as far as they teach them very often. The diagrams of light, and I'm trying to think of most of the resources that I've seen have been about the light landing on the object. But not then a secondary picture that shows it moving on to the eye. So whether that is part of the connection I don't know. Even in our GCSE textbooks we show a picture of the light landing on the object and then reflecting off. Just reflecting off [indicating this with her hand]. If we had an eye at the end of it as a receptor then maybe that might help with that confusion later on that we encountered.**
- 1b:59 *CLIP 14: darkness [ID: 1a-283 to 294]* **TU: ...so we can't see without light?**
JK: Yes. Because it is dark.
TU: OK, so if you don't have a light, what are you saying?
JK: You can see without a light.
TU: You can see without a light. So what is the point of the torch?
JK: Make it [unclear - could be 'more powerful?'] Like a [unclear]
TU: So we've gone into a dark room.
JK: Yes
TU: Can you see the teddy bear?
JK: No, not without a torch.
EM: Not technically without a torch because some people, some people like my Dad are really good at seeing in the dark because they stay up all the time, they never go to bed. [TU starts talking at this point - see 1b-60] Um, so basically
TU: So do we mean a dark room in our houses where there is a little bit of light coming in through the curtains or are we talking about a really [with emphasis and hand gesture] pitch black, like if you go into one of these rides at the fairs where it is totally black. Let's just make sure we know what type of room we're going in.
JB: Thorpe Park [an amusement park]
EM: I think we're talking about, if we turn all these lights off. Get loads of [indicating with her hand the windows] - put some blinds there. Make sure they're properly shut and we can't get
TU: OK, so a really really dark room. And we walk in through the door and teddy is in the middle of the room.

EM: Got to make sure the TV is off.

TU: OK no TV on. Are we going to shut the door behind us in this dark room?

EM: Yes.

BN: No.

TU: Oh, we'd better agree.

BN: No.

TU: I think we're going to shut the door the door.

JB: Why?

TU: I think we're going to go in the room we're going to shut the door. Can we see teddy?

EM: Yes. [Still working on her drawing]

LN: Yes. [Still working on her drawing]

CS: No.

BN: No.

1b:60 **TU: So another expression, "I can see in the dark." What they mean is I can navigate round without using my eyes and seeing. [...are we talking about a really pitch black... are we going to shut the door behind us] so she has definitely got the concept that darkness means no light. But none of them are using that as a term. [...yes, no.] I think that is a lot to do with language. [pause] Because they're still not talking about - they're talking about darkness as if that is the concept as opposed to no light being present. I think that is where the confusion comes in. And the fact that our eyes are light receptors is a thing that we've got to emphasise in order to make it easier for them. I think that's - because it is almost like we've got darkness receptors [laughs] as well has lightness receptors. I've just made up my own phrase there.**

JR: I think [unclear] I've heard children talk about the black, [indicating pupils of eye] the pupils of our eyes as being black things rather than...

TU: Yes, rather than light reflecting...

JR: That light can go through something...

TU: They can't be holes. Because I can't put my finger through it.

JR: Incredible.

1b:61 **TU: I think we'd be better off with just ten words.**

1b:62 JR: Just ten words...

TU: It is just so - [pause] even the tense with which we say things is influencing their understanding. It has landed, it is going to land. Yes.

1b:63 CLIP 15: seeing [ID: 1a-349 to 355] CS: It has landed on teddy. I see him.

TU: How come you see him?

CS: Because the light...

JB: [Interrupts] Because light is reflecting off it. [TU talks over the video at this point - see 1a-64]

TU: What do you mean by reflecting again. You said that earlier.

CS: Reflected is where... You're standing in front of the mirror, you're standing in front of the mirror and you see stuff. That is called reflecting and you can see it like rebounding.

TU: Rebounding. So what is rebounding?

CS: [Still on her feet] the light is going...

TU: So the light is hitting teddy, and then it is rebounding off teddy [mimes with her hand light going from the torch, hitting the teddy and then bounding off towards CS's eyes].

BN: No.

CS: No, not literally like rebounding. It is shining onto him so it light up.

TU: OK, so it is shining on.

CS: It is shining on

TU: You hold it [the torch]. So it goes on.

CS: So it goes straight to teddy.

TU: But how does it get to your eyes?

CS: Because I'm looking, where I'm looking, where ever the torch light is I see it [shows what could be something coming from her eyes to the teddy - unclear]. So I can see the teddy and it all depends whether the light of the battery - whether the batteries are like half dead. You can't really see much.

CS: So I can probably only see to your [TU's] jacket. But then if I - if it was a full battery probably like see quite a way. You can like see teddy from quite a far distance.

- 1b:64 **TU: [Speaking whilst CLIP 15 is playing] You see JB has got it. The light is reflected off teddy. [pause] You see he is good at learning facts isn't he. [pause] So he [JB] has used the terminology, she has described what a reflection is but she still hasn't got the idea that it is going back into her eyes. [pause] So again... [TU indicates something coming out of her eyes] So it is like her vision is tracking and going with the light beam. So it is the directional aspect that is not really... [pause]**
- 1b:65 **TU: I think she is very much thinking forward [indicating seeing as something coming out of her eyes]. The light is going that way [towards the object]. I'm looking that way [towards the object]. That idea of it [light scattering off objects and going into our eyes] to me is not there at all. Not in what she has just said. But I think in the classroom I would have accepted that as an explanation, without having watched it back. I would have taken it at face value and possibly even filled in the gaps for myself. I think probably we do a fair amount of that in the classroom. [both nod and laugh]. Grab the good**
- 1b:66 **TU: ...bits. Ah, they're on the right track. Right OK. We'll fill in the little gaps and finish. But if they don't fill in the gaps themselves they don't really learn it do they. It is that deep learning bit that's, in a big classroom, we're not having the time for. We're doing quite a bit with project based learning about trying to give the children opportunities to learn for themselves. But I don't think they can learn for themselves, I think it is the dialogue with the adult that allows the learning to take place. Because I could have read all of this [indicating the computer playing the video clips] in ten books, and I wouldn't have... and I could have watched myself on a very loose level and not seen any of that and it is only by talking about it, talking to you [indicating JR] that is making me really deeply think about it.**
- 1b:67 **TU: We do so much on a superficial level and I think that is really what is happening there. I was happy with the fact that she'd got the light. She'd got it going onto the bear and she had got it reflecting. And then I filled the rest in. [pause] And the others were happy with that and they accepted that explanation so we moved on.**
- 1b:68 **JR: At the end she is saying something about the distance I think.**
TU: Oh, about the brightness of the bear.
JR: Or that the light - she said something about your cardigan I think or your jumper. The light was travelling a certain distance but not...
TU: Shall we watch it again?
- 1b:69 *CLIP 15: seeing (watched for a second time - see 1b-63)*
- 1b:70 **TU: [Whilst video is still playing] So again I'm happy with that. I've checked what she means. [pause] My arms are saying what the answer should be [indicates this with her hands]. And she is still not picking up on it. Again I've tried to prompt her into the right answer, my arms, my pointing. [pause] I think she has got the concept that distance the light levels decrease [looks at JR as says this]. [pause] She is using her experience that in dim light you only see things quite close to you but in - the further away it is the less light is returning.**
- 1b:71 **TU: So she does have the concept that it is coming back. But it is not going into the eye and being processed by the brain. That is the bit that she is missing isn't it. Or appears to be missing.**
- 1b:72 **JR: Are you OK still?**

- TU: Yes.**
- 1b:73 *CLIP 16: eye (ID: 1a-373) JK: When you see something it has actually come from your eye.*
- 1b:74 **TU: When you see something it comes from your eye. [repeating the clip]**
 JR: It is actually coming from your eye. I think that is what he says. And again, it is out of context but I'm pretty sure that is what he [meant - unclear].
TU: Very Superman isn't it. [pause] I think if I'd heard that better, I think I probably would have used the analogy, "What so you mean my eye is like a projector and what I see is what I'm sending out?" And see if that would then challenge then him and and say, 'No, no, no, that goes in and a projector goes out.'
And try and use those as the contrasts.
- 1b:75 **TU: ...but I don't think I even heard that subtly in that situation. I think we probably miss a lot, especially in a big class where you're moving around. There's lots of things going on and I just don't - I didn't hear it in that small group setting, so I think it is even less likely that I would have heard it in a whole class setting. And so he would have continued on with that thought. If that is a genuine thought [JR shrugs]. And not another JKism [both laugh]. You know.**
- 1b:76 **TU: And there are plenty of those in the tank. [both laugh]**
- 1b:77 **TU: The last one then.**
- 1b:78 *CLIP 17: both (ID: 1a-368) TU: If you think that you see that way [out from eyes] put your hands up. [CS and JB straight away. JK next. LN next. EM slowly. BN hand held next to her cheek - unclear if she is voting or not]*
JK: [To CS] That is only when you go to sleep.
TU: If you think that you see that way [towards eyes] put your hands up. [JK says er and stretches] [BN puts her hand up]
BN: You sort of see both ways. [JK has his hand up too - unclear if this is a vote or asking to speak].
- 1b:79 **TU: [pause] There is doubt there isn't it. They're more confident that we see that way [seeing coming out from the eyes - indicates this with her hands]. A lot to do with egocentricity of the youngsters I think [said with a hesitant tone]. You know, they see themselves, therefore they are the centre. Everything comes into them [indicating hands going towards themselves], but they are controlling everything. They control what they see maybe?**
- 1b:80 **TU: [pause] Don't know. Don't know where their thinking is there. To visualise something you have to go outwards. Unless it is something to do with the fact that it is cognitive. You're choosing to see. And you're moving your head. And because you move your head, what you see is what you control. [indicates this by moving her head and indicating field of vision with her hands]. Don't know.**
- 1b:81 **TU: Interesting though isn't it.**
[End 1b]

Interview 1c

- 1c:1 **TU: Interesting though isn't it.**
 JR: Mm. [JR nods and smiles] **[TU laughs]**
 JR: I find it just amazing.
TU: Three very simple little things. Maybe not so simple.
 JR: Chosen as children have a whole - huge range of ideas - of naive concepts.
TU: And us!
 JR: And us. [pause] I'm so grateful. I realise that is a very difficult thing to do.
TU: It gets easier as you go through each of the screens. I think when you watch the first few. I think it is that sense of embarrassment. "Why didn't I pick that up?" and "I should know that better." All of those sorts of emotions you know. That really

- have nothing to do with the learning. It is all an emotional response to those first few clips I think.**
- 1c:2 JR: And I'm not showing you all the wonderful things you did [both laugh] because I've got that on video. But I have - that is what I'm exploring. So I'm sorry if it give the context - the impression of this being difficult.
TU: No, no, no, no. I think no matter which, no matter what clips you'd have picked. I'd have had the same emotions, because it means a lot to me. If it didn't mean a lot to me I'd be far more blasé, far more flippant. And I don't think I would have sat down and really tried to think about them later on. And I think that when I was watching them I found it hard to answer because I wasn't sure exactly what I was thinking. I'm processing my own thinking and thoughts. I don't want to just blurt out something because they're just surface things really. [indicating with her hand something on the surface of her head]
- 1c:3 JR: I'm aware also that I have the privilege of a month to go through with a fine toothcomb this video. I suppose in the second part of the interview that I'd like to go onto if that is OK - it is really much more of a conversation about some of these things.
TU: That would be good.
 JR: All of those [videos] are still there if at any stage it is handy to watch any of these again. And if you'd like to see the questions that I'm asking they're available by just a click of the mouse there.
- 1c:4 JR: I suppose the first thing I wanted to ask you about - sorry, there are ten questions but - at the moment we're at 2.30? Can I just check with you...
TU: I need to meet somebody at three o'clock.
 JR: How close would you like to go?
TU: Ten to?
 JR: So if we stop at ten to and that gives us twenty five minutes. [checking if TU is OK with this] Would you like a break before we go on with that?
TU: No. I'm fine.
 JR: Absolutely sure to go straight on? I'm really grateful.
TU: I'm not used to that! [both laugh] What's a break?
- 1c:5 JR: First thing I wanted to ask you about was if there was anything that you were thinking during any of the clips that really struck you. Anything that you'd like to go back to as a thought that might still be in your mind.
- 1c:6 **TU: I think it is more the [pause] bits that stick out. I think JB worries me the most. And how I interact with him and if I'm interacting with him like that, and I'm aware of all of this, how is he treated elsewhere and how is that stunting his development?**
- 1c:7 **TU: And I think that is the thing that is really come out of that video. How many times do I tell him off? Or reprimand him or try and control him in a classroom? And actually it's his understanding and his learning that I'm not meeting his needs to move him on. He's got so many questions and I haven't got the time to answer them all.**
- 1c:8 **TU: So I think that is the bit that really will be a big change for me with that class and how I interact with them I think. And also JK. Because he is a clever lad. And I notice in there that he shrinks back and - but when he does give an explanation it is quite clean, it is quite slick and I'd like to really know whether he knows more.**
- 1c:9 **TU: Or whether he has just learnt the classroom patter.**
- 1c:10 JR: It is a fascinating dynamic between those children isn't it.
TU: Mm.
- 1c:11 **TU: Yes, and CS since then has made a massive improvement in lessons. Her confidence level has shot through the roof. Of being able to express herself in that forum. I mean it was a really really positive thing for her.**
 JR: I'm really pleased to hear that.
- 1c:12 **TU: It is a shame we can't do it with lots of little groups of five.**

- JR: [nods agreement]
- 1c:13 JR: Please can you tell me what it was like that process of thinking aloud after watching the videos. Do you think like that in a classroom? And how does this experience of watching those videos compare with what happens in the classroom?
- 1c:14 **TU: I think - no I don't analyse it to that level in the classroom. Most of what happens is instinctive. I think I do listen to the children's responses. I do try to find out where they've got those ideas from, but I think the reality of a main-stream classroom is such that there are so many other things that you need to do and so many other children to listen to that actually you pay lip service to some of it. I think you gloss lots of little ones [indicating with her hand reacting to different children] and it is a rare privilege to be able to spend that time with just a small group and really get to know them. And it is definitely beneficial. If I spent one session like that with a group of five once a term then I think their learning could shoot through the roof.**
- 1c:15 **TU: So instead of having like a test at the end of term I would rather have four or five of them, just me and them chewing over the fat of the topic and I'd really know them. They'd really enjoy it, they'd be able to move on themselves. How we'd do that I don't know. How we'd manage that is the real issue. And I don't think that it is something that you could deploy to a TA [Teaching Assistant] although we have TA's in the classroom. I think to really get to their thinking it requires quite a bit of training.**
- 1c:16 **TU: And quite a commitment on your part to want to know why they want to learn. Not just, these are the facts I have to get though, and I've got to assess this [sentence said quite quickly], and I need to judge whether they're at this level. I think all those sort of practical things, and about measuring success take over from genuine learning. We don't measure those very effectively.**
- 1c:17 **TU: So, I think it is very different from the real classroom. The individual conversations aren't that different. And the questions I've asked I don't think are that much different - because they were instinctive. I didn't have any time to plan it, so I had to react to the children's responses quite quickly. But I don't think I would have given the amount of time to it and I think that in the classroom when I got a misconception like that - like I said earlier - I would get something concrete. Do an experiment, or talk it through with them, or model something in a different way.**
- 1c:18 **TU: ...and then I'd tell it to them. ['chops' one hand with the other to perhaps indicate decisiveness] I would say, "And this is what - these are the known facts, this is how we express it, this is how we write it.**
- 1c:19 **TU: But I think with hindsight with this I might add even more detail to that.**
- 1c:20 JR: Thank you. Which questions did you anticipate coming up. Was there anything that surprised you?
- 1c:21 **TU: The heat one. The heat one I pretty much anticipated the directional movement of heat energy [see body language] and yet the random movement of air. Why does the heat have a definite track and yet air is random? [JP indicating agreement with the complexity of this issue] That - it bemuses me so the fact that they came up with that that didn't surprise me. I thought that that was as expected.**
- 1c:22 **TU: The thing that really - I think I expressed it earlier on with the mushroom - when JB was so adamant that it wasn't a living thing. That it was a dead thing. I don't think I really anticipated that. I think I had an unwritten assumption that he would know that the vast majority of foodstuffs would have been alive at one stage or other [TU shrugs - JP does as well afterwards]. And it just hadn't really occurred to me that he wouldn't get it eventually. That he would stick so rigidly to the rules. [chopping her hand to indicate decisiveness?] "But you said miss they had to do the seven things". [showing up seven fingers and speaking with a decisive tone]**

- 1c:23 **TU: And I have drummed into them, 'If they can't do all seven [holding up fingers], then they're not alive are they.'** and he stuck to my word didn't he. Because he couldn't find evidence of the mushroom moving. Therefore it wasn't alive. And when the leaves dropped off the tree the tree was dead.
- 1c:24 **TU: Because no longer did it move!**
JR: Amazing isn't it.
TU: And, you know, it made me think, the usual example that you would give of a plant responding and moving is either the root movement which they can't see or the turning of the leaves with the sunlight. Well, what do you say when it is a deciduous plant? [rhetorical question] He's right isn't he! [both laugh]
- 1c:25 **TU: His argument is stronger than mine at that point. So that I hadn't anticipated. So I think I would have to think ahead a bit more about that sort of thing. [pause]**
JR: Thank you.
- 1c:26 JR: So a few general questions. We don't need to do all of these but, a naive scientific concept has been defined as non-scientist's everyday understandings of certain bodies of information, it is not meant in any way pejoratively. How do you usually help students who have naive scientific concepts or ideas?
- 1c:27 **TU: [pause] So non-scientific everyday understandings. Well I usually start with, 'What do you understand? What have you heard? Shall we explore it? Shall we do the practicals? Shall we talk about it and see if what these people say, in everyday parlance, is fact or not or can we pr... [stops saying prove?] support those statements or not.' So that's how I would approach that.**
- 1c:28 **TU: Having said that I don't think it is just non-scientists, I think it's - if you're not a specialist in that particular field of science [JP nods]. I think that's a rather generalistic [sic] statement because I think there are lots of physics concepts that I would describe myself as non-scientist... a non-scientist.**
- 1c:29 **TU: And yet, you know, chemistry things I'm quite happy with. Quite confident in my understanding and my knowledge base etc.**
- 1c:30 **TU: So I think I'm probably better in the biology and the chemistry fields, but I'd probably be one of the naive [indicates putting quotations around the word naive with her fingers] people...**
- 1c:31 **TU: ...in terms of my understanding of scientific concepts. I still struggle with voltage and current with students. And even when I go to the, 'Right, what do people generally think?' and then I'm thinking, 'Yes, but that is what I sort of thought as well.' And so how do I - and I'll go and find bits of work. Even when you do the practical it just reinforces that everyday thought process. Because it is easier. It is easier to accept the everyday explanation than it is to challenge your thinking about what is really going on.**
- 1c:32 **TU: So. [pause] That's how I try and tackle it, but I don't know how successful I am. I think I'm more successful in biology and chemistry than I am in - and geography even - than I am in the physics.**
- 1c:33 JR: These are deeply challenging ideas when you say about voltage and current.
- 1c:34 **TU: Yes. All the stuff about nanotechnology. It blows my head away. How is that possible? To have a guitar that plays on an atomic level? [both laugh] I've tried, I've read and it still a mystery. It is magic.**
JR: Yes. [both laugh]
- 1c:35 **TU: That is why I study it. Because I don't know the answer. And it doesn't bother me that I don't know the answers, but I'm curious enough to keep asking the questions.**
- 1c:36 JR: Are you conscious of applying specific teaching practices in your everyday work? Teaching strategies or?
- 1c:37 **TU: [pause] Emotional literacy. In terms of making the children feel comfortable and open to answering questions. And I have consciously worked on that as an**

- aspect of my teaching. And trying to give examples which are both relevant to the students and [pause] engaging.
- 1c:38 TU: What concerns me now is some of those [examples] could be misinterpreted. But I definitely do a lot of breaking down of words, breaking down of terminology. I do lot of visual diagrams, animations, those kinds of things - to cater for those children for them the words are not enough. They need to see it or they need to touch it. So I definitely employ those kinds of strategies.
- 1c:39 TU: Behaviour management strategies are more about positive reinforcement and a lot of, "Yes, I'm really interested in your opinion. Yes, OK, you think that's a bit radical. Let's go with it. Oh, you want to blow up the balloons and not use them for the experiment. OK, so what are we going to do with them then?" And I'll take it down that route and then bring them back round [indicating this with her hand] to the main task in hand.
- 1c:40 TU: So I suppose lots of those sorts of strategies I'm aware of. For those particular topics a lot of discussion. Less so in light actually. But the living/non-living we do lots of examples. But they tend to be nature examples of classical things [said hesitantly] so for example the dessert, the underwater ocean and things. Perhaps it might be better to pick more local examples because I think if we start doing that we might unpick some of those misconceptions better.
- 1c:41 TU: Because the rainforest is not in their experience. Just because they've read Jungle Book doesn't make them rainforest experts. And actually I think some of the examples that I have used because they look interesting, because they look - there's more resources for them. You tend to slip into those categories.
- 1c:42 TU: And when it is a very difficult concept I go to more trouble in finding local examples and things that the children have actually done. Whereas in that topic of living and non-living, I suppose there is almost a hidden assumption that they know it and perhaps I go for a more generalistic [sic], 'What's in the textbook?' [indicating the quotation marks with her hand - tone suggests this is not good]
- 1c:43 TU: There you are. Guilt. [pretends to strike herself on the forehead and leans back in the chair] [both laugh]
- 1c:44 TU: I think it is time. It is laziness sometimes, you know, when I know that this area is something that they have traditionally struggled on then I'll invest more time in it. And I'll try and help them and support them more. Whereas they tend to score more highly on those kinds of topics - the living and the non-living - because even though they've got all those massive misconceptions, by the time it gets to the assessments, generally speaking - by what means, whether it is some sort of mystical - it is in the ether, they seem to resolve it.
- 1c:45 TU: Even if it is - JB will in the next test mark a mushroom as non-living because I've told him it is not. [It is possible that TU meant the converse here from the context]
- 1c:46 TU: Specific practices. [Reading next question] A lot of assessment for learning for those students. So they write it down. I'll then give them feedback on what they need to include next or give them sort of key words and see if they can incorporate them in the right context, those kinds of things.
- 1c:47 JR: Please could you tell me about any experiences you've had with children solving scientific problems themselves. What ways do you try and influence children's problem solving?
- 1c:48 TU: Mostly with cognitive conflict really. I sort of start off with something that they know about and then keep challenging it. An example might be with the Year 7, they're supposed to be doing melting and freezing and boiling - state changes. So we just got bars of chocolate and we just spent a lot of time about how could you stop the chocolate melting in the summer?

- 1c:49 **TU: And did all chocolates melt at the same temperature? By looking at the labels and they came up with some really quite interesting - you know milk chocolate verses dark chocolate. Things like that. So that kind of problem solving I do quite a bit.**
- 1c:50 **TU: ... with the youngsters because we've got the time to do that. And I think it does get them to question a lot more things. And I think it is a very effective strategy, but they can also very easily go off on a tangent and come up with theories which are not accurate. And that is the danger of those kinds of - those sort of open ended investigative problem solving activities.**
- 1c:51 **TU: The other one - with the older ones I've done things like global warming. But again the evidence there is so subjective that they are going out - they are coming up with possible solutions but they can't always see if they come to fruition. An example of that would be they went away and they've worked out that the school could save hundreds of pounds if it had solar panels fitted to the sports centre roof etc. So they'd done all this work. But then it is so frustrating for them because they see then that they've got a possible solution to the school's problem, and yet they have no power to influence that change. It's not going to happen. So what was the point of that exercise?**
- 1c:52 **TU: [pause] So they get disheartened sometimes. It is not like the same as doing a puzzle is it? Where there is an end product. And I think that is - with my problem solving I enjoy doing it, I enjoy working with the children, and I think they enjoyed the process, but I think they find the end product quite frustrating.**
JR: I'm conscious of the time. We've got to quarter to... Are you OK for another quick question?
TU: Of course I am.
- 1c:53 JR: Would you tell me about any experiences you've had where your own scientific and or teaching ideas changed?
- 1c:54 **TU: [pause] Erm. Probably A-Level chemistry really. I never understood organic chemistry at all. Didn't have a clue. Just wrote learnt all the various reaction pathways etc. The ones I needed for the exam. So very much like the children. But teaching it, you know, this idea of curly arrows and electrons moving was like the green light from heaven [smiling and speaking enthusiastically]. It was like, "Oh now I understand it!" So it doesn't matter what the reaction chain is now, I've got behind it, I understand the theory behind it and I just don't ever understand why I didn't understand it. Why I didn't teach it very well.**
- 1c:55 **TU: So for me that was a eureka moment in terms of teaching and helping other children succeed. But on the back of it I changed how I taught Year 11 as well. And I've got a much more simplistic approach. And it is all about patterns, it is not about learning facts. It is about working out the patterns. So I think that has been a big influence to the way I teach. Because I'd focussed on learning reaction pathways. If only I'd learnt the process behind the reaction pathways I'd have saved myself hours.**
- 1c:56 **TU: So now I teach the children patterns and sequences. I don't teach facts, unless right at the end and - like the mushroom - you have to know that's alive. [pause] That is probably the biggest change for my own experiences and how I teach.**
JR: Thank you.
- 1c:57 JR: It has been a real pleasure talking with you. Is there anything about the whole process of this research that you'd like to say or or about this or anything else you'd like to add?
- 1c:58 **TU: No, I think it is really good. I think it makes you think. [pause] You don't have much time to do that. You're so busy doing. And [pointing at the laptop] it is like the last question there. If I could think about the process behind it then it would make everything else flow so much more easily. If I could understand more about how the children think then I'm going to be more effective.**

- 1c:59 **TU: I'm dying to know what happens and whether there are any common ideas and common thread of things they do or things that we do that can bridge that gap.**
- 1c:60 **TU: Yes, I'm all for it. I'll read your book. [both laugh]**
- 1c:61 JR: On that note. I'm so grateful for everything you've done on both these interviews and for helping me get this sorted. Many thanks.
TU: It's alright.

[End 1c]

Interview 2a

- 2a:1 [Preparation - filling in informed consent letters]
- 2a:2 [Introduction]
- 2a:3 [Question 1]
- 2a:4 [Question 2]
- 2a:5 **TV: OK. So we're going to start with the first topic, which is going to be this [reaches over to the resources table to get the cup of tea and ice cubes]. Right, I have - I'm going to put them here in front of you - you have a mug. Let's assume you have hot tea in there and then a bowl that contains ice cubes. Can you tell me what you think is happening there?**
- 2a:6 SF: The ice. The ice cubes are melting. [Points at the ice cubes]
- 2a:7 BB: And the water - the hot water is getting colder.
- 2a:8 **TV: OK. Why do you think that is? [Looking at BB]**
- 2a:9 LD: Because the...
 SF: You [LD] go first.
 LD: ...the environment and the atmosphere with the ice cubes [pointing at them] is warm and the ice cubes are cold which means that the ice cubes get heated up and they start to turn into water [LD looks at TV].
- 2a:10 **TV: Do you agree with this? [TV looking round at ES and UG]**
- 2a:11 All: Yes.
- 2a:12 **TV: OK. So where does the heat go then? We can take one at a time [pointing at the ice cubes]. So what is happening to the heat in that case [the ice cubes]? In the case of the ice cubes?**
- 2a:13 BB: It [heat] is actually melting the ice cubes.
- 2a:14 **TV: The heat is melting it. OK. Do you [BB] know where it is coming from?**
- 2a:15 AC: [Short pause] Body temperature.
- 2a:16 **TV: The body temperature. Whose body?**
- 2a:17 SF: Us. The students. [AC saying the same]
- 2a:18 **TV: OK. So how does it go there then?**
- 2a:19 BB: Breathing? [Indicating something coming out of his mouth with his hand].
- 2a:20 **TV: OK. Can you expand that?**
- 2a:21 BB: [Unclear] when you blow it you'll be trying to make it colder.
- 2a:22 **TV: Would I want to do that myself or does it happen anyway?**
- 2a:23 BB: Maybe because, it you wanted to drink the tea really badly you can just blow it. But if you wanted to wait for a bit you could just wait for a bit.
- 2a:24 **TV: OK. Are you talking about things getting colder. So this applies to the tea. So the tea is getting colder. Is it because of us around [looking round and indicating students round the table with his hands]? Have we got something to do? If we were not in that room what would have happened. Would it have made a difference?**
- 2a:25 SF: The cubes wouldn't have melted so fast because there is less heat in the room.
- 2a:26 **TV: OK. So the heat is coming from us.**
- 2a:27 SF: Well, most of it. Because the overhead projector... [points at the projector]

- 2a:28 AC: Any you've put on the temperature probably in order to keep us all warm [unclear as AC is speaking very quietly]. [AC points and looks at the radiators in the room so appears to be referring to these].
- 2a:29 **TV: Oh. That's very good. So you have actually identified the heat sources in the room. Right, so the heat sources - they travel to the ice cubes?**
- 2a:30 AC: Yes.
- 2a:31 **TV: In what way?**
- 2a:32 ES: [unclear - speaking very quietly indeed].
- 2a:33 **TV: So the heat spreads out from the heat sources [indicates this with a movement of his hands]. And er... therefore temperature wise. What do you think is happening to the ice cubes? In terms of temperature what can you tell me?**
- 2a:34 BB: They're getting warmer. [Repeated by other students]
- 2a:35 **TV: They're getting warmer. And... yes. [BB starts to speak].**
- 2a:36 BB: And the tea is getting colder.
- 2a:37 **TV: So do you think that the tea's temperature... the heat. Is it because of the hot and cold [indicating the cup and bowl with his hand] placed next to each other? That makes a difference?**
- 2a:38 AC: [Shaking his head]. No. [BB seems to be agreeing with AC].
- 2a:39 **TV: It won't make a difference?**
- 2a:40 **TV: So it would happen wherever I put the tea and cold... ice cubes? OK. So what is your theory then? Can we sum up? Can we sum up anything. Can we have something that is general?**
- 2a:41 LD: The warmer the atmosphere and environment the... [BB interrupts]
 BB: ...quicker the ice cubes melt.
 LD: Yes. And the tea... [pause].
 BB: The colder the atmosphere is, the colder it is.
- 2a:42 **TV: Which one?**
- 2a:43 Several students at once: The tea. [BB points at the tea cup].
- 2a:44 **TV: The colder the tea gets.**
- 2a:45 AC: The atmosphere is a lot more colder than the actual tea itself, so that is why it cools it down.
- 2a:46 **TV: So therefore... [AC says something - unclear]. What is being passed from the tea to the atmosphere?**
- 2a:47 AC, LD and BB: Heat.
- 2a:48 **TV: OK. And er can you, I think I'm quite interested with the way the heat is transferred to the atmosphere. Can you tell me what makes that... what takes that heat to the atmosphere?**
- 2a:49 SF: The steam coming off the water.
- 2a:50 AC: The evaporating water.
- 2a:51 **TV: OK. That is good. Is there any other way the heat is going to the atmosphere? Apart from the steam.**
- 2a:52 AC: Well it's because there is no lid on it. It is just open so the atmosphere can get into it and go into it.
- 2a:53 **TV: OK. So...**
- 2a:54 ES: [Unclear - very quiet. Seems to be saying that the heat can go into the mug.]
- 2a:55 **TV: It is warming up the mug? [ES nods]. OK, and the mug, what is the mug doing? Is the mug contributing to cooling the tea down?**
- 2a:56 ES: Yes. Because if it was in a plastic bottle it would insulate the tea.
- 2a:57 **TV: OK. So the plastic bottle would keep the heat in? [Indicates the sides of the bottle with his hands]. And... [ES interrupts]**
- 2a:58 ES: The plastic one wouldn't work as good [as the tea cup] because the heat would be escaping easily.
- 2a:59 **TV: So the heat is escaping easier with this one [indicating the cup of tea].**

- 2a:60 SF and others: No. It [the mug] is keeping it more in.
- 2a:61 **TV: OK. Right. And if... what would happen then if it were metal container?**
- 2a:62 LD: A metal container would become hotter because if you've got hot tea in there and it is in a metal container, because metal is a conductor of heat [BB says conductor at the same time] and electricity. If you were to touch it then the metal would be as hot as the water inside it.
- 2a:63 **TV: So would it cool down faster with the metal? [Question directed at LD]**
- 2a:64 BB: [Shaking his head].
- Another student [unclear who]: No.
- 2a:65 **TV: No? Even if it conducts the heat away? If it takes the heat away? It is a better conductor of heat? So does it not take the heat away from the hot tea?**
- 2a:66 [pause]
LD: [With a smile] Yes. Yes it does.
- 2a:67 **TV: Why did you change your mind then?**
- 2a:68 LD: Because the metal is actually taking the heat from the water - from the tea - so that is making the tea colder and the metal container hotter
- 2a:69 **TV: OK.**
- 2a:70 ES: You get those... er... I don't know what they're called. [mines shape of the object].
AC: Flasks.
ES: Yes, flasks. And on the outside they're cold so they aren't giving off any heat from the outside and that's how they keep them warm.
- 2a:71 **TV: So you would then know if the surface if the surface is cold that the heat...**
SF: Stays in
TV: ...stays in, and if it is hot, then... [pauses]
AC: It is insulated.
TV: or is... [pausing signalling with his hands that something more is needed]
AC: is coming out.
TV: Is coming out. [Said in a tone that confirms what AC has just said]
- 2a:72 **TV: Right. So the word insulated here... if you, when... I would rather say that the heat is being conducted away... [pauses and looks at AC as if confirming that AC is in agreement] alright? Rather than insulated. Insulated is the opposite of...? [Waiting for an answer]**
- 2a:73 AC: Oh yes. [Presumably 'of conduction']
- 2a:74 **TV: Do you agree? Insulation is when you stop something from going beyond. Yes? Are you happy with this?**
- 2a:75 Several students: Yes.
- 2a:76 **TV: So are we happy with the theory? So... [pauses and looks round at UG]. I haven't heard from you, so can you just very quickly tell me about the theory?**
- 2a:77 UG: Err, well the ice cubes - the reason they get warmer is because of the heat in the room.
TV: Yes.
UG: And our body temperatures. And the hotter it is the quicker the ice cubes will melt.
TV: Good.
- 2a:78 UG: And the tea, [pause] the lower the temperature in the room, the quicker it will cool down.
- 2a:79 **TV: OK. Right. So, essentially it is about where the heat is going. Right. The heat will always go where?**
- 2a:80 **TV: [After a slight pause] In terms of temperature. If you have a high temperature here [indicating the high temperature with one hand held high] and a low temperature there [the other hand is held low down] which way will the heat be going to?**
- 2a:81 AC and BB: Down.
- 2a:82 **TV: From...? Always from a...? ...from a hotter object to a...**

- 2a:83 Several students: colder
TV: colder object. [Tone confirms the students' answer].
- 2a:84 **TV: So this is a hotter object [indicating the tea with his hand] so the heat tends to go out [shows movement out from the cup of tea with his hand]. And...**
- 2a:85 BB: This is a colder one so it would go up. [Indicates something going up with his hand]
- 2a:86 **TV: So heat goes from the hotter to the colder. So that's the theory is it? Does everyone agree with that?**
 Several students: Yes.
- 2a:87 **TV: Right. OK. We'll move on now to another activity. Right, and we're going to see whether your ideas change during the course of that second discussion we're going to have. OK, it is not a difficult - something difficult you're going to do. So what I'm going to ask you to do is - I'm going to give you a set of cards - right, each of you. [Says this while getting cards and mats ready] and two mats. Right? Like this, right. Cards - two mats. [TV is handing out materials]. And you will have to work individually. You're not looking at what neighbours are doing. So - but we are going to discuss the ideas straight away after that. And those cards would be about living things and non-living things - it is for you to sort them and place them on the right matt.**
- 2a:88 **TV: Yes. OK? [pause while students get cards out of the packets]**
- 2a:89 *JR: Just to add that it is OK to change your mind on this one - you know, afterwards. Pop them down and then we'll talk.*
- 2a:90 **TV: You might want to move them to some other place. From one to the other.**
- 2a:91 **TV: [TV starts to get his own pack of cards out and sort them onto the mats. I go over and quietly asks him not to do this until the students have finished putting their cards out. I was concerned that students would have a 'teacher answer' on the table which they might copy.]**
- 2a:92 [Pause while students sort cards. TV picks something off the floor - probably a card that has dropped off. TV stands up and looks at the mats as the students continue to sort the cards. JR removes the plastic bags which the cards came in from the table - this was because they might stop students from seeing each other's mats and because they were on top of the audio recorder and might have muffled the sound recording. TV walks round the table looking at the mats. TV pauses for a moment next to AC looking at his matt.]
- 2a:93 **TV: Are you convinced about everything? [Said to AC. TV walks back round the table to his seat]**
 AC: No.
- 2a:94 **TV: OK. Any doubts?**
- 2a:95 AC: By candle does it mean a lit candle or just a candle stick?
- 2a:96 LD: Lit candle. Hence the picture. [Looks down at her mat whilst smiling]
 SF: [Looking at AC with an amused and incredulous expression on her face.]
TV: [TV is smiling as well]
- 2a:97 **TV: [unclear] can you? So was there any problem deciding - because was it going to be lit. OK. We can discuss that.**
- 2a:98 **TV: OK. So I can see we're nearly there. [Pause]**
- 2a:99 *JR: Sorry, would you mind if I took a photo of the desk at that point? I know things are going to change as you talk. But it would be just really interesting as regards my work just to have a snapshot of that. Is that OK with everyone?*
- 2a:100 **TV: Is that OK? Yes?**
- 2a:101 *JR: Thank you. [Takes a photo of the desk] Like I say, no problem about moving things afterwards. Just a quick photo of the desk. Thank you.*
- 2a:102 **TV: OK then. So, you have pretty much a good idea of what you consider as living and non-living. Right. Now, is there anything that you already had in mind about living things and non-living things before you put those pictures on those mats? Yes SF?**

- 2a:103 SF: I was going to say that living could be something that... [BB interrupts]
 BB: Moving around
 SF: Yes, is moving. Like a person has organs that keep us alive and stuff like that.
- 2a:104 **TV: Anything that moves about you would consider as living. [Slight question in the voice perhaps] Yes. Any other feature about the living things... [LD has her hand up].**
- 2a:105 BB: Anything that can... um... get nutrients.
- 2a:106 **TV: Anything that picks up nutrients from somewhere. Alright, so that's another one. What? OK. [inviting LD to speak]**
- 2a:107 LD: Anything that grows or develops into something else. For example a tree grows bigger and bigger, and a person grows bigger and bigger, and a dog grows bigger and bigger. But a brick would just stay the same size. It can't get physically larger.
- 2a:108 **TV: Yes. Alright. OK, and what would you say? [AC is trying to come in and TV invites him to speak]**
- 2a:109 AC: It is like something that can make its own decisions and not controlled by anyone else. Like a dog has got its own mind. But a brick, you move it around. It can't move by itself.
- 2a:110 **TV: I see. Any anything else you would like to - helps you decide whether living or non-living?**
- 2a:111 BB: You need to do MRS NERG.
- 2a:112 **TV: MRS NERG. OK. So you learned that where? Where did you learn that about MRS NERG?**
- 2a:113 BB: I learned when I was in Year 4.
- 2a:114 **TV: Right, can you tell me about MRS NERG then? Can you expand on that please.**
- 2a:115 BB: [pause] Nutrients... [pause]
- 2a:116 LD: Isn't it movement, respiration, [counting them off on her hand]
 SF: Isn't it reproduction? [quietly to LD]
 LD: No, reproduction is the second R I think.
 SF: Yes.
 LD: Yes. S is [pause]
- 2a:117 **TV: Sense? Sensitivity?**
 LD: Yes, yes.
TV: To the environment. Yes? OK?
- 2a:118 LD: Nutrients, or nutrition [someone else says nutrition at the same time].
- 2a:119 **TV: And?**
- 2a:120 LD: Excretion, reproduction and fertilization [looking at TV as if not sure of this last one].
- 2a:121 **TV: Reproduction and G growth. Alright.**
 LD: Oh yes. Growth.
TV: OK. So, summing up. MRS NERG. M for movement. R for reproduction. S - sensitivity. N... [pauses]
Several students: nutrition.
TV: Nutrition. It takes nutrition. It takes nutrients from somewhere. E... [pauses]
Several students: excretion.
TV: Excretion. You [BB] said energy and now excretion. Very good. Then after E we have R. And you [SR] were talking about the second R was reproduction and G you [ES or UG - unclear] were saying...
 UG: Growth.
TV: Growth.
- 2a:122 **TV: Looking at your pictures now. Anything that moves would fit into what? Living? Right. OK. So if we just do it this way [indicating with his hand to go from living matt] we look at everything that moves. Do they all move?**
- 2a:123 AC: The candle... [pauses]

2a:124 BB: The egg doesn't.

2a:125 AC: You can if you push it.

2a:126 LD: But you see the ball falling...
SF: you have to make it...
LD: Yes. You have to actually drop it.
SF: Because if you put it on a table it won't move unless you do something to make it move.

2a:127 **TV: OK. Therefore so, alright. So let's wait until the end. Right. Err. Then R would be?**

2a:128 Unclear which student: Respiration

2a:129 **TV: Respiration. Does it [the ball?] respire?**

2a:130 BB: No.

2a:131 **TV: So the things that you have put on the living matt. So do you have things that respire? Now I can see you've [LD] put cloud on your living matt. Do you think clouds respire?**

2a:132 BB: Well not really.

2a:133 **TV: OK. What sort of things respire?**

2a:134 AC: Humans.

2a:135 **TV: Humans.**

2a:136 BB: Animals.

2a:137 **TV: Therefore animals. Yes? All animals?**

A student (unclear who): Yes.
TV: Yes? What about plants? Would you say - do you think plants respire?

2a:138 BB: Yes. [Another student - unclear who - repeats this]

2a:139 **TV: So therefore they respire to produce energy. This is the name of the process. They produce energy. Now - so would you say that clouds therefore produce energy?**

2a:140 SF: Yes. They produce rain.

2a:141 **TV: Do they respire to produce energy?**

2a:142 BB and LD: No. [SF seems to shake her head slightly - it appears she is accepting that clouds do not respire to produce energy]

2a:143 **TV: No. Alright. Is there anything that you would change then as we are going through?**

2a:144 SF: I've changed the clock! [she laughs as she says this]

2a:145 **TV: OK, you've changed the clock. It moves, but it doesn't respire. It doesn't produce energy. What about S? Is it sensitive to conditions around them?**

2a:146 SF: Yes. A person is.

2a:147 **TV: A person is.**

2a:148 SF: And a dog.

2a:149 **TV: OK.**

2a:150 BB: A lion is.

2a:151 **TV: Yes OK.**

2a:152 SF: And a spider is.

2a:153 **TV: Yes. Do you think the sun is sensitive. You [SF] put it on the living? Do you think that the sun is sensitive to its environment?**

2a:154 BB: Well it is a star.

2a:155 LD: The sun is part of the environment that we're talking about. It is sensitive to it.

2a:156 **TV: Because it is part of the environment, does that make it sensitive?**

2a:157 **TV: For example that table, it is part of the environment, does that make it sensitive to the environment?**

2a:158 BB: No. [Shakes his head]

2a:159 **TV: [Pause] OK? What do you [LD] think?**

2a:160 LD: It could [speaking quite slowly - appears to be thinking about this] because of the...
[TV starts speaking]

- 2a:161 **TV: OK. Let's look at the other ones. You might find it easier to eliminate it if we carry on. Now nutrition. Does it need to be fed? Does it need to have nutrients to grow?**
- 2a:162 SF: Yes. Plants do and trees.
- 2a:163 **TV: OK. Does - little - OK. If you think that you can move them right. So erm. Does it need something in order to live? Right. So that is why you've got to think. Does it make any difference to yours [UG]?**
- 2a:164 AC: Yes.
- 2a:165 **TV: Right. Living? [BB moves a card]**
- 2a:166 **TV: The candle. Do you think that the candle is living? Does it need nutrients from the environment?**
- 2a:167 BB: No.
SF: It needs to be lit.
BB: It needs wind.
- 2a:168 **TV: It needs wind.**
- 2a:169 SF: It needs to be lit by a...
AC: How does it need wind?
- 2a:170 BB: So it can spread out.
- 2a:171 **TV: So is that wind a nutrient?**
- 2a:172 BB: No.
- 2a:173 **TV: No. OK. Do you [ES] agree with what we're saying? So the candle. Alright, we'll go around and then we'll go and discuss this further. So you can ask me if you have doubts. OK then, so after nutrition - excretion. Excretion means they are producing wastes.**
- 2a:174 SF: Yes.
AC: You know plants. Do plants do that [excrete]?
- 2a:175 **TV: Plants do that [excrete] yes.**
- 2a:176 **TV: What waste do we get from plants? [asking AC]**
- 2a:177 ES: [unclear - something about leaves dropping off]
- 2a:178 **TV: OK. So the leaves die. Because of...**
- 2a:179 ES: [unclear - very quiet]
- 2a:180 **TV: OK. That could be considered as waste. What about when you have respiration. The plants produce... they take carbon dioxide in. Yes? And they release... [pauses]**
- 2a:181 LD: Oxygen.
AC: Oh yes.
- 2a:182 **TV: Yes? So in that sense they don't need the oxygen do they. At that time. Right. OK. Then excretion. After excretion reproduction. Now that could make a difference to your pictures. Now do they reproduce? Do they reproduce?**
- 2a:183 SF: A bicycle doesn't. [Moves the bicycle card from living to non-living]
LD: [Quietly to SF] Why did you put it there? [unclear - but I think this is right]
SF: Because it moves. [Laughing with LD]
- 2a:184 **TV: So does the sun reproduce? So why did you [SF] make that change then?**
- 2a:185 SF: Because a bicycle doesn't reproduce, unless you make another one.
- 2a:186 **TV: OK. They don't make another bicycle. [Smiling and laughing a little]**
SF: Sorry.
- 2a:187 **TV: Right. Agreed? Right, what is the last one then?**
- 2a:188 Several students: Growth.
- 2a:189 **TV: Right. After reproduction is growth. So do they grow? Can they grow?**
- 2a:190 LD: Do rivers grow?
- 2a:191 BB: Yes they can.
- 2a:192 **TV: Do rivers grow?**
- 2a:193 SF: Yes, that is what I was thinking.
- 2a:194 BB: No.

TV: Why not?
BB: Well...
AC: They can.
AC: I thought they could but they can't. [Sits up as he says this]
SF: Because if more rain falls into it, wouldn't it grow bigger? [speaking with BB - indicating with her hands the river swelling].

2a:195 **BB:** Yes.
AC: But that is not growing for itself.
LD: I think the word is erosion on the rock on the side [showing the river eroding the bank with her hand]. Maybe it can wear out the sides - meaning that it grows bigger. [She says the last word 'grows' more quietly than the other words in the sentence].

2a:196 **SF:** And then more rain can come in. [Showing the river swelling with her hands].

2a:197 **TV: So when you have more water it goes - it swells then. But do rivers reproduce then? [Tone implies that they don't]**

2a:198 **SF and LD:** No.

2a:199 **TV: No. Right. Now remember the MRS NERG thing is about living things. All living things should be doing all the things we said about MRS NERG. Right? OK? So what I'm going to say to you now is - think about all the seven characteristics of life and tell me that each - if each and every picture that you have put on the living mat lives - they meet all those conditions.**

2a:200 **TV: Right. So you're allowed to change - to move them again. Right, if you think that the living things do not meet all of the seven conditions. Right. What are you moving? [Addressing ES]. So you're still stuck on your pictures? You haven't moved...**

2a:201 **ES:** I think seeds grow, and then they reproduce. I think they germinate.

2a:202 **TV: They grown then. Yes.**

2a:203 **AC:** [unclear - conversation simultaneous with 203 and 204]
LD: They don't though do they. [Speaking with AC - unclear but it appears to be about whether seeds are alive]
SF: Seeds don't reproduce do they? Do seeds reproduce.

2a:204 **ES:** This [the leaf I think] doesn't reproduce. But it grows.

2a:205 **TV: So as long as it is in contact - connected to the tree would you say that the leaf can grow?**

2a:206 **ES:** Yes.

2a:207 **TV: Right. Does the leaf take in nutrients?**

2a:208 **ES:** Yes. [LD has her hand up]

2a:209 **TV: Where does it get the nutrients from?**

2a:210 **ES:** The soil.

2a:211 **BB:** From the stem.

2a:212 **LD:** Roots. Or the soil. [Still has hand up].

2a:213 **TV: From the?**
ES: The sun.
BB: The stem.
TV: And where does the stem get the nutrients from?
ES: Oh.

2a:214 **TV: Nutrients are the minerals which it collects from the soil which go up through the stem. Right? So as long as it is connected to the...**

2a:215 **BB:** Stem.

2a:216 **TV: Branch, or stem, it is living. Isn't it?**

2a:217 **AC:** It is not like the dead leaf is it. [Said like a statement rather than a question]

2a:218 **TV: Right. When they come off the tree then...**

2a:219 **BB:** It is dead.

- 2a:220 **TV: It is dead because it can no longer take nutrients from the tree. [TV sees LD's hand and turns to her].**
- 2a:221 LD: With the embryo, it does lots of things, but it doesn't reproduce. Would you still put it as living because if it was living it would be a person, because it reproduces when it grows older?
- 2a:222 **TV: OK. Now is a person something that can reproduce itself?**
- 2a:223 SF, BB and others: No.
- 2a:224 **TV: A person. Don't we reproduce? Don't we produce new ones?**
- 2a:225 SF: Oh yes. Yes but we won't...
AC: We need someone else. [With a smile - SF and LD laugh]
- 2a:226 BB: Unless they're cloned.
- 2a:227 **TV: Yes. We have the ability to reproduce. We need a male and a female. We can't reproduce all by ourselves do we.**
- 2a:228 SF: No.
- 2a:229 **TV: Can we reproduce from birth?**
- 2a:230 Several students: No.
- 2a:231 **TV: No. Right. So the same thing - do you think the same thing applies to an embryo?**
- 2a:232 AC: No. [Shaking his head]
- 2a:233 **TV: So they are living things aren't they. I mean - the question was, 'Can they reproduce?'. Yes, but there is a time for reproduction. We should be prepared to do that. We should be ready. Now you, if you think of children at a very early age, they can't reproduce can they?**
- 2a:234 Several students: No.
BB: They'll usually just play around. [SF turns to LD laughing - TV and BB join in]
- 2a:235 **TV: Right. OK. So still talking about reproduction. So there is a time for it, isn't there?**
- 2a:236 **TV: Even though we are living - we consider ourselves to be living things, but reproduction comes at a later stage. [SF and LD still giggling]**
- 2a:237 **TV: Now, OK. So now, so. Embryo, does it meet the other requirements [asking SF]? About growing...**
- 2a:238 Several students: Yes.
- 2a:239 **TV: So does that take... are you happy when I say to you the reproduction - we will still consider this as a living thing, but the reproduction comes at a later stage?**
- 2a:240 SF and LD: Yes.
- 2a:241 **TV: Is there any question you want to ask me about anything that you have [indicating with his fingers something in the mind].**
- 2a:242 BB: The sun. Because it does kind of actually reproduce.
LD: [Looking and sounding incredulous] But not other suns.
SF: Yes, but it produces the rays of sunlight.
- 2a:243 BB: Yes.
- 2a:244 **TV: Are you trying to say that they are reproducing energy. They are producing another thing of the same type?**
- 2a:245 BB: Yes.
- 2a:246 **TV: So that energy, what... what can we say about it? [Turning to the group] Can we reproduce energy?**
- 2a:247 Several students: Yes.
ES: It can be transformed into different things.
- 2a:248 **TV: OK. Have you... [BB tries to come in]. Yes. Do you remember we talked about - Mr [unclear]. You must have done that in some lessons before. What did we say about energy?**
- 2a:249 AC: Kinetic, potential...
BB: There is kinetic, sound, light, heat and kinetic.

- 2a:250 **TV: OK. So what was the idea about energy. Can they be produced? Can we produce energy?**
- 2a:251 BB: Yes we can. Like that diagram of when you [pointing at a diagram on the wall which shows energy transfer of a ball falling in a gravitational field] or just this one [picking up a card on the table and dropping it] when you just lift it up then you drop it.
- 2a:252 AC: That is not us producing energy. [unclear - said to BB while ES is speaking with TV - see below]
 ES: That is like transferred [unclear]. So that is basically other energy that has come from other things. It has been kind of recycled.
- 2a:253 **TV: OK. Are you [BB] happy with this idea? [from ES]**
- 2a:254 BB: Yes.
- 2a:255 **TV: Yes, so what ES was saying that energy is not produced, but it comes from somewhere else. Alright. [Several students say yes]. We need something to transfer the energy. And in that case [the card showing a person with a ball] it is your stick person picking up the ball. So the person is only an excuse for transferring the energy. Isn't it? [BB agrees] Right. OK. So what can we say therefore? Do you have any question about... Now look at the non-living thing. Right. OK. I will ask you. Very quickly. Now an egg. Living or non-living?**
- 2a:256 Several students: Non-living.
- 2a:257 **TV: Non-living? Why non-living?**
- 2a:258 AC: It doesn't reproduce.
- 2a:259 **TV: It doesn't reproduce. Didn't we agree...**
- 2a:260 SF: It doesn't really grow.
 BB: It does...
 AC: It could be a boiled egg.
 LD: If we didn't have the picture of it, it could [be alive]. Because it could be a different kind of egg.
 AC: That is an eating egg. That is an egg ready to eat. [points at the picture TV is holding up].
- 2a:261 **TV: Right. OK. You think - when it is... OK. Therefore it is boiled, yes?**
- 2a:262 **TV: When you boil it it becomes living or non-living?**
- 2a:263 Several students: Non-living.
- 2a:264 **TV: Non-living. But before that? Was it living?**
- 2a:265 ES: It depends whether the chicken has...
 SF: Don't people like inject stuff into the egg to make it like...
- 2a:266 **TV: Freshly laid from the...**
ES: If the chicken hasn't been around a male - a cockerel, if there hasn't been sexual intercourse [SF looks at LD and starts to laugh. LD doesn't laugh but smiles] then because they're basically - that's like... It is like a woman's egg so it is just like a woman's periods.
- 2a:267 **TV: OK. Now you say a woman's egg. Is that living or non-living?**
- 2a:268 ES: It is non-living.
- 2a:269 **TV: Non-living?**
- 2a:270 SF: Yet. Not living yet because it hasn't been fertilised by...
 LD: Male sperm.
 SF: Yes, male sperm.
- 2a:271 **TV: OK. I'm going to put that to you. An egg. Is it a cell or not?**
- 2a:272 SF: Not sure. [The expression on her face matches this]
 BB: Erm. Well. [pause]
 AC: The shell is kind of like the cell wall.
- 2a:273 LD: And the yolk is kind of like the nucleus.
- 2a:274 **TV: If I said to you now, OK, that this is a cell that you're looking at. This is one of the largest cells that you can see. Right. Now by definition, is a cell living or non-living?**

2a:275 SF and LD: Depends.
 BB: Living.

2a:276 **TV: Living? Why?**

2a:277 AC: [After a short pause] Because it... when they join they reproduce other cells.

2a:278 **TV: Cells can multiply?**
 AC: Yes.

2a:279 **TV: So they take nutrients from outside? They can move can they?**
 BB and AC: Yes.

2a:280 **TV: Yes. They can move. Are they sensitive?**

2a:281 Everyone: Yes.

2a:282 **TV: Yes? So they can produce wastes, can they?**

2a:283 Everyone: Yes.

2a:284 **TV: Yes. OK. So if a cell can do all these, would an egg be a living thing then?**

2a:285 SF: We don't know if it is a cell or not. [Head is leaning on her hand - tone and facial expression may indicate she is not happy about something].

2a:286 BB: Yes it is a cell.
 SF: Oh.
 BB: But we don't know if it is cooked or not.

2a:287 **TV: OK, freshly laid. Living or non-living?**

2a:288 AC: Living.

2a:289 **TV: Living. Alright. So it can produce - you can get a chicken out of it can't you?**

2a:290 Everyone: Yes.

2a:291 **TV: So therefore it can grow into a chicken. So therefore it is living. When you boil it...**

2a:292 AC: It is killed.
 BB: That is when it is non-living.

2a:293 **TV: OK, so what makes it different then when you boil it?**

2a:294 LD: It turns into food. [Said very quietly]
TV: Sorry?
 LD: [Louder] It turns into food cooked. [TV smiles]

2a:295 **TV: It turns into food. So it destroys when you're cooking. It destroys its ability to...**

2a:296 SF: Live.
 LD: Grow.

2a:297 **TV: To grow. It changes it. The plant?**

2a:298 Everyone: Living.

2a:299 **TV: OK. Do you all agree? [Looking round] Yes. OK. If you don't agree you tell me. Right. Firing a gun?**

2a:300 Everyone: Non-living. [Students are looking tired]

2a:301 **TV: But it is moving?**

2a:302 SF: But it doesn't... it doesn't grow.

2a:303 AC: It is not sensitive.

2a:304 BB: Somebody, somebody like pulled the trigger, so...

2a:305 SF: It doesn't grow.
 LD: It is only moving because a person did it.

2a:306 **TV: OK. Someone else activated it. OK. Right. What about this one which is a dead leaf?**

2a:307 Everyone: No.

2a:308 **TV: The word gives it away doesn't it. [TV and students laugh]**

2a:309 **TV: What about fire? [Holding up the card]**

2a:310 Everyone: Non-living.
 AC: It doesn't reproduce.
TV: But it moves. [Tone suggests surprise]
 AC: It doesn't move. It is not sensitive.

LD: It does move.
 SF: It does move doesn't it, because like spreads out and that...
 LD: It doesn't reproduce. That means it grows.
 SF: Oh.

2a:311 AC: It doesn't get with another piece of fire and make a small piece of fire. [LD laughs]
 2a:312 **TV: OK. Right. So there are things that you can eliminate because they are things that do not fit with MRS NERG. [Holds up another card - unclear which one]**

2a:313 Everyone: Yes. [living]
 2a:314 **TV: Fine. The soil. [Holding the card up]**
 2a:315 Everyone but starting with BB: No. [Said more tentatively than the last one].
 2a:316 **TV: Spider?**
 2a:317 LD: Yes.
 2a:318 **TV: All agree? [JR knocks the camera slightly by accident and BB turns round to look].**

2a:319 **TV: Water?**
 2a:320 AC and others: No.
 2a:321 **TV: Water is non-living.**
 2a:322 SF: Yes.
 2a:323 **TV: Water can move can't it?**
 2a:324 ES: [unclear as BB is speaking at the same time]
 UG?: Yes, but it can't reproduce.
 BB: [unclear] shaking it.
 ES: [unclear - very quiet] [TV looks at JR - I was pointing at my watch to indicate that we needed to go onto the final question soon if we were to have enough time to discuss it.]

2a:325 **TV: Brick?**
 2a:326 Everyone: No. [SF and LD laugh]
 2a:327 **TV: Why did you eliminate brick?**
 2a:328 SF: It doesn't do anything. It just sits there.
 AC: It just sits there and does nothing.
 UG?: It doesn't move.
 ??: It can't do anything.

2a:329 **TV: [TV holds the picture of the clock up].**
BB: Clock.
 AC: Non-living.

2a:330 **TV: It makes noise.**
 2a:331 ??: Yes, but it doesn't reproduce though. [TV laughs]
 2a:332 *JR: I'm really sorry to interrupt. Would you mind if I took another photo of the desk so we can see the changes from this side?*
Everyone: Yes.

2a:333 *JR: Thank you very much. I really appreciate that.*
TV: Car?

2a:334 SF: No, because the person is making it move and stuff like that. And it doesn't reproduce.

2a:335 **TV: OK. That one? [Holding up another card - unclear which one].**
 2a:336 Everyone: Yes.
 2a:337 **TV: Dog?**
 2a:338 Everyone: Yes.
 2a:339 **TV: Mushroom**
 2a:340 Everyone: Yes. [Clearly more hesitant than dog]
 2a:341 **TV: Can it move?**
 2a:342 BB: No.
 2a:343 ES: [unclear - very quiet]
 2a:344 SF: It grows and develops.

2a:345 SF: And as it grows it kind of moves.

2a:346 **TV: That is the movement I was talking about. When it sways it is the wind. Yes? But when it is growing it is pushing the soil away - the roots are pushing the soil away so it is moving isn't it.**

2a:347 **TV: [Holds up a card - unclear which one] Yes?**

2a:348 Everyone: Yes.

2a:349 **TV: This one - sun?**

2a:350 Everyone: No.

2a:351 **TV: Do we agree why?**

2a:352 LD: Yes. Doesn't reproduce.

2a:353 **TV: Clouds? [Holds up the card]**

2a:354 Everyone: No. [Seems a bit hesitant]

2a:355 **TV: [To LD] So you changed your mind on this one? [TV has a slight smile] What made you change your mind?**

2a:356 SF: I thought it was living.
LD: Because it doesn't reproduce. It just turns into water. It doesn't really grow either.

2a:357 **TV: Can you give me another reason why I would take it out of the living?**

2a:358 SF: Doesn't have any sensitivity.
LD: It is made up of evaporated water, so it is not really...
AC: So if water is not living then... [clouds can't be either]

2a:359 **TV: OK. Doesn't reproduce. Does not grow. Well, you can say that lots of clouds come together to make a bigger cloud, but by itself.**

2a:360 BB: No. [Agreeing with TV from the tone]
AC: But that could be one of them little clouds coming together to make a big cloud. [Showing clouds coming together with his hands].

2a:361 **TV: OK. So, it won't reproduce. Yes. OK. Milk? [Holds up card].**

2a:362 Everyone but BB: No. [But not very confidently]
BB: Actually I'm kind of in the middle [alternately raising and lowering his hands - as if he is comparing the mass of two objects on scales] because...
LD: [Smiling] No.
AC: Definitely not.
SF: It doesn't reproduce, it doesn't really grow.
ES: It is what a calf or like a chicken needs to stay alive. [Speaking towards TV, TV listens, then points towards BB]
AC: It doesn't move.

2a:363 SF: It doesn't reproduce.

2a:364 **TV: Why are you not sure?**

2a:365 BB: Well, I don't really know. Because when you think of it I just think of it as alive. But sometimes I'd actually say that it is living.

2a:366 **TV: Can milk move by itself?**

2a:367 AC: It is not living.

2a:368 SF: No. [Said quite loudly and in a tone that indicates this is obvious - could SF be frustrated - her body language is sitting with her chin on her hand].

2a:369 **TV: It can't reproduce itself right. It can't make other milk. Right, so we've only got two [left]. Silent gun?**

2a:370 Everyone: No.

2a:371 AC: It is not reproducing.
SF: And it doesn't grow.

2a:372 **TV: Wind?**

2a:373 Everyone?: No.

2a:374 AC: It may move, but it doesn't reproduce.

2a:375 **TV: OK. Bicycle?**

2a:376 Everyone beginning with BB: No.

2a:377 **TV: Reasons?**

2a:378 AD: No reproduction. [simultaneously with LD]
 LD: No reproduction.
 LD: [To AD] Is that all you think about? [With a smile - AC, SF and LD laugh]

2a:379 ES: [Simultaneously with LD in 381 above] [unclear as very quiet]
 BB: Kinetic energy.

2a:380 **TV: Seed is, right, living? Tree?**

2a:381 Everyone: Yes.

2a:382 **TV: OK. Embryo?**

2a:383 Everyone: Yes.

2a:384 **TV: Ball.**

2a:385 Everyone: No.

2a:386 **TV: Candle?**

2a:387 SF and others: No. [Quite loudly - others repeat]

2a:388 **TV: Right. Ball on floor.**

2a:389 Everyone: No.

2a:390 **TV: Bicycle.**

2a:391 Everyone: No.

2a:392 **TV: And river?**

2a:393 Everyone: No.

2a:394 **TV: OK. Do we agree now on the river? Looking at SF.**

2a:395 SF: [Nods]

2a:396 **TV: OK then. Can you put these away.**

2a:397 *JR: If I could just take them. I'll pop them on the side like that. I'll sort them out afterwards. Thank you very much indeed. Please just put one on top of the other and then we'll put them on the side. I'll sort them out afterwards. [JR helps remove the mats and cards. TV gets resources ready for question 4c].*

2a:398 **TV: OK. Now you may or may not want to use this. OK. These flash boards, but if you feel that you can draw on it quickly [handing out boards while giving these instructions] going to have another one. Right OK. Right so, now I'm going to ask you to come up with your ideas. Right.**

2a:399 **TV: Imagine you have this teddy [holding up a teddy bear] in a dark room.**
SF: [unclear] scared me. [SF laughs]
TV: Did I? OK. Sorry about that. So imagine you're going into a dark room, you've got the teddy there and you use this torch. Alright, you turn it on and you will then... What do you think will happen? [TV is standing up for this bit]

2a:400 SF: You will see the teddy bear.

2a:401 **TV: You will see the teddy bear. Right. So how does it work? How can you see the teddy bear? [TV's hand moves a few times near his eyes. At one point he seems to show movement from his eyes]**

2a:402 Everyone: [A number of student try and speak at this point].
TV: Right OK. [Putting his palms up to stop students speaking]. I want you now thank you... I know you have lots of ideas, I want you to show - explain this to me in the way... either by drawing it or by explaining it to me or both ways.

2a:403 *JR: Stick people would be fine.*

2a:404 **TV: Yes. Stick people would be fine.**

2a:405 Everyone: [Quiet drawing - SF looks at LD's drawing. UG's pen doesn't work and TV helps him change it.]
 AC: Done.

2a:406 **TV: I can see some diagrams and some labels as well.**
Everyone: [continue drawing]
TV: I can see some people not only drawing but annotating the diagrams - trying to put some explanation there. That is good. Right. Now.

- 2a:407 *JR: Would you put your initials on them? Please.*
- 2a:408 **TV: Right then. So that we can see the teddy in a - with a torch in a dark room. So can you come up with an explanation. I'm going to ask each one to contribute. SF?**
- 2a:409 SF: The light is shining on the bear. You can see the teddy bear because of the light coming from the torch. So the light is like the energy and er its... erm [pause - AC has his hand up]. I don't know how you explain it. The light is like bright, so like you can see the teddy bear so - and... erm. That is all I can really think of to explain it.
- 2a:410 **TV: OK. At the moment.**
SF: Yes.
TV: At the moment. You might have some light at the end of the tunnel. [Smiling] OK LD?
- 2a:411 LD: The torch can be - otherwise known as the light source, where we get the light from.
TV: Good.
LD: So the light from the torch - because the room is all dark, you won't be able to see anything. Obviously. So as soon as the torch turns on...
TV: Yes. [Said very quietly]
LD: ...the light from the light source will shine and beam onto the teddy bear. And because the light bounces off it you're able to see what the teddy bear looks like.
- 2a:412 **TV: So... OK. Now let's hear from AC?**
- 2a:413 AC: So the torch, otherwise known as the light source. [Looks at LD and LD, TV and JR all laugh] Err. Goes out and it gets bigger and bigger [indicating this with his hands] as it goes forward, but the light gets dimmer. It eventually hits the teddy. And you can see it because the energy comes from the torch, hits the teddy and comes back to your eyes. So you would be able to see it.
- 2a:414 **TV: So the energy comes to your eyes.**
- 2a:415 AC: Yes. So you can see it.
- 2a:416 **TV: OK. [Indicates to BB that it is his turn by pointing]**
- 2a:417 BB: Mine is the same as his [indicating AC with his hand], but when you shine out you kind of see a shadow behind it [indicating with his hand the space behind his own body]. So you'll be kind of able, using the shadow to your own advantage.
- 2a:418 **TV: So you can see the teddy because of the shadow? [Tone of voice is a bit incredulous and TV's expression indicates the same]. Is that what you're saying?**
- 2a:419 BB: Well yes. If you did it from - let's say sideways ish [showing this with his hand - TV is holding the teddy]. Right, so you can see the contour of the teddy. But what about the teddy itself? If there were no shadows. If there were no shadows [moving his hand around the teddy showing the outline of the teddy].
- 2a:420 BB: [Pause] You would just [unclear - 'run into blur?'] the front.
- 2a:421 **TV: So what about the front side of the teddy?**
- 2a:422 BB: You would see it.
- 2a:423 **TV: You would see this [indicating the front of the teddy]. So would you have a shadow at the front?**
- 2a:424 SH: You'd have it behind and at the sides.
LD: You'd have it behind because the opaque and is not translucent or transparent so it would have a shadow but it would be behind, like on the wall or the floor.
- 2a:425 **TV: Do you need the shadow to be able to see... [shakes teddy to indicate he is talking about it]?**
- 2a:426 Several students: No.
- 2a:427 **TV: No, OK. So there is something that you may have to change you reckon [using a puzzled expression and looking at BB - BB may be moving a card at this point - hard to see from this camera angle, the other camera may reveal this]? OK, UG? What do you think? What is your theory?**
- 2a:428 UG: You get the torch, you shine it onto the teddy, the light would reflect.

- 2a:429 **TV: The light will reflect, from... [pauses waiting for UG to complete the sentence].
From where to where?**
- 2a:430 UG: From the teddy to your eye.
- 2a:431 **TV: To your eyes. So that is the way we see things? [unclear if this is a question]**
- 2a:432 UG: Yes.
- 2a:433 **TV: Alright. So we can use the same principle. The same idea in where?**
- 2a:434 **TV: So if you see me right now. What does that mean? Where does light - how is light travelling. If you're seeing me right now?**
- 2a:435 SF: The lights.
BB: It is coming from the lights there [pointing to them].
UG: It is coming from the lights there and it is reflecting into my eyes.
- 2a:436 LD: Is it the light is coming from there [pointing to the lights on the ceiling], bouncing off your face and into his [UG's] eyes. Into his eye (sorry) - so he can see that happening - he can see you.
- 2a:437 AC: That is right. In a dark room there is no light, so it can't reflect off you so you can't see it.
- 2a:438 **TV: So in the absence of light, if you had the torch turned off... So?**
- 2a:439 AC: You can't see anything.
- 2a:440 **TV: Because...**
- 2a:441 AC: Because there's no reflection of the light.
SF: No light source.
- 2a:442 **TV: No light coming towards your eyes?**
- 2a:443 Several students: Yes.
- 2a:444 **TV: [Turning to ES] Do you share this idea?**
- 2a:445 ES: Yes.
- 2a:446 **TV: Is there any difference in what you thought about before and now?**
- 2a:447 ES: Um [pause] no. I already knew that light bounced off things - but with the torch it would usually - it would only - well not only, but um it wouldn't reflect the rest of the room, because it is only shining in one bit, so it is reflecting back.
- 2a:448 **TV: So that part you're shining on, you're shining the light on, is sending that light back to you [this appears to be a question from the context]? [TV: mimes something hitting the torch, bouncing off and going back to ES]**
- 2a:449 ES: Yes. So if you're pointing the torch somewhere else [mimes pointing the torch in one direction and looking in another] it can go away [unclear].
TV: Yes.
ES: It is less easy to see because the light from the torch is only shining on one - bouncing
- 2a:450 **TV: OK. So in the background [indicating the space around the teddy with his hand], it is dark. Why is it dark?**
- 2a:451 SF: Because the teddy bear is blocking it - the light.
- 2a:452 SF: Because when the light is shining on the teddy the light - his whole body is like making a shadow and that's black. Because you can't see through him. If you know what I mean.
- 2a:453 **TV: OK. So. OK therefore when it blocks the light there is no light in the back that comes to your eyes [miming this with his hands and the teddy]. So therefore - will it be black? [LD has her hand up].**
- 2a:454 SF: Not all of it.
TV: OK.
SF: His body shape would be black because it is the only bit you can't see.
- 2a:455 **TV: That part that you can't see - therefore, if you can't see that part it is not bringing the light to you?**
- 2a:456 SF: Um. [pause] It brings light to you, but just not the bit you can't see through him.
- 2a:457 **TV: OK. What is your theory? [LD] I'll come to that in a minute.**

2a:458 LD: Because the teddy isn't transparent, or translucent, the light can't go through the teddy and come out the other side [LD mimes this with her hands]. Teddy - because it is opaque it blocks the light and the light has to come round the sides rather than going straight through the teddy.

2a:459 SF: I said it in a simpler form. [LD smiles at her and SF also smiles]

2a:460 **TV: OK, you think that the light has to go round? [Mimes light going round the teddy - possibly with a curved path]**

2a:461 LD: No.
AC: It goes straight.

2a:462 **TV: It goes straight. The light travels in straights lines.**

2a:463 AC: Because it is the first object that the sun - kind of like hits it. It reflects off that. But some of the light won't go in it. It will go straight past it [showing light going past with his hands] and hit the back of the wall.

2a:464 SF: [unclear]

2a:465 **TV: OK. The principles in which - the principles therefore. Can we sum this up then? Can we think of... OK. Did you think differently before?**

2a:466 LD: Definitely. [Smiles and looks down - SF looks at LD].

2a:467 **TV: If you look at your diagrams - right. Do you have light going from the source to the teddy? Do you all have it?**

2a:468 Everyone: Yes.

2a:469 SF: [unclear]

2a:470 **TV: Now where is your eye? Where have you shown your eye?**

2a:471 SF: There. [Points at her diagram] Oh no. I just drew a hand because I didn't realise I had to draw an eye.

2a:472 **TV: OK. So if you had to place an eye on your diagram, where would that be?**

2a:473 *JR: I'm sorry. Can I take a quick photo of the desk again?*

2a:474 **TV: So where would your eye be? Have you shown the eye? Yes? Are you showing that light travels from the source to the teddy [LD is the only one changing her drawing]. Have you all done that? Have you shown that the light is travelling from the teddy to the eye?**

2a:475 SF: Yes.

2a:476 **TV: Have you all done that? And now the fact that the light [tracing the outline of the teddy] - you can see. If you're projecting the shadow of the teddy onto a screen, right, the shadow - would it be the same shape?**

2a:477 AC: Yes.
LD: Yes.

2a:478 **TV: Would you [ES] agree? If I project the light onto that teddy, and I could see the shadow of the teddy on the screen at the back, yes? Would I be able now - would it be the same shape?**

2a:479 ES: It might be bigger.
AC: Bigger.

2a:480 **TV: It might be bigger - yes.**

2a:481 AC: Because the light is getting bigger and bigger as it goes further away [AC is miming this with his hands as he speaks].

2a:482 **TV: The light gets bigger...**

2a:483 ES: When it comes closer it blocks more of the light trying to get out.
TV: OK.
ES: Well not trying to get out [smiling], just travelling in straight lines.

2a:484 **TV: Right. So the light going - the light gets blocked. The part that gets blocked will not appear on the screen. But what about the rest of the screen, could get the...**
SF: Light.

- TV: ...light [showing light hitting the area behind the teddy on the screen not directly behind the teddy]. So you can see actually the shape of the teddy on the screen. A bigger shape, but it will be the same shape of the teddy?**
- 2a:485 Everyone: Yes.
- 2a:486 **TV: What do you think makes it have the same shape on the screen. Why would it have the shape of the ear, shape of the arm [tracing round the ear and the arm with his finger] shape of the hands, shape of the legs? Why would it have the same shape on the screen?**
- 2a:487 LD: Difficult to explain, but I'm going to try. Because the light is beaming at the teddy. And because parts - right the ears [miming these on her own head - TV still has the teddy] are blocking the light from getting past it.
TV: Yes.
LD: The outline of it will show up on the screen behind.
- 2a:488 **TV: Right. So wherever it is getting blocked, [showing this with the teddy and his hand] won't appear there. But the rest will appear and the fact that you can see the other side - you can't see the teddy, but you can see the shadow. The rest of the screen, what is it going to do to the light? [pause] What is it going to do to the light?**
- 2a:489 Students stay silent.
TV: Right, so we are beaming light towards the teddy, right. And teddy catches some light, and the rest of the light goes where [showing the light hitting the area of the screen around teddy with his hand]?
- 2a:490 SF, LD and BB: To the screen.
- 2a:491 **TV: What happens to that light there?**
- 2a:492 AC: Instead of getting reflected off the teddy into our eyes, it gets reflected off the screen into our eyes.
SF: It wouldn't be as bright.
- 2a:493 **TV: Yes [AC] sorry.**
AC: Instead of reflecting off the teddy it is reflected off the wall into our eyes.
- 2a:494 **TV: Into our eyes. So we can see the screen then. Yes? And you said it won't be as bright. Why did you think it won't be as bright?**
- 2a:495 SF: Because the teddy's shadow would be blocking most of the light coming through to it - onto the screen.
- 2a:496 **TV: OK. And the fact that it goes to the screen and comes back. Do you think that all the light is coming to our eye?**
- 2a:497 AC: [Shakes his head. SF and LD are looking tired].
- 2a:498 **TV: All the light that is reflecting from the screen. Do you think the light comes to our eyes? All of it?**
- 2a:499 SF: Not all of it.
ES: [Unclear] like comes past [indicating with her hands light passing her face]. If you're sitting far away you're [unclear].
- 2a:500 **TV: OK. So what I was trying to get at was the light that shines - that reflects from the screen - does it go to the same person?**
- 2a:501 **TV: Everyone can see the teddy right? [points at the teddy] Why can everyone see the teddy?**
- 2a:502 SF: Because it is right in front of us.
- 2a:503 **TV: It is in front of you...**
- 2a:504 SF: And the light is coming from the... [points at the ceiling light].
- 2a:505 AC: It is reflecting off it into all of our eyes.
- 2a:506 **TV: Exactly. So the light that is coming from the teddy to your eyes is going in all the directions. So the light is not all coming to - let's say BB's eyes. They are being reflected in all directions [shows this with his hand whilst still holding the teddy].**
- 2a:507 **TV: Yes? OK. So, is there something that you - at the beginning of this discussion that you had about the teddy, is there something that changed in your mind?**

- 2a:508 AC: I didn't realise like that it would be like - because the shadow - I didn't realise that it would be the exact same shape. I thought it would be different slightly.
- 2a:509 **TV: OK.**
BB: Like when the sun went to - like the light is at your back - you'd see much more longer shadow.
- 2a:510 **TV: OK. Right. Is there anything that you've changed your mind about while we were talking about this?**
- 2a:511 SF: Yes. The reflection when we look at it. Like er - like LD said. When the light is all off - you're focusing on something -
TV: The teddy for example.
SF: The light - it reflects into our eyes. I didn't really kind of realise that. So...
TV: Now you know.
SF: Now I know.
- 2a:512 **TV: Is that all because of the discussion?**
- 2a:513 SF: Yes.
- 2a:514 **TV: OK. Now. So. What is it that you - from those discussions which we had today - what is it that you would remember most?**
- 2a:515 [Pause]
BB: [unclear]
AC: The living things.
SF: Yes.
TV: Right.
BB: [Unclear] the ice cube.
- 2a:516 **TV: Why? [to AC]**
- 2a:517 AC: Because I didn't realise that to be a living thing it didn't have to be all of those categories - I just thought it had to move.
- 2a:518 SF: Yes. Same with me. I didn't realise it had to be MRS NERG.
- 2a:519 **TV: MRS NERG. OK. That's good. Now can I just very quickly recap on what my views are when we discussed all this. So we talked about first the heat. That transfers from from or to and object. So something becomes hotter or something becomes colder it is simply because of... [tone goes higher at the end of the sentence to indicate TV is waiting for an answer].**
- 2a:520 BB: The atmosphere.
- 2a:521 **TV: Heat? Heat transferring to or away - going away from. So that was an example of the hot tea and the ice cubes. And then we discussed the difference between living things and non-living things. What came out of this was the fact that we talked about MRS NERG and all the time. To be able to sort them out. And then I - we talked about the fact that we can see objects in the dark - like the teddy - in the dark room using a torch. Now is there something that I may have missed out in my summary?**
- 2a:522 Everyone: No. [Several students looking very tired]
- 2a:523 **TV: Come on - be honest. I may have...**
- 2a:524 AC: Basically that was it.
- 2a:525 LD: Actually. No it's not [laughs].
- 2a:526 **TV: That won't be rude at all. Just let me know.**
- 2a:527 LD: No, it is not something you missed out. I just thought that you know you were talking about how the size of the shadow on the screen could increase, wouldn't also the light go dimmer as it is withdrawn? [Mimes moving the torch further from the teddy]
- 2a:528 **TV: Yes. That's what - Yes. Why would it get dimmer? What is your theory?**
- 2a:529 LD: Because it has to travel further. So that way most of it would actually go out rather than go direct. Because it has to travel so far.
- 2a:530 **TV: Yes. I think [unclear]. Because I was saying to you the light - not all the light comes your way. The light gets... [pause - mimes light spreading out with his hands] spread out. So the further away you are the more spread out the light is - just like**

the sun or the stars. If the star is further away than the sun can you see it as bright as our sun?

2a:531 Everyone: No.

2a:532 **TV: Why not?**

2a:533 LD: Because it is further away.

2a:534 **TV: And therefore [miming light spreading out] the light gets so spread out that we only get a tiny bit of it. And that is why even the star might be brighter than our sun, because of that distance it is so far away - even a brighter star than our sun - the spreading of the light will make it look like it's dimmer. Yes? OK? [Looks at the questioning route] Right. OK. [Looks over at JR] I'll say thank you very much to you. Thank you for taking part in this. And I think it will help. I will try to share that with you when Mr... when John-Paul comes back to me. And I will definitely share that with you. Is that OK?**

[End 2a]

Interview 2b

2b:1 *JR: Thanks ever so much for agreeing to do this. I really appreciate it. Just to give a little formal introduction. Please watch each video clip, and then think aloud. By that I mean talk freely about anything that comes to mind about the video. I'm interested in how you might 'solve' these problems. What you would actually do to help the children when they think like this. Please just report your thinking as accurately as you can in your own words. You don't have to edit, explain or justify your thoughts. We'll leave how you understand the issues raised to the second part of the interview. Everything you say will of course be anonymous. There are thirteen clips here. But we don't have to use them all. Try and do some from each of the three topics. That's the... [indicates the three topics on the laptop screen]. I'll keep an eye on the time, so you don't need to worry about that. After that I'd like to ask you a few questions which will take about another thirty minutes. Please feel free to say when you've had enough or if you need a break. I can just pause everything. I'll try not to interrupt you while you're watching and responding to the video clips. Please don't worry if you can't make sense of what the children say in some of these video clips. If you have trouble hearing something, because often there is lots of noise please say - I could help. Some of the ideas which came up are very challenging, even for us as trained scientists. Since I started exploring children's naive concepts I've discovered several of my own. Please just say if you'd like to unpack an idea together. I'm aware that you're being asked to do something which is difficult. Namely to respond immediately to some very challenging naive scientific concepts. In the classroom we often have to respond quickly, and it is this type of thinking that I'd like us to explore together.*

TV: OK

JR: Is there anything you'd like to check out about this before we start?

2b:2 **TV: No, that is fine.**

JR: Many thanks for doing this.

2b:3 *CLIP 1: 2a:24* **TV: If we were not in that room what would have happened. Would it have made a difference?**

2a:25 *SF: The cubes wouldn't have melted so fast because there is less heat in the room.*

2a:26 **TV: OK. So the heat is coming from us.**

2a:27 *SF: Well, most of it. Because the overhead projector... [points at the projector]*

2a:28 *AC: Any you've put on the temperature probably in order to keep us all warm [unclear as AC is speaking very quietly]. [AC points and looks at the radiators in the room so appears to be referring to these].*

2a:29 **TV: Oh. That's very good. So you have actually identified the heat sources in the room.**

...

- 2b:4 **TV: Right. I think that was actually quite a difficult concept for them. Because it is invisible. And they had to use their imagination about where heat could be coming. Because they can't see it - it is invisible. And that is why we had only one or two immediate responses. The rest were quiet because they were not too sure about the concept of heat I think - in the first place. And the fact that we were talking about sources as well. And sources [Tannoy message starts here: "I'm sorry for the interruption..."] Yes, err. I think that in there I was expecting them to talk to me about the source of heat, and I realise now looking at this that they had a problem thinking about where the heat could be coming from. And I gave them a clue as heat coming from the body. But although they thought they couldn't spot other sources - that explains why they were quiet. And I think the teacher here has got to give them that knowledge about the source of heat. [TV looks at JR, then clicks on the next clip].**
- 2b:5 *CLIP 2: atmosphere [2a:48-52] TV: ...what takes that heat to the atmosphere?*
 2a:49 *SF: The steam coming off the water.*
 2a:50 *AC: The evaporating water.*
 2a:51 **TV: OK. That is good. Is there any other way the heat is going to the atmosphere? Apart from the steam.**
- 2a:52 *AC: Well it's because there is no lid on it. It is just open so the atmosphere can get into it and go into it.*
- 2b:6 **TV: Yes, interesting this one because they think that heat will always be going up. They have not been exposed to the situation where - well as part of their teaching - that heat will be travelling through a substance like here it is a mug. Going downwards - it could be going downwards. And they don't - I think they're not relating it with the fact that they have radiators at home and there they didn't think about the fact that heat could be travelling away from the mug in the form of radiations [sic]. So there are a number of concepts that I was expecting them to be able to talk about at the same time. So this lesson was I think quite demanding. Looking back, because the things I had to go through during that session it expected them to talk about new stuff. They haven't been made to talk about in the first place and in the second place it was just exerting a lot on their brain to make - to come up with an explanation. So it was challenging for them. I think they have not ever been exposed to situations where they had to talk about heat travelling. They can subconsciously talk about heat going upwards, because I think they must have had hints from fire - flame [shows fire rising with his hands] always rising. But the idea of heat going downwards or sideways was a little bit difficult for them to comprehend.**
- 2b:7 *JR: So we've just had the atmosphere one there. Unless you'd like to see one again.*
- 2b:8 *CLIP 3: metal [2a:61-64] 2a:61 TV: ... what would happen then if it were metal container?*
- 2a:62 *LD: A metal container would become hotter because if you've got hot tea in there and it is in a metal container, because metal is a conductor of heat [BB says conductor at the same time] and electricity. If you were to touch it then the metal would be as hot as the water inside it.*
- 2a:63 **TV: So would it cool down faster with the metal? [Question directed at LD]**
- 2a:64 *BB: [Shaking his head].*
Another student [unclear who]: No.
- 2b:9 **TV: Oh, that's another challenge for them. The girl correctly said that the heat would be conducted away. Looking at their reactions the other four they were still trying to work out how the heat was going to go away - and the other thing is when I was asking about the fact that with the metal it was going to be faster or slower - they didn't react because they had to work out the mechanism of the conduction in**

the first place and work out why, if it is a metal, it would be different. That was another problem for them. So they did struggle with that concept of the heat, the fact - how the mechanism of the transfer and talking about metals and non-metals [Tannoy interrupts for a second time, "Mr A. ..."] Yes, the idea of metal and non-metal - unless there were a reference was made to the idea that in winter time - or when it is in the morning - you touch a metal and a non-metal how different that is. That type of thinking they may not have been exposed to and that is why they struggled to come up with an answer. [TV looks at JR who nods].

2b:10 CLIP 4: gravitational analogy [2a:80-85] 2a:80 TV: The heat will always go where? [After a slight pause] In terms of temperature. If you have a high temperature here [indicating the high temperature with one hand held high] and a low temperature there [the other hand is held low down] which way will the heat be going to?

2a:81 AC and BB: Down.

2a:82 TV: From...? Always from a...? ...from a hotter object to a...

2a:83 Several students: colder

TV: colder object. [Tone confirms the students' answer].

2a:84 TV: So this is a hotter object [indicating the tea with his hand] so the heat tends to go out [shows movement out from the cup of tea with his hand]. And...

2a:85 BB: This is a colder one so it would go up. [Indicates something going up with his hand]

2b:11 TV: OK. When I was explaining that I was trying to give them a hint - when I was talking about higher temperature and lower temperature [holding one hand high and the other low] I wanted - even though I didn't refer to the fact that, well, gravitational analogy here, so a ball will tend to roll down a slope, down a hill - here I was just trying to give them, using my body language, trying to help them to go towards the idea that heat will flow from a higher temperature to a lower temperature [holding one hand high and the other low again]. But... because... Well that was for the sake of the explanation, to get the idea of higher to lower, but the risk here is the fact that they would tend to think that it needs a slope somewhere [showing something moving down a slope with his hands]. And that - this could be a dangerous as well - I do realise that, because they would think that, OK there has to be a slope, in terms of when they're looking at the analogy. And heat can travel in any direction - all round - as long as there is a temperature difference. And I was trying there - I was trying to emphasise on the difference and the fact that it goes from higher to lower. But there was a risk of creating another misconception in that case.

2b:12 JR: I found the reaction here as well interesting. I don't know how to understand it really. When he [BB] said about, 'it goes up' there at the end. What do you think?

2b:13 TV: Yes it has to, as I said to you, the danger is trying to use an analogy to explain an abstract concept. And while using the analogy the analogy itself may not be perfect. So the words that I used were 'up' 'down' and he [BB] was using the word 'up'. But that was slightly another context. Because I was trying to explain that there is the difference [showing one hand high and the other low] and the heat will go from higher to lower, and he was talking about heat going up. And that is another context. So treading on two different [graphs? - unclear] at the same time was going to be a bit - slightly more difficult. So I think what I should have - what I will be doing if I get into that situation first is trying to visually to show to explain the idea using perhaps pictures. To show actually that the heat always goes from hotter to lower rather than using the idea of higher and lower, because there I see he picked that up in another context. He picked on the words, but was talking about the heat going up. And when I was talking about temperature; heat going from high temperature to lower that was a different context. I was speaking about it from a graphical point of view, in terms of numbers whereas he was talking about heat going up like physically. If you are talking about some hot air - hot air rising. So he was on a

- different situation - a different story from mine. Using my words he picked up my words, but was going on a different story, because I was talking about a different concept. So we could see we were separating there.**
- 2b:14 JR: Fantastic. Thank you.
- 2b:15 JR: Can I just check, are you OK?
TV: Yes.
- 2b:16 JR: Just before we play that can I just check that the camera is OK? Yes, everything is fine.
- 2b:17 CLIP 5: candle [2a:94-96 and 2a:166-172] 2a:94 **TV: OK. Any doubts?**
- 2a:95 AC: By candle does it mean a lit candle or just a candle stick?
- 2a:96 LD: Lit candle. Hence the picture. [Looks down at her mat whilst smiling]
 SF: [Looking at AC with an amused and incredulous expression on her face.]
TV: [TV is smiling as well]
- 2b:2a:166 **TV: The candle. Do you think that the candle is living? Does it need nutrients from the environment?**
- 2a:167 BB: No.
 SF: It needs to be lit.
 BB: It needs wind.
- 2a:168 **TV: It needs wind.**
- 2a:169 SF: It needs to be lit by a...
 AC: How does it need wind?
- 2a:170 BB: So it can spread out.
- 2a:171 **TV: So is that wind a nutrient?**
- 2a: 172 BB: No.
- 2b:18 **TV: OK, here we were discussing about the characteristics of living things. And of course we were referring to MRS GREN or MRS NERG [mnemonic for the characteristics of life - Movement Respiration etc.] and the first idea was we were discussing the first idea which was to do with nutrition. And something that helps it to grow - that it needs to take from the environment. And they found it a bit difficult there because the flame is taking materials or needs something from the environment like oxygen here, which was not explicit there. And living things need to absorb things from the environment. I think they found a similarity there and they were finding - they were not too sure then - by the definition of living things (the characteristics of living things) if they are taking things inside them in order to be able to live then in that case the flame is taking the air, and someone referred to the wind. So surely there should be something from the environment being taken into the flame. Now based on this criterion, would that be considered as a living? Here they lost the big picture there and they were focussing on one single item. And my question was focusing on nutrition. So they played the game and they talked about the very idea was putting forward - nutrition. And they, for a few seconds, I think they might have lost the big picture and they were considering living things from only one criterion. And this is what I think was happening. So I think here we need to be able to keep inside the big picture, in order to be able to decide whether things are living or non-living. And always be aware that we need to keep focussing on the big picture - but based on one of the criterion it was a bit difficult to decide there. Because they were actually considering that living things absorb materials from the environment and here the flame of the candle [is] also taking things from the environment. So for them they know it [the candle] is actually not alive, but how do you come out of that situation where both of them are similar?**
- 2b:19 JR: Just, sorry, just at the start where the student here [AC] asks whether the candle is lit or not.
TV: Yes.
 JR: Before placing it. I thought that was fascinating.

- 2b:20 **TV: That is also something because he thought that was going to make a difference. Whether it was lit or not. Because you can see the flame moving and the fact that it is moving it is an animation and I think subconsciously [touches his head] when they are watching animation, movies and things, 'well, that must be alive'. So if the flame - if there is a flame there it will be in action. So to him, there are other things that might be required in order to - other factors which need to be considered in order to decide whether it is living or not. So this boy was thinking that that might make a difference. Lit or unlit. Because the flame might cause a difference. And the other girl- the girl who was sitting next to him [LD] said, 'well looking at the picture'. I think there, to her, the picture was giving a clue about whether it was lit or not. But that was not the question. The question was to do with whether it was living or not. I think there the boy got distracted - by the flame.**
- 2b:21 *CLIP 6: organs [2a:102-107] 2a:102 TV: is there anything that you already had in mind about living things and non-living things before you put those pictures on those mats? Yes SF?*
- 2a:103 *SF: I was going to say that living could be something that... [BB interrupts]
BB: Moving around
SF: Yes, is moving. Like a person has organs that keep us alive and stuff like that.*
- 2a:104 *TV: Anything that moves about you would consider as living. [Slight question in the voice perhaps] Yes. Any other feature about the living things... [LD has her hand up].*
- 2a:105 *BB: Anything that can... um... get nutrients.*
- 2a:106 *TV: Anything that picks up nutrients from somewhere. Alright, so that's another one. What? OK. [inviting LD to speak]*
- 2a:107 *LD: Anything that grows or develops into something else. For example a tree grows bigger and bigger, and a person grows bigger and bigger, and a dog grows bigger and bigger. But a brick would just stay the same size. It can't get physically larger.*
- 2b:22 **TV: I think the elements we would consider for living things. They were talking about movement, growth, nutrients. I think this is the list of their personal experience, because if an animal is eating, moving, and... I think this is what they relate with. So this comes from their personal experience. Now the other concepts like reproduction and being sensitive, these have not been mentioned there. So I think the first reaction to that was from their own experience - rather than they have been - they haven't referred to things they have been taught early on. So the first initial reaction was to do with their initial experience. Rather than remembering, recalling, from [Tannoy interrupts "This is a message for..."] So the way I look at it is whenever they have to answer questions it is what they have experienced themselves. And had I given them a clue about MRS NERG or used the acronym - and then I think that could have triggered something, they would have remembered - 'Oh, actually there are other things that we need to look at.' But they haven't considered that. OK, so movement, nutrition, ... I can't recall [laughs].**
JR: Excretion and...
TV: Yes, they didn't consider excretion actually. Yes, so these are the first things. Nutrition, and the other stuff. [Laughs] I think it is just because I'm thinking about the camera. [Both smile]
JR: Please don't worry.
- 2b:23 **TV: I think that will be cut.**
- 2b:24 JR: And the student here [SF] mentioning about organs. I thought that was interesting.
- 2b:25 **TV: I didn't pick that up.**
- 2b:26 JR: Shall we just replay that one?
- 2b:27 **TV: OK, so. [Replays clip 6]**
JR: Quite near the start.
CLIP 6: organs [see 1b:21]

- 2b:28 **TV: I wonder why she said organs then? Because this is the - well - I suspect there she was talking about organs, internal organs. But I would have thought if she was referring to these then she might think that there are internal body parts in the person - most probably she was thinking about animals. Therefore - then non-living things could be just homogeneous. And not having distinct parts in the body. And I think that she is linking the fact that you have distinct parts in the body and all different parts doing different things and working as a system. And I think that is a little bit more advanced thinking here. So she might say to us - OK, like a piece of wood looks like uniform, a piece of metal - uniform. So surely a living thing must be a complex structure. And I think that is something that I didn't pick up. Watching that clip as well I - that went unnoticed for me. Because it was said in a very low voice.**
 JR: Quiet voice.
TV: And I was expecting them to say it loud and I was expecting them to say some key words. This is something that I missed out and I think that is something that I could have taken up and discussed that. Yes. There are actually systems that work within a living thing. But then I would have challenged her about certain machines that have subsystems. Like in a car or something like that. I could have challenged her and it would have been interesting to see what she would have said. But it was an interesting thought there, living things made up of organs. Different systems within themselves.
- 2b:29 CLIP 6: organs [see 1b:21]
- 2b:30 **TV: Yes. She did refer to the dog. And she was talking about movement, growth, and nutrients. So these are the three things that come out of the seven. But we couldn't see any - the girl did mention organs there. But we wouldn't have mentioned them as part of them because we know that machines - complicated machines do have subsystems and in no way is it a characteristic of living things. So as I was saying earlier, those three things are the things they relate quite easily with, whereas excretion, reproduction, being sensitive - these are a little bit quite a high level of thinking and they do not come as - will not come as a first instinct. And she was referring to a dog because this is quite a common creature and therefore I think my - as I was saying - they will relate to their own experience first before actually - well if they get time - more time then they will say, 'Oh, what else?' And that can be helped by the teacher in the teaching. So we need to remind them about the other things and using an acronym would be very helpful here.**
- 2b:31 CLIP 7: movement [2a:114-126] 114 **TV: Right, can you tell me about MRS NERG then? Can you expand on that please.**
- 2a:115 BB: [pause] Nutrients... [pause]
- 2a:116 LD: Isn't it movement, respiration, [counting them off on her hand]
 SF: Isn't it reproduction? [quietly to LD]
 LD: No, reproduction is the second R I think.
 SF: Yes.
 LD: Yes. S is [pause]
- 2a:117 **TV: Sense? Sensitivity?**
 LD: Yes, yes.
TV: To the environment. Yes? OK?
- 2a:118 LD: Nutrients, or nutrition [someone else says nutrition at the same time].
- 2a:119 **TV: And?**
- 2a:120 LD: Excretion, reproduction and fertilization [looking at TV as if not sure of this last one].
- 2a:121 **TV: Reproduction and G growth. Alright.**
 LD: Oh yes. Growth.

TV: OK. So, summing up. MRS NERG. [TV pauses here - see 2b:34] M for movement. R for reproduction. S - sensitivity. N... [pauses]

Several students: nutrition.

TV: Nutrition. It takes nutrition. It takes nutrients from somewhere. E... [pauses]

Several students: excretion.

TV: Excretion. You [BB] said energy and now excretion. Very good. Then after E we have R. And you [SR] were talking about the second R was reproduction and G you [ES or UG - unclear] were saying...

UG: Growth.

TV: Growth.

2a:122 **TV: Looking at your pictures now. Anything that moves would fit into what? Living? Right. OK. So if we just do it this way [indicating with his hand to go from living matt] we look at everything that moves. Do they all move?**

2a:123 AC: The candle... [pauses]

2a:124 BB: The egg doesn't.

2a:125 AC: You can if you push it.

2a:126 LD: But you see the ball falling...

SF: you have to make it...

LD: Yes. You have to actually drop it.

SF: Because if you put it on a table it won't move unless you do something to make it move.

2b:32 **TV: Right, here. I was trying to help them. Indirectly I was trying to say to them that it is not just those three elements that you mentioned early on. So that was trying to get them to think further. It was a bit difficult for them to recall. You can see there were moments of hesitation over there. And the girl who remembered it was referring to the other characteristics. And it seems to me that the other four were not - because they couldn't remember the words, couldn't remember the key words, I was expecting them to come up with, even though after giving them this acronym they find it difficult to recall, because this is something like text book work. And they can't relate with so it was difficult for them to remember all this. And that I think explained - goes in the same direction as I was saying earlier. The first thing they would come up with is from their personal experience, and the rest is for them to just be reminded of. And when I reminded them of that, then we had other, the other characteristics of living things and I think there was like a kind of consultation between them. A discussion that OK, 'What is R, what is N...' and things like that. So there was a discussion. They were aware of that, but it was just the inability to remember those key words that was a hindrance for them to decide whether things were living or non-living.**

2b:33 CLIP 8: rain [2a:127-140] 2a:127 **TV: Then R would be?**

2a:128 Unclear which student: Respiration

2a:129 **TV: Respiration. Does it [the ball?] respire?**

2a:130 BB: No.

2a:131 **TV: So the things that you have put on the living matt. So do you have things that respire? Now I can see you've [LD] put cloud on your living matt. Do you think clouds respire?**

2a:132 BB: Well not really.

2a:133 **TV: OK. What sort of things respire?**

2a:134 AC: Humans.

2a:135 **TV: Humans.**

2a:136 BB: Animals.

2a:137 **TV: Therefore animals. Yes? All animals?**

A student (unclear who): Yes.

TV: Yes? What about plants? Would you say - do you think plants respire?

- 2a:138 BB: Yes. [Another student - unclear who - repeats this]
- 2a:139 **TV: So therefore they respire to produce energy. This is the name of the process. They produce energy. Now - so would you say that clouds therefore produce energy?**
- 2a:140 SF: Yes. They produce rain.
- 2b:34 JR: At the end there she says, 'They produce rain'.
- 2b:35 **TV: Yes, well actually they were just picking on the word I was using. I was using 'produce'. I think we started a type of exercise which was just like 'What is the meaning of that key word.' And it started to become quite literal. In the sense that, as you were mentioning, 'produce' rain. So they were trying to see what words I was using now because we started with an acronym. So with the acronym it is just we are trying to remember the processes via words. So now just the words have taken over in that part of the session. Because I think that the word produce here - they thought, 'Oh, what could a rain [cloud?] produce?' Sorry, a cloud could produce. If a cloud could produce rain. Now is that a living thing. Because I think the idea of respiration there was a little abstract to them. Because producing energy - they couldn't make sense out of this. So what else - if they produce anything at all, then the fact that it produce [sic] something now I could tick a box for living things. And I think they were just trying to come up with anything just from the words rather than looking at the big picture again. So while talking about living things I think they need a constant reminder - Oh, big picture. Living things they have to do all those seven things. Now if we start looking at one, and it ticks that box, then they think, 'Oh, it could be living things according to our definition there. Because it is doing this bit - ticks that box [mimes ticking boxes in the air], ticks that box.' But I think they start doubting themselves as to what makes a living thing. If we go too deep into each and every aspect. So if they lose sight of the big picture, then they might be finding it difficult to come up with what is actually a living thing. So I think constant reference to the seven things being met at the same time. That is key. So there I think as we go deeper into a particular characteristic that is when they find the demarcation line a bit fuzzy between living and non-living. So they keep thinking living and non-living based on that particular criterion rather than on the big picture. I think if I have to do it another time, I would constantly refer to the big picture and keep asking them that question. While going on every single example you had on that mat. Because I was questioning them not on M, R, S separately, I was looking at the picture and then I was expecting them to use one of those elements or one of those characteristics for them to be able to decide whether alive or non-alive (not alive)**
- 2b:36 **TV: ...The reference to the big picture is essential there. Not lose sight of the big picture. I think they get lost when you go down into a more detailed level. More detailed explanation. I think that is where they start to find it quite hazy. The demarcation line becomes quite hazy, when keep discussing the point that they come up with, you challenge it and at some point they find it difficult to respond because, as I said, they lose sight of the big picture.**
- 2b:37 JR: Can I check, are you OK?
TV: Yes.
 JR: Are you happy to carry on?
TV: Yes. Have I done this one?
 JR: You've just done rain, so you're on to sun.
TV: Have we misses that?
 JR: We did that.
- 2b:38 CLIP 9: sun [2a:145-160 and 2a:242-243]
- 2a:145 **TV (teacher): What about S? Is it sensitive to conditions around them?**
- 2a:146 SF: Yes. A person is.
- 2a:147 **TV: A person is.**

2a:148 SF: And a dog.

2a:149 **TV: OK.**

2a:150 BB: A lion is.

2a:151 **TV: Yes OK.**

2a:152 SF: And a spider is.

2a:153 **TV: Yes. Do you think the sun is sensitive. You [SF] put it on the living? Do you think that the sun is sensitive to its environment?**

2a:154 BB: Well it is a star.

2a:155 LD: The sun is part of the environment that we're talking about. It is sensitive to it.

2a:156 **TV: Because it is part of the environment, does that make it sensitive?**

2a:157 **TV: For example that table, it is part of the environment, does that make it sensitive to the environment?**

2a:158 BB: No. [Shakes his head]

2a:159 **TV: [Pause] OK? What do you [LD] think?**

2a:160 LD: It could [speaking quite slowly - appears to be thinking about this] because of the...
[TV starts speaking]
and

2a:242 BB: The sun. Because it does kind of actually reproduce.
LD: [Looking and sounding incredulous] But not other suns.
SF: Yes, but it produces the rays of sunlight.

2a:243 BB: Yes.

2b:39 **TV: OK. Now when I was doing this I realised that they are being challenged on a number of concepts without having a discussion before that. So you - what was originally intended was what do they - how would they react to certain situations. Now clearly here they were not too sure about what sensitivity meant. And well sensitivity - I could have explained that early on to them, 'OK, look at the root of the word.' We would be talking about senses. Senses, organs of senses. That would have been easy then for them to think, 'Oh, the sun doesn't have eyes.' And you know the organs of senses. Then by the very fact that they don't have organs of sense the sun could not be sensitive to the environment. Now for example if we consider the plant then, a plant would be sensitive to the environment because it didn't get enough of light or water, nutrients or something like that. So they could show, you could show the consequence of the fact that they needed more light so they have been stretched. Or they could have been affected, the leaves could have been affected. But, had I explained that to them that we were looking for organs of sense they would have found it easier. But to them just presenting it like 'Oh, what do you think about the sun, is it living or non-living?'. The girl was mentioning the environment. The idea of the environment having an effect on the actual object we are considering. So to the girl, the fact that we had an environment, there could be a case for discussing the living and non-living thing right then. And it maybe could have ticked boxes. Because we had some areas where boxes were ticked. And she could have thought. 'OK, that's interesting. OK, we could tick a box here for the living thing.' Because - simply because there was an environment. But I think if I just swayed that discussion towards the fact that there were organs of senses to be considered, that could have, I think, given a way [towards?] what I was looking for, and therefore we would have said the sun is non-living because the sun doesn't have organs of senses. And therefore not responding to the environment. I think that is something they didn't have the tool, if you want, at that stage to be able to decide which way to go. And I think key word is organs of senses.**

2b:40 JR: Thank you.

2b:41 CLIP 8: egg [2a:255-298] 2a:255 **TV: ...Now an egg. Living or non-living?**

2a:256 Several students: Non-living.

2a:257 **TV: Non-living? Why non-living?**

2a:258 AC: It doesn't reproduce.

2a:259 **TV: It doesn't reproduce. Didn't we agree...**

2a:260 SF: It doesn't really grow.
 BB: It does...
 AC: It could be a boiled egg.
 LD: If we didn't have the picture of it, it could [be alive]. Because it could be a different kind of egg.
 AC: That is an eating egg. That is an egg ready to eat. [points at the picture TV is holding up].

2a:261 **TV: Right. OK. You think - when it is... OK. Therefore it is boiled, yes?**

2a:262 **TV: When you boil it it becomes living or non-living?**

2a:263 Several students: Non-living.

2a:264 **TV: Non-living. But before that? Was it living?**

2a:265 ES: It depends whether the chicken has...
 SF: Don't people like inject stuff into the egg to make it like...

2a:266 **TV: Freshly laid from the...**
ES: If the chicken hasn't been around a male - a cockerel, if there hasn't been sexual intercourse [SF looks at LD and starts to laugh. LD doesn't laugh but smiles] then because they're basically - that's like... It is like a woman's egg so it is just like a woman's periods. [TV pauses video at this point]

2a:267 **TV: OK. Now you say a woman's egg. Is that living or non-living?**

2a:268 ES: It is non-living.

2a:269 **TV: Non-living?**

2a:270 SF: Yet. Not living yet because it hasn't been fertilised by...
 LD: Male sperm.
 SF: Yes, male sperm.

2a:271 **TV: OK. I'm going to put that to you. An egg. Is it a cell or not?**

2a:272 SF: Not sure. [The expression on her face matches this]
 BB: Erm. Well. [pause]
 AC: The shell is kind of like the cell wall.

2a:273 LD: And the yolk is kind of like the nucleus.

2a:274 **TV: If I said to you now, OK, that this is a cell that you're looking at. This is one of the largest cells that you can see. Right. Now by definition, is a cell living or non-living?**

2a:275 SF and LD: Depends.
 BB: Living.

2a:276 **TV: Living? Why?**

2a:277 AC: [After a short pause] Because it... when they join they reproduce other cells.

2a:278 **TV: Cells can multiply?**
AC: Yes.

2a:279 **TV: So they take nutrients from outside? They can move can they?**
 BB and AC: Yes.

2a:280 **TV: Yes. They can move. Are they sensitive?**

2a:281 Everyone: Yes.

2a:282 **TV: Yes? So they can produce wastes, can they?**

2a:283 Everyone: Yes.

2a:284 **TV: Yes. OK. So if a cell can do all these, would an egg be a living thing then?**

2a:285 SF: We don't know if it is a cell or not. [Head is leaning on her hand - tone and facial expression may indicate she is not happy about something].

2a:286 BB: Yes it is a cell.
 SF: Oh.
 BB: But we don't know if it is cooked or not.

2a:287 **TV: OK, freshly laid. Living or non-living?**

2a:288 AC: Living.

2a:289 **TV: Living. Alright. So it can produce - you can get a chicken out of it can't you?**

2a:290 Everyone: Yes.

2a:291 **TV: So therefore it can grow into a chicken. So therefore it is living. When you boil it...**

2a:292 AC: It is killed.
BB: That is when it is non-living.

2a:293 **TV: OK, so what makes it different then when you boil it?**

2a:294 LD: It turns into food. [Said very quietly]
TV: Sorry?
LD: [Louder] It turns into food cooked. [TV smiles]

2a:295 **TV: It turns into food. So it destroys when you're cooking. It destroys its ability to...**

2a:296 SF: Live.
LD: Grow.

2a:297 **TV: To grow. It changes it. The plant?**

2a:298 Everyone: Living.

2b:42 **TV: I couldn't hear there.**
JR: I'm sorry. It is really quiet. These are on maximum. She is explaining that if there hasn't been a cockerel present, so there hasn't been sexual intercourse between the cockerel and the hen, then the egg is not fertilised. And she is making an analogy with a woman's egg. That if the woman's egg doesn't meet sperm inside the woman's body then the egg doesn't become fertilised. So I think she is suggesting that living has something to do with fertilisation.

2b:43 **TV: Yes. OK. I'll listen to what happens next.**

2b:44 CLIP 10: egg [continues from 2a:267]

2b:45 **TV: [Smiling] That was a very interesting discussion. They needed that support, that guidance to be able to, literally, digest the information first and - they needed that support in order to be able to see those characteristics. It was not that obvious. Because the shell, the egg shell, was making that difficult for them to understand. 'OK, that could be a living thing. Because you're getting the living - you're getting the chicken out of this and therefore it can't be just life out of something that is not living right there. And, that was really interesting. It took a while for them to - it took a while to build up that concept of living and non-living and show that it actually - they needed that convincing to see all the seven characteristics. And at the end when I was asking them, living or non-living, and they still thought, 'Not sure'. Because that shell was blocking their mind because they're thinking it is a hard shell. If you leave it in the supermarket - just they can't see it growing, can't see it developing. I think that was a - it was quite a hard battle to fight. It is very difficult to convince them. I mean, through the reasoning process, they could see, 'OK, it will develop into another - well, it will develop into a chicken.' When we referred to that as well - a female egg. Well human. We're talking about an egg developing into a baby. Fertilised. It would have to be living. Can't just go on from a non-living and just materialise as a baby and things. It was - they needed that convincing. I think to be able to understand to the last - the ultimate stage where they have to decide whether living or non-living, they needed that kind of intelligence to be able to process the information. OK you tell them, cells need to take nutrients from outside. They produce wastes. They grow. They divide. They are things - they could be moving. So they needed some kind of [miming supporting hands] understanding already of how cells work. And I think they did understand what was being said. Ultimately that shell was quite a block for them. But it was interesting to try to portray that to them. That a cell can do lots of things. That it was just hidden because they just saw the egg. And they found it difficult to associate it with things that are done by a cell in a tissue. So I had to use that strategy. I had to expand the**

- idea that, 'OK, it is a cell. A living cell. What do cells do?' So I had to use other things in order to support the idea - to fight my case there. And it was really interesting. But I think they needed that convincing before they actually decided the egg. Egg was really good challenge for them.
- 2b:46 JR: Fascinating. Can I just check with the time. We're just coming up to twelve now. Can I just check how much time you have.
TV: You've got five minutes.
 JR: Five minutes and then we must stop.
TV: Five minutes and then we've got another lesson.
 JR: So you're teaching in five minutes?
TV: No. I'm free two lessons. Two hours.
 JR: Oh I see. So
TV: So one lesson. And now we're going to - yes 1.05 we get our lunch. So we've got another hour.
 JR: So would you like a pause. Or...
TV: No that's fine. I think we're... [pointing at the screen]
 JR: Please say if you're getting tired. I know this is a difficult thing I'm asking you to do.
TV: No, no, that's fine. Let's go back...
- 2b:47 **TV: Oh, we're nearly there.**
- 2b:48 JR: I think we've just done the egg.
TV: We've done the egg.
- 2b:49 JR: The shadow.
- 2b:50 CLIP 11: shadow [2a:450-456] 2a:450 **TV: OK. So in the background [indicating the space around the teddy with his hand], it is dark. Why is it dark?**
- 2a:451 SF: Because the teddy bear is blocking it - the light.
- 2a:452 SF: Because when the light is shining on the teddy the light - his whole body is like making a shadow and that's black. Because you can't see through him. If you know what I mean.
- 2a:453 **TV: OK. So. OK therefore when it blocks the light there is no light in the back that comes to your eyes [miming this with his hands and the teddy]. So therefore - will it be black? [LD has her hand up].**
- 2a:454 SF: Not all of it.
TV: OK.
SF: His body shape would be black because it is the only bit you can't see.
- 2a:455 **TV: That part that you can't see - therefore, if you can't see that part it is not bringing the light to you?**
- 2a:456 SF: Um. [pause] It brings light to you, but just not the bit you can't see through him.
- 2b:51 **TV: [pause] I think here - this is a very abstract idea as well. So I think it is - we are explaining this without any diagram at all. So I think it is to do with their communication skills associated with learning. If they can explain it clearly what they are trying to get at, because there is the shadow, then the area that is lit. So which one are we talking about is for them to be able to explain that clearly to me. And me also to be able to tell them what I'm referring to. What I was getting at was the shad... the part of the shad... where there is the shadow - are we getting light from there? And they're finding it difficult to talk about - to think about the light coming from the screen behind the teddy bear. Because the girl [SF] was trying to explain was 'yes, I know how it works, I will be able to describe what I will be able to see.' But the next step was to do - to be able to explain it. And explain it with the idea that light travels from a source to the eye. If you can see the light. OK. So. But then it was not direct from the source of light to your eyes, it was going to the screen. So the lit part you could see it, you couldn't see the other part - light was not coming from the shadow. It was actually light coming from the lit part. And I think that is where she was struggling.**

- 2b:52 CLIP 11: eye [2a:470-471] 2a:470 **TV: Now where is your eye? Where have you shown your eye?**
- 2a:471 SF: There. [Points at her diagram] Oh no. I just drew a hand because I didn't realise I had to draw an eye.
- 2b:53 JR: I think she says 'I just drew a hand because I didn't realise I had to draw an eye.' It is difficult to hear isn't it because she speaks very quietly.
- 2b:54 **TV: OK, so she drew a hand.**
- 2b:55 JR: When she drew the diagram on the whiteboard thing, she didn't draw an eye. And I think she is saying that she didn't think it was necessary to draw an eye.
- 2b:56 **TV: OK. So she was just showing the light from the source to the hand.**
- 2b:57 JR: She drew the torch. And she drew the teddy bear. But in drawing a diagram to explain how we saw the teddy bear she didn't draw her eye.
- 2b:58 **TV: Yes. OK, then she assumes that we automatically see things, provided that the light just reaches the object. I think that is what - if I understand it right. [Looks at JR]**
JR: Could be.
- 2b:59 **TV: I think, to her, what she was saying to me was then the fact that you have a source of light, hits that object [indicating this with his hands] that's it. That is the condition for us to be able to see. I think she missed that link where the light has to reflect from that very object we're looking at, and comes to our eye. So this is an idea that I would have normally when I'm teaching that topic - I would have been saying, 'light has to come to our eye'. But she would assume that that didn't have to be the case. As long as it is shining, the light hits the surface - but she was assuming that the light would automatically - you would automatically see. The idea of the direction of the light [showing light bouncing off a surface with his hands] was not clear to her. Which way is the light going? If it is coming our - my way, then I would say , if it is going somewhere else, I might not be able to see it. So she - to her there was nothing like that. She didn't have that problem. To her the problem - the situation was much simpler. Provided that the object is being illuminated, no matter whether we know where the light is coming from, that light now is coming - being reflected our way, or going somewhere else, to her it didn't matter. So that link was missing. And that was what we were referring to there. [Looks at JR]**
- 2b:60 CLIP 13: shadow [2a:489-495] **TV: Right, so we are beaming light towards the teddy, right. And teddy catches some light, and the rest of the light goes where [showing the light hitting the area of the screen around teddy with his hand]?**
- 2a:490 SF, LD and BB: To the screen.
- 2a:491 **TV: What happens to that light there?**
- 2a:492 AC: Instead of getting reflected off the teddy into our eyes, it gets reflected off the screen into our eyes.
SF: It wouldn't be as bright.
- 2a:493 **TV: Yes [AC] sorry.**
AC: Instead of reflecting off the teddy it is reflected off the wall into our eyes.
- 2a:494 **TV: Into our eyes. So we can see the screen then. Yes? And you said it won't be as bright. Why did you think it won't be as bright?**
- 2a:495 SF: Because the teddy's shadow would be blocking most of the light coming through to it - onto the screen.
- 2b:61 **TV: Now, the gentleman over there [AC] was actually talking about light reflecting off the surface of the screen. And - because I had two problems and I didn't want her to be - I wanted actually to answer her. What she was saying - I would have also have liked to pick up that point as well. Because he was right. And what I was worried about was the girl [SF] not realising why the light was less intense when it came back to you. So I thought that was a little bit - I had to give priority to this one because I could have come back to that. He [AC] got it right there. So I didn't have**

to do any trouble shooting there. I was talking to the girl, and I said, 'Why do you think the light came back less intense?' Now this is also another concept that they have to understand. Because the light goes there [showing this with his hands] when it comes back not all the light comes back to you. And now the light gets spread out in all directions again. And that is why you get it less intense. I wanted to see if I could have gone that far with her thinking. That is why I focussed on the girl [SF] rather than on the boy [AC]. Because I knew the boy [AC] was right. Because the light was reflecting. That is why I could see the screen. I deliberately went on to talk about the idea of less light coming to us. Therefore less bright. So that is why I decided to go towards the girl [SF]. But the other boy [AC] was answering the question correctly. [Pause] I wish I could have had more time to discuss that with the boy [AC] and that would have answered the original question. Why can I see the screen? It is because light is coming my way. And if I mentioned that - I mean I developed that later on - then I would have reinforced the idea that to be able to see something, light needs to come to my eyes. And that was the very point I was discussing. I think it might be - the other one was a little bit more important at the time [laughing]. I didn't want that girl [SF] to go away thinking, 'OK, there must be a reason, but it wasn't clear to me at the end of the lesson.'

- 2b:62 JR: [TV goes to start the next video clip] That's the shadow one which we've just done. Thank you very much indeed. I'm really grateful. I know that is a difficult thing to do.
TV: Yes [laughing]. That is the first time I've gone through that. And I just felt the pressure slightly [looking at the camera and smiling]. Being on camera. I've never done something like that before.
JR: That is brilliant. Thank you very much indeed. I'll just check the camera is on. Yes, that is fantastic. Are you OK to carry straight on?
TV: No, no, that's fine. We've got like fifty minutes. So I hope that will be...
JR: Fifteen minutes?
TV: Fifty. Five zero.
JR: I'll pop the watch there just so I can keep - so this should take about half an hour, so we would be finishing about twenty to?
- 2b:63 TV: Yes that's fine.
JR: Thank you ever so much.

[End 2b]

Interview 2c

- 2c:1 JR: Having been through all of those clips, can you recall anything that you were thinking during any of them that you'd like to raise. Any ideas that you might not have mentioned yet, or that...
- 2c:2 TV: I - well, lots of these pictures they actually reveal a number of misconceptions. I can see that. Some of them also show me that they haven't got a clear idea of where the science is, or - they won't think about science, they won't think about a logical explanation to why this is the way it is. I'm thinking about the picture of the cloud. The flame. Then the egg, and we came to talk about the light. So I think when - what I get from this is, when they are going to answer a question in a scientific way, they will always go back to their own experience. And what they have learnt in school becomes secondary. They always come up with what relates to them first. And now then - in some of the clips I was trying to help them with things they have already learnt, like MRS NERG. Maybe they haven't come across certain situations in class, in secondary school, for example the heat, the concept of the heat, and I - we talk about this at GCSE level. Where we talk about conduction, convection and radiation. And that was actually stretching their imagination - and they rightly remembered that anyth... heat travels upwards, and that was mentioned somewhere

by one of the childrens [sic]. And the idea of heat going from a higher temperature to a lower temperature when I was explaining that graphically, I think they did struggle with this. The idea of - the concept of MRS NERG - they have learned it, because a girl - as proved by the girl [LD] who was discussing the words associated with the initials. She clearly - they all have gone through that stage where they remember the acronym. But they didn't use this when the question - when they were challenged about certain topics. And the other thing I was going to - I found interesting was constantly referring to the bigger picture. Because when they were challenged on every single item within the MRS NERG acronym, they find it difficult to come back with a conclusion about actually if it is alive or not. That was a big problem for them. When you go down to that level of detail. It was interesting to also realise that, OK, when we're talking about light, the idea of the words - the way you communicate your ideas - you have to have some kind of literacy background. You have to be able to explain yourself. This is one. And the idea of the light - if you see something - you need a source of light, you need the object and automatically that means that you're going to be able to see, but what was assumed was the fact that the light will come necessarily in your direction. But it is interesting to think that, for them, from their point of view, light will reach you anyway. Because the moment that light hits that object, it will come to you. So I think there is an understanding that light travels in all directions from a point. And that was assumed. And it was a good thing to assume that light would go in all directions, because she might have related it to the sun. From the sun, if there is light coming from the sun it is going in all directions, so why should we not assume that from the teddy, if it is being illuminated, why should we not assume that the light will come to us anyway? So she didn't think that it was necessary to show the eye in her diagram and the light coming towards the eye, because this is assumed. And I think it is coming from her own experience. The fact that you illuminate something you will be able to see. Whether the light comes - there should be a reason for the light not coming to you. She hasn't even considered that. And there were the rain - the cloud produces the rain [Tannoy interruption, 'Could year...'] So when you stress a lot on the words, that could distract them as well. Because they are not thinking in the way they want to, they [Tannoy interruption, 'Apologies...'] Yes, I was saying that literally, they are taking that point literally and therefore they are being distracted by the words, in this particular case, because the clouds - when I was talking about producing something they would say, 'Oh, the cloud produced the rain.' So the fact that it is producing something it could be living. Tick that box. But they lost again the sight of the big picture - for it to be living it is not just whether it is able to grow big in size, because you could have expansion, a balloon expanding - I don't know whether we had that picture. I can't remember. A balloon expanding - if you blow a balloon, is the balloon growing, yes it is growing. It is growing bigger, but is it alive? Because when it is being inflated it is taking things from outside is it alive? Not it doesn't because it doesn't do other things like producing wastes and things like that. So I think the idea of living things - even though it looks like quite straightforward - there are seven things, we just need to look at them. I think they keep losing the focus - OK, they have to be all at the same time.

2c:3 JR: Fascinating. Thank you.

2c:4 Please tell me about what it is like thinking aloud for you personally after watching the videos. Do you think like this in the classroom? And how does the experience of watching these videos compare with what happens in the classroom?

2c:5 TV: Yes, thinking aloud I get my students to do that most of the time [smiling]. But I rarely do that. That was - I must say I was a bit uncomfortable with this. Because I have got my line of thought and I know what comes before and what comes after but I don't do that normally because I let the students do that themselves and then I take

corrective actions by just saying, 'OK, this is the bit where you got it a bit wrong.' But I let them do that. I tend to be the spectator rather than being the one who actually does it. OK, so it was a bit difficult for me to think aloud. I would think aloud - I normally think aloud when I'm doing a demonstration and that's when - I'm already prepared for that - to explain why I'm doing such and such a thing while I'm doing a demo. But I do it rarely, so I do not have that habit of thinking aloud, so it was a bit difficult for me. Yes. [TV and JR smile]

2c:6 JR: Especially in front of a video!

TV: Yes, especially in front of the camera.

JR: Thanks for doing it.

2c:7 JR: Which questions and ideas from the pupils did you anticipate coming up. Was there anything that you hadn't anticipated?

2c:8 **TV: Well, clearly I didn't anticipate the difficulty I was going to have to explain the idea of something living and non-living. I was not always stressing the idea of the big picture. It has to meet all the seven conditions. I was not stressing that. The other thing I realise is, because we haven't taught them the idea of heat travelling from a hotter to a colder area, I knew they were going to struggle with it because normally we are thinking of boiling water - bubbles going up. When we heat something it tends to go up. When something explodes it tends to go higher up in the air. We are associating all these things with heat. It is always going above. And even something exploding it is always going above the ground. We rarely see things going downwards. So if something - it is normally associated subconsciously, I think, heat is always going up. The fact that we were talking about the mug, and being able to heat the base and then the table, they don't really think about that. Because it is hidden and they don't - therefore they're not challenged about this. About the fact that heat coming by the sides of the mug [he shows this with his hands] they didn't really consider that. I think most of them were only thinking about heat going up because it is all from their day to day experience. You see bubbles going up, you won't see bubbles going down. Because the water is getting hotter and the heat is going to the surroundings so bubbles going up to them subconsciously something must be going up. You can't let it go otherwise. And if I think, if I even talked about a radiator, if they were just standing in front of a radiator, they would have gathered that. They would have understood, 'Yes now, I agree now, heat goes on the sides of the mug.' But for them to think also, heat going down [showing this with his hands] via conduction was going to be a challenge. Was going to stretch the imagination a bit further. So these are their ideas that I think they need to be exposed to be able to say, 'OK, I now understand the mechanism of - well I now know that heat doesn't always have to go up, it can go down, provided that you have hotter, and a temperature difference. And if the temperature difference did pose a problem with regards to the type of material. If it was a metal or if it was a non-metal. So there they didn't know about the idea, I thought couldn't remember or maybe they haven't been taught. Pretty much I would have thought they haven't been taught about the mechanism of heat transfer. So that is where they were struggling with the concept.**

2c:9 JR: Thank you. Somebody has defined a naive scientific concept as, "non-scientists' everyday understandings of certain bodies of information", it is not meant in any way pejoratively, how do you usually help students who have naive scientific concepts?

2c:10 **TV: Well, they'll use models. Because naive concepts - I think it is from their personal experience. So when they come in school it is all already embedded in their minds. So this is what it is. And to understand science I need to rely on my own - my personal experience - my understanding of how the world works. I will build up on that. So when they come in class they are not coming to think - they are not thinking they are going to change what they originally thought was right. And then I would**

clear that up [hands make a movement like clearing papers off a desk] and I'm going to start from there [hands make a building mime]. Because they think that they already learned this. Particularly, in secondary school. They think, 'Oh, I've done science in primary school. So what I've learned so far is fine - is correct - should be correct. So I only need to build up on that.' But there are things that - because they were not at the right level of - they didn't have that level of intelligence I think. If I can say that. At that particular stage, they wouldn't have understood it otherwise. So they got a simplified model when they were lower down [indicating something low down with his hand]. Now that they come to this level, we would expect them to show - to be able to have - to be more able to understand that OK, what we have learned as a simple model doesn't work really in the real world. And now we've got to use different models. But to be able to get - to be able to overcome that barrier, to be able to get them to open up and say, 'OK, what I've learned earlier on should not be taken as the whole - gospel truth.' I think it is a difficult battle for the teacher to engage in. So preconceptions - misconceptions that they bring in school is a very difficult one. So how I'm going to - to answer your question then. How do I explain new things to them. I will still be using models and I will show to them, 'OK, we've got data, we've got to do experiments to be able to say whether what I'm saying is right or wrong. So we've got experiments to try to find out whether it works one way or the other. Or if there is another possibility. And if we come up with an explanation. Try to expand the idea and see if we can apply it in other situations. As long as it works we know our idea is right until we come across another situation where our idea gets challenged so we should be prepared to change our minds. But I think at this particular point in time when they come in, they would assume that whatever they have learned is all correct, there is no way of going back. No way to challenge those early ideas and get rid of them. So it is a - we have to be able to - at least for the teacher, to be to - through questioning - to find out whether they actually have some misconceptions there. And I think that discussion will be, needs to be had after a practical or an experiment and say, 'OK, now after putting you in front of that situation, is there anything that you have learnt that actually goes against what we have learnt today?' What do you think about this? And that exercise that we've gone through [indicating the video playing on the laptop] is actually very revealing so we're going to put them in different contexts and see if the same line of action, same theory, same scientific ideas still hold. If they don't hold we've got to question that. So I think that questioning - with the teachers' questioning will help that. But the students also need to be ready - they have to be trained for that - be ready to change any kind of ideas they may have come up with in the classroom in the first place.

- 2c:11 JR: There is a couple of times where you've used the word 'battle'. I find that really interesting as a an analogy.
- 2c:12 TV: I think here I was - when I was talking about battle I was referring to the fact that, OK, what they have learned - what they consider as scientific for themselves is - they're not going to change their mind straight away. They're not going to change their mind because those clips that we've seen - I can already see that their first reaction is their own experience. And they will think that 'My experience cannot be wrong.' If I got burned [showing his finger with the other hand] from a flame, I will think that, OK, it is only a flame that can burn me. It cannot be radiation. Because I've got to be physically in contact with that flame. So they might not think that radiation can be as dangerous as a flame. So there are things that we've got to make them - so what is the flame actually? Is it energy? A source of energy? A source of heat? So if there is another source of heat - let's say you're using a lens, you're focussing the lens somewhere. So that is a concept of another form of energy. Heat energy. So they might think, 'OK, if I can't see it can't be harmful'. So they might

think in a way, 'OK, it can only burn me if I'm in contact with the flame.' So I can't get burned without having a flame. So these sorts of ideas - because it is all down to their personal experience. They would think, 'OK, this only works - I only get burned when I have a flame'. So there are experiences they have gone through and they would say that it is tried and tested. But if you expose them to a situation where they haven't tested themselves they will still keep this as being the real thing - and try to move on and say, 'That can't go wrong.' And I'll build up on that. So what I'll build upon is what I think is right and I will carry on. And I will not change my idea about this. So the battle is actually being able to get them to say - to have an open - to open up their minds. Open up their mind - be ready to accept that, OK, what I learned beforehand, before I came to this class is not actually the real thing. So that also happens with adults. Adults have got their habits. [JR nods agreeing] So many years of experience I've got about this. If I'm being challenged on that I will still think that is right. So I think it is the way we work. It is based on - we always say 'tried and tested'. If I've tried it and tested it personally, I will still be convinced - my mind is programmed like that. My own ways of testing - it will be subjective, but I'll still think it is right. Because I have experienced it. In just the same way the teacher says, 'OK, we've got an experiment and we're going to experience something new but I will not question what I have experienced myself. I think this is where the battle is. To be able to clear up a misconception which you think 'it works always'. That is where - that is what we have to work on. And I think most of the students reacted from - when they were put in front of a challenge, they were trying to recall what they themselves experienced. And the girl was talking about a dog earlier on. If it is moving, if it is eating, if it is growing - it is alive. So I've seen my dog growing, it is alive, so I'll refer to my dog. So this is first-hand experience. It didn't come from the books, it came from her own experience. So talking about reproduction, she has never seen that act, so it is out of her mind. So therefore most of the answers came from first-hand experience I think.

- 2c:13 JR: Thank you. Are you conscious of applying specific teaching practices in your everyday work. Specific strategies or ...
- 2c:14 TV: Well um, in science if we're talking about strategies we're talking about - we have got a national program which is 'how science works'. It is all about querying - putting everything in doubt. Whatever you see, don't always take it for granted. You've got to question it. What you see may not be real. So, and then you've got to investigate. You start with a question. You try to investigate this. You may or may not get the answer to your question, but at least you get to see - when you don't get the answer to your question you've got to ask yourself the question why you didn't get that answer. What is it that has been an obstacle to this. Was the way you tried to test it, was it wrong? So you question - there are different stages. You have to look at all these stages and see where it went wrong. So you've got to review your method of investigation. So if you're talking about practice - I guess you're talking about the way I teach science - or is it to do with my personal...
- 2c:15 JR: For you as a teacher, are there particular techniques that you try and apply consciously during lessons?
- 2c:16 TV: Well. When I try to - well - when I teach I use personal experience. I look at what is in the real world. Examples where things - for example if you're going to teach about heat coming from the mug and things like that. I would say to them, 'OK, I put my mug here. Why did it become cold?' So I will get them, first of all get their own experience - make it relevant to their own experience. So when I'm teaching new concepts - and pick up from this and say [coughs], sorry, and say, 'Where else can we apply this?'. So always refer to their experience. In that way I know where I'm starting from. Because you were right to say, I was talking about a battle. I'm also talking about situations which actually go in line with what I'm

teaching and then challenge them with situations where this is not always the case. And I ask them, 'What if?' - 'What if we put it in a different situation?' So I start with something that they're actually comfortable with and then I go to the unknown. This is the way I think makes it easier for them to build up knowledge. Rather than start from the unknown and then come back to what they knew already. So I make the transition from known to unknown. This is what I would do.

2c:17 JR: Thank you. Please would you tell me about any experiences you've had with children solving scientific problems themselves. In what ways do you try and influence children's problems solving?

2c:18 TV: Well. If it is an abstract concept, then we start with the basics. I say to them, 'In science we've got five basic things we always talk about'. We talk about particles, we talk about energy, we talk about force, we talk about cells, interdependence.' So these are the five concepts [shows his five fingers using the other hand]. When they get this right then we say, 'OK, any other thing that we can be talking about in terms of science will have to relate to those five basic ideas'. So that is where I would always ask them to refer to in anything we do. If we're talking about abstract concepts like current or pressure - anything like that. So we try to go back to what we'd agreed on. What is a force? What is a particle? And things like that. If we could use these ideas in explaining new concepts then I think they will find it easier to understand science that way. So I will always start with the five basic concepts. So when I was talking about cells I was talking about the biology component. Cells and interdependence. And then the chemistry and physics component you have force, energy and particles. So that is where I will always refer to, what I will always refer to when I teach the science. And in any practical that we do I will always try to get them to link up with some of the concepts which I mentioned earlier. So that is how I would help them to understand new concepts.

2c:19 JR: If you'd been teaching the three topics like this to a class rather than the small group, please could you talk a little bit about how it might have been different.

2c:20 TV: **Small group rather than class.**

JR: Whole class situation rather than just six students.

TV: Now because it was a smaller group there was more interaction with them. That type of interaction you would not have as much in - with a big class, unless you get them to do - you set them the work - 'OK, you're doing an investigation'. And then you move around and you talk to the groups and then try to make it as if it was a small group you're talking to. And then try to see where the ideas are coming from. Who is coming up with the ideas and see if you can challenge that. And get other people to try and explain to one another - those ideas that you're actually trying to teach them. So that is how I would make that situation happen from a big class. I would break it into smaller groups and then I go, I move about. That is what I would do. But sometimes when you are solving problems you have to assess their learning as a whole. Then you would have to use certain assessment for learning strategies. Which is show [no?] hand, traffic light system, and things like that, to just gauge their understanding. But I try to do as much practical stuff as possible - as far as I can - so that I can have the opportunity to go and discuss with smaller groups their ideas, so I can pick up misconceptions. And if I do do that, do find any misconceptions, then I discuss that with other groups as well. So in my plenary then I say, 'Oh, actually I learned something from that particular group. They did it that way. Did you do that?' And I will discuss that with the others. Maybe they haven't come across that situation. Now they are at the end, they will be aware of the situation. So I try to split them - make every single group come up with something - a learning experience let's say. And they share the learning experience with the bigger group. So I use it to my advantage.

- 2c:21 JR: Thank you. I'm conscious of the time. Normally we said we would finish at twenty too. Which would be in a minute.
TV: No, that's fine. I can go on.
 JR: Are you OK for a little bit longer?
TV: Yes.
 JR: Another five or six minutes?
TV: Yes, yes, fine.
 JR: Please say if you're exhausted.
TV: No, no, it is OK. We will have lunch time anyway so...
 JR: Thank you. We're getting quite close to the end anyway. How do you ensure you've understood what pupils say?
- 2c:22 **TV: Um. That is through the assessment for learning. Those strategies that I use as I mentioned earlier on. I get the people to - if I'm not too sure if they've actually understood the question I will ask them, after explaining that to them, I will ask them to explain it to me. So I would say with any question I asked them, I would say, 'Explain it to me now. I'm your student - tell me what you have understood.' That is what I would say to them. Or in other situations when I get them to discuss - convince each other. I get them to do that as a paired work. 'So try to convince each other who is right.' Let's say if you've got like - an issue where they're very divided on that - on that issue. So I get those people on one side to convince the others. And if they are getting the principles right I will let them carry on. But if they are actually doing - well going wrong in some cases then I will stop [shows this with his hands]. 'OK, here are the basics, do you get that?' And then I will move on. And after we will have done this, I think we would go through the traffic lighting system. That is what I could do. Or if not - they have understood - they think they have understood - so they still have some quite hazy grey areas. I would ask them to write down about things that you would like to know more about. So in that case we actually have a constant discussion, a dialogue about things they think they understand and other people have doubts about. So we still - I think through dialogue we will be able to - I will know whether they are actually getting the point right or not. So it is only through dialogue. Of course marking their books and all that. When I mark their books I make a note of what different students have had problems with. So when I give them back their books I say, 'OK, I've noticed that the diagrams - for example the drawing in terms of the light - the rays were not joined up. Arrows were not drawn. Is there a problem with the diagram? Is there something that was missed out?' I will make that into a discussion. So after marking their books, so this is another way. I would discuss any kind of misconceptions.**
- 2c:23 JR: Thank you. I think you've actually answered a little - you've said quite a bit about my next question which was going to be, 'Are you conscious of directing conversations with pupils?' I think you've just been saying a little bit about how you...
- 2c:24 **TV: Yes of course. Trying to find out where there are common areas of problems and also I do say to them, for example we were doing a practical this morning and we were doing - I got the same practical - because I have six A2 students - I got them to do the practical separately. And they were saying, 'Why could we not use the same set of readings?' And we could do that as one group. Well, less work for them! But I said, 'No, actually if they set it up wrongly they will know whether they - well they may not be able to get any results, and you would be getting results, and they will automatically know whether they got it wrong because they wouldn't be getting any readings. So I would know where to go and troubleshoot. That doesn't mean that you would have got it right. I would be checking anyway - but at the same time - if they got it wrong you could help them and vice versa. So actually they got the circuit right, but one happened to not have the setting on one of the measuring instruments right. So actually it turned out to be useful to them. I said, 'OK, so you**

know they got it right, but you also learned from your mistake.' And they also learned from your mistake because they know that this particular quantity didn't have to be measured. So therefore we're learning from other people's mistakes and the more people hands-on the better. You'll not leave this to the others to do the work and then you just collect the results. So more hands-on - that will tell you - I mean it will be [revealing in itself - unclear]. There are lots of things to learn. The more you participate. [Tannoy interrupts - "Apologies for the interruption...]. We've got fifteen minutes.

2c:25 JR: Two more questions?

TV: No, no, that's fine.

JR: If a student disagrees with you, how do you persuade them?

2c:26 **TV: Oh, that's a good one. If a student disagrees with me then I get other people to voice out their opinions. And if they - well - there have been situations like that where actually that happened. And there was one student who actually was convinced that - because he knows he is very bright - but he got the basics wrong. And he was talking from personal experience. And I said, 'OK, do we have other people who agree with this?' So I tried to get the classroom involved. I don't try to say - the teacher is not always right. I always say that to my students. So of course he won't be - I think his first reaction will be, 'Well, I don't really think the teacher' - don't understand it from the teachers' point of view. Well what if my - there his friends will be able to explain that to him in their own - in his own language. Because sometimes I make use of that. Students explaining something to themselves in student speak. It clicks. When it clicks then I intervene. I say, 'OK, what made it click?' How is that different from what I said to you? So then that makes - what makes the difference is the word - the technical word that I used and the word that they used could be different. And they say, 'Oh yes, I meant that.' So that is where - when I would intervene I would let the other students do the work of convincing in student speak. And I use, 'OK, this is actually not the word that you should be using, it should be that word.' 'Oh! That's what you meant.' This happens.**

2c:27 JR: Just to be difficult, what if they all agreed with the student that you're trying to persuade?

2c:28 **TV: Alright. OK. That has not happened for - well OK I would say, 'How does that work with our basic principles?' I would refer them back to that. Those basic ideas. We can explain lots of things in terms of particles, energy, force, cells and interdependence. So does that agree with our definition or our principles? Well, what you're saying to me is they all agree to be wrong...**

JR: I'm just being difficult. [smiling]

TV: They all agree to be wrong. Now it is your role to convince me that whatever you're saying agrees with those basic ideas. And if you can use those ideas in a logical way - using any of those five basic principles - then we'll see where the problem lies. Because it does not - it is not logical to me, because I know how it works [indicates the five principles by holding up his hand]. And you are finding it difficult as a group. So let's try to see if we can make it work using those five basic ideas. If it doesn't work, do you agree that there is something wrong in your reasoning? We need to establish that first before we say, 'OK, now try to explain it with basic...' So we're going to agree so now try to explain it with basic - so we're going to agree on the fact that if you can't reconcile your ideas with the five basic ideas of science then would you be able to say to me that yes, there is a problem in the way that you're thinking? If we have established that, then I will let them - 'Now, OK, you reconcile your ideas with the five basic ideas - we need to get the rules of the game clear first so - I will accept I'm wrong if you're going to use the five basic principles of physics. Then I'm fine. I entice them first, and then let them explain, and in the way they explain I'll say, 'OK, is that a logical argument you have?' So

that way I would try to entice them first - so that they can open up. I say, 'I'm playing according to your game - to your rules. But are you happy to play according to what I put in front of you? That is basic ideas of science. So I try to get them...

2c:29 JR: Thank you.

2c:30 JR: I think several of these we've actually covered a lot in what we've been talking about. So I'm going to leave those. I'm also conscious of the time. Perhaps these last two just quickly. In what ways might the timing of what you do influence the children's learning?

2c:31 **TV: I think there was one thing [pointing at the laptop] one clip where I was clearly more concerned about the girl talking about the light - the issue of the light than the other one giving the right answer. So I was aware of the fact that I couldn't carry on with just focussing on just one idea because I was conscious that there were other things to be done. So I prioritised, and I thought about where is the greater good. So I know he was right. So I would have said, 'OK, well done. Well explained.' This needed a bit more attention, so I thought the greater good would be focussing on one of the issues where I think the girl would have left the classroom and said I really didn't understand that bit. Whereas the boy already understood, so this is how I would have prioritised my teaching within the timeframe. So I look at where is the better more to learn - more to gain from the lesson.**

2c:32 JR: Is there anything about this whole process that you'd like to say at the end?

2c:33 **TV: Yes. I would like to have the opportunity to do a similar sort of reflection about how things work in my class. I think these are good things - unfortunately we have that time concern as you said - we've got to complete a certain [indicates this with a spread of his hands] so I might - I mean I think I will have to - I will be using some of the things to just challenge some ideas in my class. I find it very interesting. I think it will be beneficial to my students and to myself. To be able to get to that level of discussion. And bearing in mind that, OK, language communication skills could be one of the things that could be a problem to the learning. And the fact that because we didn't use other than the picture as a challenge rather than a picture to support the explanation wasn't used. So it came down to who can communicate the problems or the ideas clearly. The others were quiet because - I think they could have lacked the vocabulary. Or maybe could be shyness as well. I don't think, the people who were chosen normally they are quite - in their normal environment they would be able to talk normally - speak up. But I think there were some quite challenging questions there. And they - and other than their own experience or maybe lack of experience - from lack of experience they couldn't express themselves. They didn't say anything. But I would suspect also the vocabulary in the absence of something that you would use graphical approach. Yes, there are people who find it difficult to express themselves.**

2c:34 JR: It has been a huge pleasure talking with you and working with you. Thank you very very much for giving up your time like this. I hope you know how much I appreciate it.

2c:35 **TV: I hope that because this is an interview there are things that I could have - I might say that... But that is not unedited.**

JR: Please don't worry. That is the nature of the data.

TV: Exactly. I'm looking forward to looking at your analysis and what I could learn from yours. So I can improve my teaching.

JR: Thank you very much.

[End 2c]

Interview 3a

3a:1 [unclear]

TW: It is a bit like a board room isn't it. Only I'm not going to fire any of you. What is really important to remember is that there is not necessarily a right or wrong

answer today. This isn't about being right. It is a bit like that show 'Quite Interesting' - I don't know if you've ever seen that. [Pause] Are we ready? [to JR]

JR: *Yes. All ready.*

3a:2 **TW: I wasn't sure it was ready. Right, thank you very much for being part of this. Firstly well done. Because not only have you volunteered, but also I talked to Miss D and she said that you'd be really good at this. And that's a compliment in itself, so that's really nice. Erm. We're going to talk about science in general, so it is not about the topics you might be studying at the moment with Mrs D, it is not about anything specific. And as I've said already it doesn't matter whether we come to a perfect answer, the getting there is the important thing. The thinking [stresses this word by saying it more slowly] is the important thing and you having ideas. And it doesn't matter if they're a bit silly or if they turn out not to be the right answer or anything, it is just about thinking, and about talking about things. So this is one lesson where you've got to do lots of taking, rather than sometimes you get told to 'shush' don't you. So the first thing I'd like to talk to you about is how you - start by telling us who you are, so the camera picks up who you are and how you feel about science. Who thinks they'd like to start that off?**

3a:3 **TW: [Pause] Shall we have a minute to think? So who we are, and how we feel about science.**

DL: [unclear]

TW: Well, shall I start off as a little demonstration? So, hello!, my name is TW, and I am a science teacher and I really love science. Do you [DL] want to go next?

3a:4 DL. OK. Hello. My name is DL and I like science because you do experiments and learn things you didn't know about.

3a:5 UA: Hello, my name is UA, and I really like science because it makes you learn about new things.

3a:6 KG: My name is KG and I like science because you get to use the microscopes.

3a:7 GS: I like science... My name is GS and I like science because you get to experiment new things, you get to learn about different types of cells or... different stuff.

3a:8 VH: My name is VH and I like science because we do lots of experiments and... yes.

3a:9 LM: My name is LM and I like science because we learn new stuff that I didn't know about.

3a:10 **TW: OK, excellent. So what is the first thing you would think of when someone says the word science to you? If you just had to think of one word that would sum it up, what would that word be for you?**

3a:11 GS: Crazy - like scientist crazy hair. [Indicates hair sticking up with his hands]

3a:12 **TW: OK! Anyone else got an idea? What does science make you think of?**

3a:13 UA: It makes me think of understanding.

3a:14 DL: Everything?

3a:15 **TW: Ooo. [Looking round towards VH and LM]. Any other ideas?**

3a:16 VH: It makes me think of experiments and [pause]

TW: Experiments [looking round the group], that came up a lot when you were discussing why you liked science, that is probably why you think of it. Anything about science that you [KG] think of?

3a:17 KG: Solids, liquids and gases.

3a:18 **TW: OK. [Looking round at LM]**

3a:19 LM: Everything about Earth.

3a:20 **TW: Wow. Can you think of a situation where you've actually had to change your mind about something or someone has changed their mind about science, because of an experience? So maybe an experiment you've done or something that happened to you. That made you change your mind about something to do with science. [Slight pause] That is an interesting question isn't it. [UA puts his hand up and TW is**

- looking at him] You might need a couple of minutes to think. Have you got one already UA?**
- 3a:21 UA: Um, when I was younger I asked my mum to buy me a Bunsen burner [TW nods] and I was in my room playing with it and I actually found I could change the flame, but accidentally when I changed the blue flame to the blue flame I had a knock on my door so I turned and it actually burnt my clothes. [TW has her mouth open in a shocked expression] So now I know to make sure I turn the Bunsen burner off before I do anything else.
- 3a:22 **TW: That is quite an experience [with an impressed tone of voice]. I did not know that you could have Bunsen burners at home. How does the gas supply - does it come with its own little gas supply?**
- 3a:23 UA: Yes.
- 3a:24 **TW: How interesting. Well I'm glad you've learnt that lesson without harming yourself. [Turning to LM and VH] Anyone else got any experiences where they've learnt - and that [turning to UA] is quite a dramatic one isn't it. [Turns to DL] DL.**
- 3a:25 DL: I always thought that sugar, salt and sand was always liquid. Because it fit into the shape of its container. But I actually found that each individual one is a solid in itself, even though they all flow in the thing - the shape of the container.
- 3a:26 **TW: That is where there is overlap isn't there. There is not always a perfect answer to science is there? Because sometimes you know it is a solid, but it behaves a bit strangely. Things like custard confuse that as well. Anyone else got any experience that they've thought of? [Slight pause] It could be in a science lesson you did back at primary school. [Pause] That is a difficult one isn't it. Well maybe, as we go [GS indicates he wishes to come in]... Go on GS.**
- 3a:27 GS: [Unclear] safety issues. And like you're always - you always - like once at home there was like this piece of liquid, it was science. I tipped it over. I didn't know it was a poison. So... [pause]
- 3a:28 **TW: So what do you think you learnt from that experience? [Smiling with GS]**
- 3a:29 GS: Um. [Pause] To be careful.
- 3a:30 **TW: That is an important one again. I think safety is probably the first thing you learn about when you come to secondary science isn't it. Because it is pretty safe at primary. Things get a bit more dramatic here. Well as we go through today, if something comes to you and you think, 'Ooo, that reminds me of a story, or that reminds me of something that happened.' then we can come back to that question later. But now, we're going to think about these two things [indicating the cup of tea and bowl of ice cubes on the table]. Now we've got a hot cup of tea. And that is quite impressive, because sir has brought that with him and that is still quite hot. And in there we've got ice cubes. Do you want to pass them round. Try not to spill anything. This is obviously very warm, probably not hot enough to burn you but be quite careful. [Ice cubes go one way round and the tea the other way round. Each student feels them both] So my question to you - I'll let you feel them all first [Pauses - noise from the sliding cup]. I just want you to be thinking about the hot tea, thinking about the ice. Careful as you pass them round. [Pause] Everyone has had a look. Not something that you've not seen before. Right, but. Now we need to think about what is happening, right now, to this hot cup of tea and to these cold ice cubes? [UA, GS and possibly KG with hands up] OK, shall we go round again. Do you want to start UA and then we can go round. See if we can add as much detail as possible [said in an animated way with hand gestures] so if they've said something [indicating DL and UA] you can sort of nod along that you agree, and if there is anything you want to add you can add to it.**
- 3a:31 UA: In the ice cubes, the ice is slowly melting so that is going to create more water in the bowl. [TW nods] And with the hot cup of tea, because, I'm not sure, I don't think it is boiling but there is steam coming from it.

- 3a:32 **TW: What would you like to add to that DL?**
- 3a:33 DL: The ice cubes are melting and if you were to put a - like if the steam, if you were to put a cover over the top it would be condensating [sic] - on the side of the glass.
- 3a:34 **TW: Oh yes. So we could do our own little experiment here and produce some condensation [on this last word TW turns her head once more towards DL]. Excellent. What would you like to add LM?**
- 3a:35 LM: Ice was a solid when it started and now it melts so it comes out a liquid.
- 3a:36 **TW: OK. Anything else [looking at GS or VH]? VH, do you want to have a go?**
- 3a:37 VH: I wanted to say what she [LM] just said.
- 3a:38 **TW: You wanted to say that. OK. Look at the ice. Is there anything else you can tell me about it? [Long pause] There is a word I thought we might have used by now. Are you going to use it GS? Let's see.**
- 3a:39 GS: Melt. Melting?
- 3a:40 **TW: Ah no, UA has already used that. That was a very good word.**
- 3a:41 GS: Freezing.
- 3a:42 **TW: OK, why might we use that word?**
- 3a:43 GS: Because it was - it froze to an ice cube, it was actually a liquid. And it froze to an ice cube. But because the atmosphere and our body temperature is quite hot and mixed with the ice cube it melt into water.
- 3a:44 **TW: OK.**
- 3a:45 GS: It is coming a bit - it is coming is going to come colder in time because there is nothing to cover it and all the air is coming in to it. And it makes it colder.
- 3a:46 **TW: OK, so lots of you have talked about changes. You've talked about changes from changes of state. So we talked about things going from solid to liquid. What kinds of changes was GS talking about there? If something becomes colder what kind of change are we talking about? [UA has hand up] Have you [KG] got an idea, because you've not said anything yet.**
- 3a:47 KG: Is it freezing miss?
- 3a:48 **TW: That would be a change. What would I have to do to this [indicating with her hand the bowl of ice cubes in water] to make it freeze? Is it freezing now?**
- 3a:49 VH: No. You put it in the fridge.
- 3a:50 **TW: OK, so what kind of change. [Pauses] Hang on fridge or... [pause] freezer.**
- 3a:51 VH: Freezer.
- 3a:52 **TW: That would still melt in the fridge. What kind of changes are we talking about? If I put something in the fridge or the freezer what am I changing about it?**
- 3a:53 VH: If it was an ice [sic] - no, if it was a liquid and you put it in the fridge yes it becomes a solid.
- 3a:54 **TW: OK, maybe what I'm asking is why? What's changing? [GS has his hand up] DL.**
- 3a:55 DL: The temperature.
- 3a:56 **TW: That's the word. Now you were all discussing it, I think you might have mentioned it GS, but the kind of changes we're talking about are temperature changes. [Emphasises the word temperature with voice and says it more slowly than other words in the sentence] So let's try to stick to that idea now. Can we make a link. Can we make a link between the temperature and the other changes? [Pause] UA nods. [Said with feeling] Go on then UA!**
- 3a:57 UA: The change in temperature you can link to say like to water. If you say like 100 - if it is over 100 in temperature it has become to its boiling point. So that could create gas.
- 3a:58 **TW: Ah. Who talked about gas earlier?**
- 3a:59 DL: [unclear - but appears to be something like 'I talked about condensation']
- 3a:60 **TW: Oh. Is condensation a gas?**
- 3a:61 DL: [unclear because said very quietly, but seems to be:] It is gas sort of turning into liquid on a cold surface.

- 3a:62 **TW: Yes, that is exactly what condensation is DL. Well done. Someone did mention that they thought there was some gas coming off this [holding the cup]. If I just got it from the kettle, what do you think you would see?**
- 3a:63 Several students simultaneously: Steam.
- 3a:64 **TW: That's the gas isn't it. Yes? So if a liquid changes to a gas UA has explained the change that must happen, there must be a temperature change and for water that is over a hundred. So what is the change here [tapping the bowl of ice cubes with her hand]? Why is there a change here?**
- 3a:65 GS: Because um, that [the bowl with ice cubes] is at zero degrees I think.
- 3a:66 **TW: If I wanted to make it freeze.**
- 3a:67 GS: Yes. It is at zero degrees. To bring it back, I think, you'd have to boil it. No, you can't steam. You can't steam...
- 3a:68 **TW: OK, what is it doing at the moment?**
- 3a:69 VH: It is melting.
- 3a:70 **TW: It is melting. So what sort of temperatures must we be getting for it to melt?**
- 3a:71 DL: Room temperature. [TW looks over at DL as DL answers - the first time this is said is it very quiet] Room temperature.
- 3a:72 **TW: Room temperature. What is room temperature?**
- 3a:73 UA: Twenty nine.
- 3a:74 **TW: Oh, that would be a bit sweaty. A little bit sweaty.**
- 3a:75 GS: The atmosphere around us.
- 3a:76 **TW: It is the atmosphere around us. I wondered if you could put a number on it? UA said twenty nine, but you're a little bit high.**
- 3a:77 GS: I think it is thirty... [GS appears to be about to say another number as in 'thirty three' or something]
- 3a:78 **TW: [In a whisper and with a smile] That's higher.**
- 3a:79 GS: Thirty?
- 3a:80 **TW: Thirty is higher than twenty-nine. That would be even hotter. [TW sits back in her chair] KG? [Said with a smile and slight laugh in the voice]**
- 3a:81 KG: Thirteen?
- 3a:82 **TW: Oh, that's a bit low. [Laughs] I think we're ending up right in the middle of those two.**
- 3a:83 KG: Is it eighteen miss?
- 3a:84 **TW: Sometimes. Certainly my classroom is about eighteen today. But usually a nice warm classroom like this one will probably be about twenty one degrees. We just class that as being room temperature. Just for simplicity. Right [Said with a different tone indicating a change]. Something was said earlier about this one getting colder because cold air goes into it. Does anyone want to talk about that and talk about why this [indicating the cup with her hand] is getting colder? This cup of tea. [UA has his hand up] Just think for a moment about what we talked about. About room temperature, about warm and cold liquids and so on. Shall we have a go at that. This is difficult [TW's tone emphasises this]. This is difficult.**
- 3a:85 KG: [GS has had his hand up - TW indicates that KG should speak] The temperature of the cup of tea is kind of - the temperature of the cup of tea is very hot yea, and the temperature in this room is kind of lower so is that why it is getting cold?
- 3a:86 **TW: That is a really nice description. We've got temperature difference. But, why does anything get cold? [GS has his hand up] GS?**
- 3a:87 GS: Because you know the temperature of that [the cup] is hot but the table is quite cold. [GS is feeling the table with his hands]
- 3a:88 **TW: It is isn't it [feeling the table with her hands]**
- 3a:89 GS: When it is touching the glass, it causes the temperature to come a bit colder so the [table?] underneath [the cup?] would be I think hot.
- 3a:90 **TW: Oh I see. So where does it [heat?] go? [Pause]**

- 3a:91 DL: [unclear - could be 'Into the cup?']
- 3a:92 **TW: What the temperature? [Speaking with DL] If it is going to get colder. What are we actually talking about when we talk about temperature? If you think about the difference between a solid, liquid and a gas. If something has got a higher temperature do you actually know what it has got more of?**
- 3a:93 UA: Has it got more of...
- 3a:94 **TW: So for example a gas would have more of this than a solid.**
- 3a:95 UA: More molecules?
- 3a:96 **TW: It is not more molecules, but it is definitely to do with the molecules.**
- 3a:97 LM: Particles [unclear as said very quietly]
- 3a:98 **TW: Molecules or particles. Yes. That is a good word. [TW nods as she says this] [Pause] What do gas particles do that solid particles can't?**
- 3a:99 GS: [Has hand up and really wants to come in] Miss you know particles in a [solid?] - in - it is quite close to each other.
- 3a:100 **TW: Mmm. [Nodding and leaning forwards]**
- 3a:101 GS: So in a solid it is just close together, so when it melts it vibrates I think and it goes...
- 3a:102 **TW: There is a good word. Keep going...**
- 3a:103 GS: It goes apart to a liquid [TW is nodding] and when it goes to its boiling point it starts um... going [TW nodding]
- 3a:104 **TW: Right, so someone, a person maybe, not even a particle, is mov...**
- 3a:105 GS: Going hyper.
- 3a:106 **TW: ...is going hyper. What have they got more of?**
- 3a:107 GS: Energy
- 3a:108 **TW: Someone said it. [TW points with index fingers of both hands] I think maybe one of the girls said it as well. GS, [sitting back in seat] excellent. Energy [Said with considerable emphasis and lengthening the word]. So when something has got a high temperature, really we're thinking about how much energy it has got. So if this is getting cooler [indicating the cup] where is the energy going? [TW crosses her arms as if stumped by this question]**
- 3a:109 KG: Is it into the air miss?
- 3a:110 **TW: Sort of, yes. Keep going with that idea.**
- 3a:111 UA: Does the energy go along with the steam?
- 3a:112 **TW: Tell me more. [TW leans her head on her hand in a 'listening' posture]**
- 3a:113 UA: Maybe because the steam is showing the energy of the particles in the tea and it is so hot the particles need to get away so they're turning into gas to escape?
- 3a:114 **TW: That was a really nice word. They actually escape [emphasises the word escape] when liquid boils. It is like a particle [TW mimes running with her arms], "I'm free, I'm free!" Whoosh! [TW indicates something flying off with her arms] They shoot off, because now they're not confined to the cup [TW touches the cup]. The kettle or whatever. What were you going to say GS?**
- 3a:115 GS: I was going to say the top bit [GS is standing up and reaching towards the cup] it stays at the top bit. When it gets to its boiling point - because if it was a kettle it goes really really quick up in the air. So the particles just go really quick. [TW is nodding] Like I said [unclear but may be 'and frees itself in the air'] [TW nods and smiles]
- 3a:116 **TW: But we've actually got the opposite happening here haven't we. Because our cup of tea is sadly not boiling. It is not that the particles are going to get [indicating with her hands particles moving into the atmosphere] out, get free. What is going to happen to their energy? [TW looks at DL]**
- 3a:117 GS: [Puts his hand up and says 'Oh' - TW continues to look at DL as if not noticing GS - VH has her hand up slightly but not as enthusiastically as GS]
- 3a:118 **TW: [Pause] It is something to do with... KG, can you just remind us what you said? [GS puts his hand down]**

- 3a:119 KG: I said that if the temperature in the room is much cooler than the temperature that the tea is at that is why it is getting colder.
- 3a:120 **TW: You also told us where the energy was going to go.**
- 3a:121 KG: In the air.
- 3a:122 **TW: In the air. [Pause] OK. Not just in the air, where is that energy going to go? [Pause] [KG puts his hand up then brings it down again. GS puts his hand up]**
- 3a:123 GS: We're going to breath it in.
- 3a:124 **TW: We might yes! That is really nice isn't it. I was doing it earlier when you're a bit cold [holding the cup of tea in both hands] you always see teachers hugging their cups of tea when they're out on duty. Why do we do that?**
- 3a:125 DL: Because the heat transfers from - if you have your hands on the cup like you feel like your nerves. Your nerves like pass the heat on. Sort of thing.
- 3a:126 **TW: Does anyone know what it is called when the heat transfers?**
- 3a:127 UA: [Puts his hand up] I think it is called conducting.
- 3a:128 **TW: Excellent. So if that goes through from that liquid, through that cup and to my hand it is conducting through. And actually it will take it away. You actually take the heat away. So of course that liquid is getting colder and colder because the energy is, in this case, going into me. Or in this case, [TW puts the cup on the table] ... where is it going?**
- 3a:129 VH: Table.
- 3a:130 **TW: Table or the air. Some will come out here [indicating heat coming out through the side of the cup with her hand]. Some will go that way. It is all about energy transfer.**
- 3a:131 GS: You will put some of the heat from your hands into the cup.
- 3a:132 **TW: That is true, I don't think I actually have any today though [TW feels her hands]. I've got such cold hands, even though I've been holding that, I've got such cold hands. You can see they're really pale today. But you're [GS] right [TW picks up the pace with which she is speaking this last sentence]. In fact [said with emphasis] let's try and use that to explain - if you touch something metal [TW and students touch the metal edge of the table]. That's not a good example. But if you were to touch that door handle for example. GS, would you do that for us? [GS gets up and goes to the door handle and touches it]. Will you tell us how it feels?**
- 3a:133 GS: Cold.
- 3a:134 **TW: Right, why do metals feel cold then? [DL, UA, KG and GS all have their hands up - TW is looking at DL]**
- 3a:135 DL: Because metals conduct heat and that is why when you're cooking you don't use a metal spoon to cook if you're boiling - if you're cooking on a fire [TW nods] because metal - the heat passes through metal. It doesn't pass though wood.
- 3a:136 **TW: Excellent, so add a little more detail to that. So let's go through the steps. GS has walked over [TW mimes this as she says it] and he put his hand on the handle. Tell me step by step about the energy and what is happening.**
- 3a:137 GS: Because my hand was quite warm, I put my hand on the metal handle, so it is conducting heat from my hand onto the metal handle.
- 3a:138 **TW: Yes... [TW's tone invites GS to go on] [Pause] Anyone want to add to that? That was a nice description GS [TW looks over at UA who has his hand up. KG also has his hand up].**
- 3a:139 UA: And erm, so before GS put his hands on the door knob, because there was no heat touching or reacting to it before - it was cold, but the second GS put his hands on it the energy transferred.
- 3a:140 **TW: Well sort of. I mean there is no real thing - there is no such thing as cold. There is only the absence of hot. That's a bit complicated [This last sentence is said in a quieter voice than the one before]. But the reason it feels cold is because it is actually**

- stealing from you. [Pause] When you touch metal it is stealing from you. What was it stealing?
- 3a:141 DL: Your heat.
- 3a:142 **TW: Your heat. It is stealing it. It is taking it away. Because it takes it away quickly it feels cold to your touch. I think that was a very interesting discussion. Before I get rid of it, does anybody want to say anything else about our ice or our tea? [Pause] No? Had enough of that? OK. [TW gets up, removes the tea cup and bowl of ice cubes and gets the materials for the living and non-living card sort activity]. Right. We're going to have a look at something different now. Um. Sir [to JR]. I realise I didn't mention. I don't actually have a watch on. So!**
- 3a:143 *JR: You're doing fine!*
- 3a:144 **TW: I just thought I'd mention that. This has got a little wet [bowl of water and ice cubes spilt earlier]. Are they doing this in pairs or ones or all together? [to JR]**
- 3a:145 *JR: One each please.*
- 3a:146 **TW: One each. So you need - pass one of those. That says 'living' on it. You can be thinking what the word living means. And you need one that says non-living as well. Each bag is different yes? [Last sentence is to JR]**
- 3a:147 *JR: Each bag is the same.*
- 3a:148 **TW: [unclear - but could be 'Each bag is the same'] OK, so you need a set of cards as well. So you should have two big mats, one saying 'non-living' [TW holds this up] and one saying 'living' [TW holds this up]. OK. Wait a minute. That's a spare one [TW removes this from the table]. And then you've got a set of cards. Now there are all sorts of different cards in there. And all you've got to do is decide which side you put them on. I'll give you a few minutes to do that and then I might ask you why you've put them on either side. OK? Everyone happy?**
- 3a:149 LM?: Yes.
- 3a:150 **TW: Good stuff! [Pupils are sorting their cards. TW is standing holding a pack of cards in her hands]. Do you [JR] want them to talk about it as they're doing it?**
- 3a:151 *JR: If they'd like to.*
- 3a:152 **TW: Yes, if you want to talk about it you don't have to do it in private. Let's have a look at some of these. [TW says this last sentence in a quiet voice as if to herself. TW sits down and starts looking through the pack of cards. TW pushes her own mats away from herself to give room on the table and then starts laying out her hands on the table - these are not sorted into living or non-living]. It doesn't matter at all if you don't have the same one as the person next to you. If you don't agree with them that doesn't matter. [Silence for some time as students sort cards] [TW checks the questioning route. DL looks at UA's mat]**
- 3a:153 DL: [Sits back as if in fright] That's scary!
- 3a:154 **TW: What's scary? The spider? Ahh! Did it jump at you? [Silence for some time] What an interesting selection. [Some students continue to sort] How did you start going about doing that UA. You seemed very confident. You've just gone boom boom [miming placing cards confidently] Splitting them all up. Did you have an idea in your mind [indicates thoughts swirling in the head with her hand]?**
- 3a:155 UA: Yes. I had an idea. Some... I thought some things, well say, let's take the river for example. Because it has got erm - because the area around it, it feeds off the area around it - so I thought it could be considered living.
- 3a:156 **TW: OK, so you've gone through it, you've used some sort of criteria to judge. OK. There is no rush by the way. [DL just finishes] Did you [DL] have a criteria? How have you thought about it?**
- 3a:157 DL: Erm. I just think that all the plants are living. Mushrooms they grow, so they must be living. Like a bike doesn't grow. An embryo is a baby. Lions grow. Everything [unclear - could be 'on living?'] really can get bigger. And like, I think, yes... [DL trails off]

- 3a:158 **TW: That's OK. We'll remember that word, because that might be useful to us in a bit. Are there any words you don't know? The pictures are pretty helpful aren't they. Is there anything on there that you don't recognise? There is a very difficult word embryo [TW holds up this card]. Do you know what it is?**
- 3a:159 DL: Yes
UA: It is a baby that is being formed in the mother's womb. [Said very quietly]
TW: Say it again for me. [TW cups her hand round her ear]
UA: Yes. It is a baby that is being formed in the mother's womb.
- 3a:160 **TW: OK, so very early stage it is called an embryo. It doesn't look much like a baby yet does it. Once it's been a few weeks old.**
- 3a:161 UA: Unless I'm mistaken male horses give birth so... Male sea horses give birth.
- 3a:162 **TW: Oh. I see what you mean. You worried me there for a moment! Male horses. Is this a bit of science I don't know? [UA laughs] That one to me when I saw that picture [of the embryo] I thought it looked a bit like a kidney. [TW is holding up the card] It looks a bit like a kidney if you dissected it - maybe in one of your science lessons. What is really interesting to me looking round - I don't know if they're just not in the same order - but you all haven't all done it the same way. Now that is really interesting to me. So maybe if you have finished, think about what you use to decide where you put each thing. Because then you might, this might be an experience that makes you change your mind about science. One of the others might convince you to move one of your cards. Maybe if I do this one [TW moves her mat towards the centre of the table - it is still empty]. Then we can do our group list on there. What do you think? How are we doing?**
- 3a:163 KG: Finished.
- 3a:164 **TW: Good job. So be thinking, "What have I done?" "How do I know that one went there or that one went there [TW is miming putting a card on a mat and then putting another card on a different mat]?" OK? [Pause] Everyone happy? [GS nods] OK. GS would you like to start us off with an example and where you put it and maybe tell us why you've put it there.**
- 3a:165 GS: Um. I put an egg on living because a baby - a chicken gives birth to an egg and inside that egg there is a chick. So if you don't eat it and it comes into a chick which will become into a chicken.
- 3a:166 **TW: OK. Does everyone agree? [Pause] You had it over here LM. Why did you put it under non-living?**
- 3a:167 LM: I couldn't think of anything. I couldn't think that it was living. Because if you eat it you can't think that it is actually living.
- 3a:168 **TW: Interesting. So does eating something change it?**
- 3a:169 DL: No, because that [the egg] looks like it is on the breakfast table. That is what you put an egg in.
- 3a:170 **TW: Oh right. So what do you think you've probably done to it in that picture?**
- 3a:171 DL: You've probably boiled it.
- 3a:172 **TW: So would it be alive if you've cooked it?**
- 3a:173 DL: No.
- 3a:174 **TW: But, going back to what GS said, if it wasn't that picture, and it just said egg [TW holds up the card covering over the egg cup with her hand but showing the word egg] - say your explanation again.**
- 3a:175 GS: The chicken gives birth to a chick, but it first needs to be in an egg, so when it comes out of an egg it is already transformed to a chick and finally it breaks its egg and hopefully comes to a chicken.
- 3a:176 **TW: Great. So that is a really good example of one you could probably put in either list. If you just looked at the word, you might agree with GS. If you looked at the picture [again covering over the word and showing the picture of an egg in an egg**

- cup] you might agree with LN and DL. Are you [GS] thinking of changing one then [TW has seen GS moving one of his cards]?**
- 3a:177 GS: Yes.
- 3a:178 **TW: Ooo, interesting. Maybe we'll talk about that one next then. I don't know where to put mine now. Because they were such good convincing arguments. I might put it in the middle [TW places the card between the mats] just to be awkward. GS, what was the one you've just decided to move. I think it is interesting that you've decided to move it.**
- 3a:179 GS: Bicycle, because on this bicycle there is just a bicycle bicycle. But on this one there is actually a person on the bicycle which...
- 3a:180 **TW: LM you're nodding.**
- 3a:181 GS: Because a person is living, they're using their energy on the bicycle to pedal, it makes it [the bicycle?] living.
- 3a:182 **TW: Oh, OK. So, you talked about three different cards there [TW holds them up so students can see them]. KG do you agree? Where have you put these three?**
- 3a:183 KG: Well, now from what GS has said I'm changing my mind and I'm putting the person on the bike on living because - I don't really - I don't know miss [lifts and drops his hands in a sign of resignation?]
- 3a:184 **TW: You sound like you've been convinced.**
- 3a:185 KG: I wasn't sure where to put it, because it says just bicycle and I wasn't thinking - I was thinking just bicycle. You know, living or non-living. But after what GS has just said is making me think like it is true. Someone is riding on a bike.
- 3a:186 **TW: OK. So it sounds to me like it is a bit like the egg one. If it was just the word bicycle - or it was that one [picture of a bicycle without a rider with the word bicycle underneath it] where would you put that one [TW is holding up the card]?**
- 3a:187 DL and others: Non-living. [TW then puts that card on non-living]
- 3a:188 **TW: You're all categoric [sic] about that. So why isn't a bicycle living?**
- 3a:189 GS: Because... [TW is looking at DL]
DL: Because it is made of metal.
- 3a:190 **TW: OK, so nothing metal can be alive?**
- 3a:191 GS: Because it is man-made [TW continues to look at DL while GS is speaking].
DL: Yes, because it is not growing [TW smiles with DL] it is not made with... [DL trails off]
- 3a:192 **TW: OK. No, [indicating this with her hand] I'm not saying you're wrong. I'm just asking. So if something is made by a man...**
- 3a:193 GS: Because if somebody made it, somebody invented it, it wasn't just there naturally. [TW says 'Umm' and looks upwards as if thinking] If somebody invented it. If it was there...
TW: Do you...
GS: ...naturally, for example trees - just appear to be on Earth.
- 3a:194 **TW: Do you think scientists ever make anything living? [TW is looking at DL]**
- 3a:195 GS: Probably.
DL: I don't know.
UA: Not unless they... Well they [scientists] can make something living, but the only thing is to make something living you've got to make sure that it is possible to actually [GS has hand up] - It has got to have some form of intelligence. [TW looks upwards as if thinking about this] It has got to have some form of knowing what it is doing for it to be alive.
- 3a:196 **TW: Has it? Does a tree know what it is doing?**
- 3a:197 UA: [Pause] Well, [pause] well, if you think about it the cells that make up a tree the nuclea [sic], the nucleus, it gives out instructions so it must know what its instructions to help the tree survive. [TW looks over at VH and LM]

- 3a:198 **TW: What do you [VM] think? Do you agree? Do you think a tree knows what it is doing?**
- 3a:199 GS: No.
DL: No. [unclear as very quiet]
- 3a:200 **TW: You've [LM] put it in living. So have you [GS].**
- 3a:201 GS: Yes it does, because if it doesn't know what it is doing it won't grow. Because you need to have some sort of brain which would make be able to have the intelligence to grow.
- 3a:202 **TW: Does it take intelligence to grow?**
- 3a:203 GS: No, it doesn't take intelligence - it needs to have some [DL has hand up] sort of intelligence to grow. It doesn't have a brain, but it must have something in it - maybe... I don't know what it has in it but it has something in it to make it grow.
- 3a:204 **TW: You're working with some very difficult ideas here [The tone this is said with is lower and conveys respect for the ideas being discussed]. There is not necessarily a right answer to this. You're doing really well guys. DL.**
- 3a:205 DL: I think it doesn't know what it is doing. I think it just takes food and then it is like - it is like humans. If they don't have a brain, it wouldn't really matter that much. The world wouldn't be the same, but they would just eat and they would just do what they do [GS, VH and LM all have their hands up - GS very high, VH and LM much lower] - It wouldn't...
- 3a:206 **TW: Can we think of examples of things that have brains but perhaps don't know things?**
- 3a:207 GS: Animals
UA: Perhaps a fish, because they've got - or a goldfish, because they've got a three second memory.
- 3a:208 **TW: Apparently it is a bit better than that. Yes, but we know them not to be exactly really clever.**
- 3a:209 UA: As GS said about the brain, as I said about the nucleus, that could be considered considering the number of cells that make up a single tree the amount of nucleuses could [TW smiles] be considered the brain of it - of the tree.
- 3a:210 **TW: So would you say that a tree would be cleverer than a daffodil, because it is bigger?**
- 3a:211 UA: Um. Well, [TW is smiling] it all depends on the number of cells it has compared to the daffodil I would say.
- 3a:212 **TW: That is an interesting way of measuring it. No one has a perfect way of measuring intelligence. What do we do in school to try and measure intelligence?**
- 3a:213 DL: Tests.
- 3a:214 **TW: Could you give a tree a test? [Smiling]**
- 3a:215 UA: No.
Others: No.
- 3a:216 **TW: Well, not a real one. VH.**
- 3a:217 VH: I think the tree doesn't have a brain because if you put on water it grows. But if not it is dying if you don't put on water.
- 3a:218 **TW: Yes.**
- 3a:219 VH: It doesn't have a brain.
- 3a:220 **TW: But by saying it can die, does that mean you agree that it is living?**
- 3a:221 VH: Yes.
- 3a:222 **TW: So what do we think? Do you have to be able to know things to be alive?**
- 3a:223 GS: No, because probably - VH said you have to water it, then it gets its gets its - it goes to its roots and stuff to make it grow. And I think that the leaves as well help by photosynthesis.
- 3a:224 **TW: Mmm. Wow, there's a nice word. UA.**

- 3a:225 UA: As GS said, I'm just giving a... I'm just asking this. As... When you said the tree, you have to water the tree. Nature must take its course for everybody. Everything must eventually die. There is no stopping that. I understand that. But, um, when nature takes its course the roots actually take water, as you said, but what - what exactly um makes the tree - the nucleus - why does it have instructions to say on a hot day use photosynthesis or on a cold day or a rainy day take water from the roots? So I was just wondering - what is your... What would you say about that?
- 3a:226 **TW: Can anyone answer that?**
- 3a:227 GS: I didn't understand what he said.
- 3a:228 **TW: Do you [DL] want to try and answer it?**
- 3a:229 DL: I did. I understand what you're [UA] saying like. On a day - if we know we're thirsty then we'll take water because it is hot. And he [UA] is saying how will the tree know to do that if it didn't have a brain. Something to think about. And I think - I think they sort of - they don't have a brain, but they have something that tells them to do this on a certain day. [TW indicates with her hand that GS can come in - he had his hand up].
- 3a:230 GS: I think the sun really helps them a lot. I think literally - because it can take food whenever it wants [VH puts her hand up] the sun just needs to be in this direction - so that is why I think um the rain can't really get to its roots because the leaves are blocking it. So... [GS stops. TW nods to VH that she can come in]
- 3a:231 VH: I think the tree doesn't have a brain, but the way [unclear] the tree grow - if you put water and - yes - first you put the seed, what tree you want to grow. And then when the wind comes it actually grows and with the [unclear - 'suns rays'?] it actually grows a lot more. And - yes, because it is raining it grows [unclear - tailing off]
- 3a:232 **TW: [Coming in quickly] So... I really like UA's question. It was a really good one. You could say the same for animals as well. Like how does a dog or a cat know that it needs to eat or go and have a drink or any of those things. But that word know [holding her hands together as if holding the word] I think we're getting a bit stuck on that [GS and KG have hands up, but TW goes with LM who also has her hand up but much lower down]. Do you [LM] want to add some ideas?**
- 3a:233 LM: I think - not really like having a brain, but it is still living because as there was a seed, it grown up [sic], and then when it is winter it actually dies because it is too cold.
- 3a:234 **TW: Does it die completely?**
- 3a:235 LM: No, but it doesn't have leaves.
- 3a:236 **TW: Ahh. What happens to the leaves?**
- 3a:237 LM: They fall off the tree. And then when it is spring again, it comes alive like - it is still a process.
- 3a:238 **TW: Mmm. I like the idea of it being a process. [TW indicates GS can speak]**
- 3a:239 GS: I think the tree - the tree by itself, only the leaves is the thing that dies. The tree could go on for ever, but if you cut it maybe not. Um. I think nature is the thing that helps because the weather helps a lot - like photosynthesis and when the water goes down the roots. And animals have got something to help with it as well. They disperse the seeds. Sometimes they might disperse it if it gets stuck.
- 3a:240 **TW: Yes. Go on UA. [Who has his hand up]**
- 3a:241 UA: Miss I've got a question.
- 3a:242 **TW: Oh well, hang on hang on. Before we go onto another question, I think GS had really started to answer your question. Now your question was more philosophy than science. Do we know... what is philosophy? I know you know what philosophy is because you do philosophy every week. What is philosophy? [Pause - several hands up] Go on then [KG]**
- 3a:243 KG: Philosophy is like a lesson all about the mind [touches his head], how we think. Like stuff that happens in life. Basically like living, like life.

- 3a:244 **TW: OK. So we started talking about life, and whether people think trees are al... - you know have brains and can think about things. And do you think science can answer that question?**
- 3a:245 DL and others: Yes.
GS: Maybe.
DL: Maybe in the future [unclear]
- 3a:246 UA: Yes, maybe in the future when we have got a greater understanding about knowledge. I would say. [TW nods] And how [unclear - 'philosophy'?] helps us and how it helps the environment and animals around us.
- 3a:247 **TW: So when we're talking about nature, whether it be an animal or a plant, we tend to call it animal instinct or a natural instinct to do things to keep it alive. The idea is that the only pressure on you is to try and survive. And so a tree wants to survive and a plant wants to survive and a rat or a dog wants to survive. So they try - we can monitor their behaviours - but I don't know that we can find out what - even if there even is a thought process. [DL has hand up]**
- 3a:248 DL: I remember in primary school we had a question that was - my teacher said that - I think she said it was like a - like a clock down time like. What is happening is the tree is growing and it knows in the winter that by the time the clock stops the leaves fall off and the clock starts again [DL indicates a clock face with her arm] and the leaves grow and then they fall off. And the teacher said that that is how sort of nature is. It has got a time and then it stops. And then it starts again.
- 3a:249 **TW: [Nods] Hmm. [TW turns to GS who has his hand up indicating he should speak next]**
- 3a:250 GS: I think that [unclear - could be 'with the'] cup the atmosphere around us goes into the cup and knows it is cold.
- 3a:251 **TW: Did we say it went into the cup?**
- 3a:252 GS: No it...
- 3a:253 UA: True.
- 3a:254 **TW: No, [to UA] he is comparing it to the last one.**
- 3a:255 GS: You know on the cup, the atmosphere and... the cold air is getting into the water.
- 3a:256 **TW: Is it going in? [TW uses a tone of voice slightly quieter than normal to say this and uses her hands to indicate something going into the water] Did you say it was going in?**
- 3a:257 GS: It is not going in, ...
DL: it is surrounding it [showing with her hands the air around the sides of the cup]
GS: ...but it is surrounding yes.
TW: OK.
GS: It seems like [unclear] so when the cold goes to the tree or wet air goes to the tree it knows what's coming. It's... [GS trails off]
- 3a:258 **TW: Again you're doing what your [TW indicates DL with her hand] primary teacher does, a lot of people give feelings and emotions and talk about animals and trees as if they're human. But [pause] it might trigger a response, but that doesn't necessarily mean the tree thought, "Oh, I'm a bit chilly and I'll do this." Because that's a very human thing. We try and put those emotions onto other living things. Shall we leave that bit there and carry on with our cards, because I'm not sure science can answer that question. Certainly not at the moment. UA, [who has his hand up] do you want to tell us about another card?**
- 3a:259 UA: Yes. I was wondering about fire.
- 3a:260 **TW: Uhu.**
- 3a:261 UA: How, how easily the cells can overpower other cells. And which the fire can consume but not actually take the cells. Um.
- 3a:262 **TW: What would the cells be in in that example? What is on fire in your example?**

- 3a:263 UA: Um, so say like a leaf on fire. At least [unclear] on fire. The fire um the fire takes hold - that is the only way I can think of - the fire takes hold of the leaf and the cells on fire slowly - um slowly take over the cells. I'm not really sure the scientific word for saying that - and I - it takes over the cells and because of the he... because of the heat and the vibration - is that why the leaf would either um A still burn or B disintegrate?
- 3a:264 **TW: [Pause] OK, let me think about that for a minute. Does anyone want to come in on that? Where have we all put fire? Living, living [looking round at the mats - students indicate where they have put it] living, OK. You've [DL] put it under non-living. Do you want to argue why you think it is under non-living?**
- 3a:265 DL: Because it is fire [DL says this with feeling].
- 3a:266 **TW: [Laughs with DL]**
- 3a:267 DL: Because it is not - it can grow but it doesn't grow as in the way it gets bigger and mature. [UA and GS put up their hands] It grows as in spreads. But I don't think fire is a living thing because it doesn't actually - it uses living things around, like logs, it uses stuff to burn, it doesn't really... [DL tails off]
- 3a:268 **TW: So that would be where your [UA] cells are coming from? She is arguing that that doesn't make the fire living. [TW indicates with her hand for GS to speak now] What do you [GS] think?**
- 3a:269 GS: I say its living because when you light - when it is in the box, the match box, it is not living. When you light it a fire comes. It starts moving...
- 3a:270 **TW: OK, so movement could be a reason [GS goes to carry on speaking. TW looks down at her mat as she carries on]. But hang on, doesn't a bicycle move? [Indicating with her hand the bicycle without a rider on the group mat which everyone agreed earlier was non-living].**
- 3a:271 GS: No. No. Yes. That's what I mean if you ride it.
- 3a:272 **TW: Oh, so it has to have a person on it.**
- 3a:273 GS: Yes. Because it just doesn't move on its own. It needs to have some sort of person riding it.
- 3a:274 KG: Or a force of some sort.
- 3a:275 GS: Yes, a force or something. [TW looks over at VH who has her hand up]
- 3a:276 **TW: Were you going to say something? [Said really gently]**
- 3a:277 VH: I think it [fire] is living, because when you first light it there is something that you put with [perhaps indicating the edge of box used to strike the match? unclear]. The stick comes from the tree.
- 3a:278 **TW: Oh right, so because it came from - because a match is wooden. Yes, that is kind of your [UA] idea wasn't it. If you start with something living, if it has still got cells in it. Unfortunately, once you've chopped a tree up and made it into matches... [TW pauses]**
- 3a:279 GS: It is not living.
- 3a:280 **TW: [Nods] So the same thing. If you burnt it what do you think happens to the cells? [Said with a sad tone perhaps]**
- 3a:281 DL: They die.
VH: They die.
- TW: [Nods] [UA puts his hand up - TW indicates he can speak by nodding again at him]**
- 3a:282 UA: But miss, um do they actually die from the vibration of the cells or... [stops]
- 3a:283 **TW: Depends what you're burning, but say you're burning a log, I'm afraid it died when you cut it up into logs, when you removed it from the tree.**
- 3a:284 UA: OK, so say you had a forest fire.
- 3a:285 **TW: Right.**
- 3a:286 UA: The fire engulfs some of the trees. The trees are still standing but on fire...
- 3a:287 **TW: Mmm. [Tone and body language indicate TW takes UA's point]**

- 3a:288 UA: ...and the fire is slowly taking the - it is slowly disintegrating the tree. Does the actual cells of the fire destroy the tree by vibrating too fast?
- 3a:289 **TW: Cells only make up living things. Fire is really about an energy. Fire is a situation where you've got a very very high temperature. So it is not a living thing because it [the fire] doesn't have cells. Now it might attack cells [indicating one hand perhaps attacking the other - TW moves her right hand on top of her left. Could this represent left hand cell and right hand fire? Unclear] because it is the tree that is on fire, or a log that is on fire, but it [the fire] doesn't have its own cells. It only has that heat energy that we talked about earlier. So it is only going to go out when all the heat energy is gone [indicating something going away with her hands]. The problem with the forest fire is there is lots of things for it to keep [TW indicates with her hands a chain reaction] burning. So one of the first things a fireman might come in and remove the fuel. Sorry sir, have we gone on a bit long.**
- 3a:290 JR: *I find it fascinating. You've got some fantastic ideas. I hope everybody is OK. Can I just check with the time? What time have we got till?*
- 3a:291 **TW: Um, I'm trying to think...**
- 3a:292 JR: *It is ten to twelve now, I'm just thinking we've got one more thing to do which might take ten to fifteen minutes.*
- 3a:293 **TW: Yes, so we should probably move on to the next thing.**
- 3a:294 JR: *There is so much more we could...*
- 3a:295 **TW: It is a shame, because I think we could probably talk about these all day. Um. Thank you guys. Let's make a neat pile of those.**
- 3a:296 JR: *Would you mind just putting one on top of the other and I'll just take them away? Sorry about that. I'll do that afterwards. It is so nice to have...*
- 3a:297 **TW: I thought we could hear the bell here. [TW is looking at the questioning route - JR is helping move the mats off the table]**
- 3a:298 UA: We heard it ten minutes ago.
- 3a:299 **TW: I was so busy listening to what you were talking about I didn't hear it.**
- 3a:300 VH: I didn't hear it.
- 3a:301 UA: I heard it.
- 3a:302 JR: *[To TW quietly] Are you OK to [unclear - but I think it was 'to go on for a little bit' or something similar]*
TW: Yes [unclear because said very quietly]
- 3a:303 GS: Probably you [VH] were daydreaming. [unclear as there is lots of noise as the card sort activity is moved off the table]
VH: [Replies to GS with a smile and a withering look] I was
- 3a:304 VH: Daydreaming of France.
UA: Well that's OK [unclear]
- 3a:305 **TW: I think you've used these before haven't you [TW is giving mini whiteboards and pens to students - JR is still clearing the table]**
- 3a:306 GS: My pen's run out. [JR goes to sort this out]
- 3a:307 **TW: Right, a different situation for you.**
GS: Miss.
- 3a:308 **TW: Are there any spare whiteboard pens? I wouldn't imagine I suppose [unclear].**
- 3a:309 JR: *I think we'll need to use the paper. I'm really sorry. There aren't enough.*
- 3a:310 **TW: Try that one. [TW passes a whiteboard pen to GS]**
- 3a:311 **TW: If it works a little bit. If not, sir will give you some paper.**
- 3a:312 **TW: Let me tell you what the task is. And then we can worry about pens and things in a minute. VH. Is that one alright? OK, we'll get you a pen in a minute. Right, [JR gives TW the torch which had been under some paper] Ah. It is a dark room, you've walked into a dark room and you've only got a torch. Now the first thing you see is teddy. OK. What we'd like you to have a go at is to draw a situation where you've walked in [TW mimes the torch bobbing up and down as if it is being carried into a**

room - she points it at the teddy which she is holding in her other hand] and you can now see the teddy. So use stick men or it doesn't have to be particularly beautiful, but try and show me why you can now see the teddy ['why' to the end of this sentence is said more slowly]. So it is a really dark room. You've only got your torch. [Pupils are drawing as TW is talking] Draw me a picture explaining why you can see the teddy. OK? If you're like me and art is not your strong point, feel free to use words or diagrams to help us understand what you're drawing. I'm going to ask you to explain it. [Silence]

3a:313 JR: [JR gets up and goes to speak with TW about the timing of the end of the interview - this takes place in a whisper and is unclear]

TW: Probably about five past they can get to their lessons. I might just quickly write a note actually. [TW gets up to get paper].

JR: [JR whispers something about taking these notes for TW - pupils continue to draw]

TW: Oh no no, they'll take it with them when they go. [Silence]

3a:314 LM: [Reacts to something and claps her hands very quietly together as if she has just thought of something] [Silence] [VH looks at LM's drawing - LM does not appear to be aware of this - TW is writing the notes for the pupils] [VH sits back in her chair and turns over her paper on which she has been drawing - she then turns it back over and continues to draw]

3a:315 **TW: How are we doing?**

3a:316 UA: Finished.

3a:317 **TW: Ready?**

3a:318 ?? [unclear who]: Yes.

3a:319 **TW: Right. Would you like to show each other your pictures. Just have a little look round. At what you can see from each other [this is said in a slower measured way as TW looks at the pictures herself]. And then would anyone like to explain their pictures? [LM puts hand up first then GS and then UA]. [TW and UA are helping DL who is having trouble lifting the whiteboard off the desk] Is it stuck? Right. Lift it up. [TW is helping] Your nails are a bit of a hindrance. OK. Go on then LM. Hold it up so everyone can see your picture. And you can explain to us what you're showing.**

3a:320 **TW: [LM is adding something to her drawing] What are you adding now? Tell us what you're adding?**

3a:321 LM: The reflection.

3a:322 **TW: Oh right. OK. What did you draw to show your reflection?**

3a:323 LM: Lines.

3a:324 **TW: Lines. OK. Anything else? Yes.** [GS] [UA also has his hand up]

3a:325 GS: When you [unclear - 'shine?'] the torch on the teddy bear you can only see half of it, because um you're only reflecting on part of it. The rest would be dark.

3a:326 **TW: OK, you've shown part light and part dark. VH?**

3a:327 VH: Um, I showed the lines because it is reflection and [unclear - could be 'when you go in a room that is dark?']. When you put the light on you can't [sic] see it.

3a:328 **TW: Do you want to add to yours?**

3a:329 LM: Yes. Because if it is a light source lighting the bear it is reflecting into your eye.

3a:330 **TW: Interesting. UA?**

3a:331 UA: As LM said, when it is dark the eye can't reflect anything off of any light source.

3a:332 **TW: Hang on. Slow down and say that again.**

3a:333 UA: When it is dark and there is no light source, it is hard for the eye to see, because there is nothing to reflect the light back.

3a:334 **TW: I'm with you, yes.**

3a:335 UA: But when you turn on the torch, because it generates a light source, if you point it at a specific area the the thing or object or area that has been hit with the light you'll be able

- to see that because the light bounces back into your eye. So you're able to see - so you're able to see where it is.
- 3a:336 **TW: OK. Do you [KG] agree? You're nodding.**
- 3a:337 KG: Yes. I was going to say exactly the same thing.
- 3a:338 **TW: You've [KG] drawn straight lines as well. Why have you drawn lines?**
- 3a:339 KG: To show the [different? unclear] light kind of bouncing back to your eyes so you can actually see it [KG mimes with his hands something bouncing back to his own eyes after hitting something]. The reflection of the teddy. If it didn't bounce back you wouldn't be able to see the teddy [KG shrugs].
- 3a:340 **TW: It does interest me that you've all drawn lines. You could have drawn it [DL, UA and GS all put their hands up] as a wiggly line or all sorts of different things. [TW turns to DL] DL?**
- 3a:341 DL: If you go into a dark room your eyes immediately open up more so that you can't trip up over things. They open up more to let light in [TW nods]...
- TW: That's true.**
- DL:** ...so when you shine the torch on, your eyes sometimes close down because they've got too much light. So that is why you can actually see the teddy. The light beaming back into your eye.
- 3a:342 GS: Because light travels in a straight line.
- UA: [Sits back - clearly frustrated and gives a big and very audible sigh]
- 3a:343 GS: Light travels in four directions. This way [indicating up by pointing with his finger], this way [left], this way [right], this way [down].
- 3a:344 **TW: Just four?**
- 3a:345 GS: And... [peters out]
- 3a:346 **TW: Can light go that way? [TW indicates backwards and forwards with her hand]**
- 3a:347 UA: In any straight line.
- 3a:348 GS: Any straight line yes.
- 3a:349 **TW: Yes. That's right. Good. You [TW is talking with the whole group] know an awful lot about this. How come you know so much about light.**
- 3a:350 GS: Because in my primary school we learned about it.
- LM: [Seems to be saying something similar - several students speak simultaneously so unclear]
- TW: I thought so.**
- 3a:351 **TW: Did you [GS] come up for science lessons last year as well?**
- 3a:352 GS: Yes, in Year 6 we did our science lessons in secondary.
- 3a:353 UA: Yes. I was in your group.
- 3a:354 **TW: I know you were! Yes. I didn't teach you that though did I.**
- 3a:355 UA: No.
- 3a:356 **TW: How very interesting. So have you got any questions about how we're able to see? [Pause] So you told me that the light bounces into my eyes. Does anyone know what happens next?**
- 3a:357 UA: I think - I think there's. I'm not sure what it is called but I think there is something in your eye that allows the light to sort of - yes. As I say - bounce back. But when it bounces back to the original space so you're able to see where it was.
- 3a:358 **TW: So it bounces back. So light bounces on my eye and then bounces back to you? [TW mimes light coming to her own eyes and then bouncing off her eyeballs] So is there light coming out of my eyes? [TW looks around as if demonstrating light coming out of her eyes sweeping the room]**
- 3a:359 DL: No.
- UA: No.
- 3a:360 **TW: I'd have monster eyes! [TW mimes something streaming out of her eyes like a very realistic monster and smiles]**

- 3a:361 UA: No. The light source that comes - when that hits it - when that hits an area the light bounces into your eye so you can actually see where it is.
- 3a:362 **TW: Oh, I see! But then [pause - TW drums fingers on the table] how do I know what my eyes see? There's a question. Let's think about that for a minute. [UA has hand up. GS puts his hand up] How do I know what my eyes see?**
- 3a:363 GS: Because of your brain. Your brain tells you what you can see. So um... [trails off]
- 3a:364 **TW: Who tells my brain?**
- 3a:365 DL?: Nerves.
GS: Nerve systems. [Simultaneously]
- 3a:366 **TW: Ooo. Nerves. Interesting GS. Does anyone want to kind of summarise that? [TW indicates with her hands bringing something together?] So what must there be in your eye? [UA has hand up. KG puts his hand up]**
- 3a:367 KG: Eye socket that can like send - like the brain sends messages to the eye [KG indicates something going from his brain to his eye with his hand].
- 3a:368 **TW: Change that word slightly from sockets. Borrow his [GS's] word.**
- 3a:369 KG: Oh. Nerves like... [trails off]
- 3a:370 **TW: [TW nods and smiles]**
- 3a:371 DL?: The optic nerve.
- 3a:372 **TW: Keep going [KG]. So the...**
- 3a:373 KG: Basically, the nerves travel through the sockets [indicating something moving from his brain forward] and they basically visualise what I see [KG's hands move to enclose something]
- 3a:374 **TW: [Pause - TW nods] UA.**
- 3a:375 UA: And using the cells. I'm not sure what they're called, but I think they're called electrodes? In the brain? I'm not sure what they're... [trails off]
- 3a:376 **TW: Finish your sentence and I'll tell you. It is probably not electrodes.**
- 3a:377 UA: And when it generates it - I think it is called - sort of flashes the images in your head so you know what you're seeing.
- 3a:378 **TW: [Pause] Oh I see. I'm not sure what word you're going for. It is not electrodes. If you're sticking electrodes in someone's brain you're probably not being very kind to them, or you might be a doctor. It is not normally an electrode. Might be a neurone.**
- 3a:379 UA: Yes. Yes.
- 3a:380 **TW: Does anyone know what is interesting about what you see?**
- 3a:381 GS: Yes. Miss, you know when you watch an action movie, sometimes you get a headache, because there is so much nerves running - there is lots of flashing lights and whatever - there is so much nerves running from your eyes to your socket it makes your head ache.
- 3a:382 **TW: I'm not sure if a doctor would necessarily agree with you. But most people would probably agree that flashing lights and things makes them feel uncomfortable.**
- 3a:383 UA: I think the flashes are - can sort of do - I'm not sure if it can be considered a disease or a syndrome?
- 3a:384 **TW: Condition.**
- 3a:385 UA: An epileptic condition - because the flashing I don't think the brain can actually take that information too quickly. And I think that is what causes the epileptic condition.
- 3a:386 **TW: I think it can cause an epileptic fit. Someone either has epilepsy or not. They - I don't think they know actually why someone might have epilepsy and someone else might not. But often they have warnings don't they on TV shows if there is going to be lots of flashing. This program contains flashing images. The interesting thing I was going to tell you was that actually, everything you see has to be reversed by your brain. Because you see everything up-side-down.**
- 3a:387 DL: Yes. I know that one.

- 3a:388 **TW: So you would all be on the ceiling [VH has hand up] hanging down, but actually your brain goes, "That can't be right." and flips you up the other way. You can get special glasses to make you see...**
- 3a:389 UA: Properly.
- 3a:390 **TW: ...well not properly, but the way your eyes actually see. And they did it with a group of people your age actually, and by the end of a day or something they could actually cope with it. Their brain kind of just readjusted to it and you could see them riding bicycles by the end of the day.**
- 3a:391 VH: When I was playing on my computer these is something that happened - the image that was all green and then the computer switched off and I went in my room and it was night and I could see some - when I closed my eyes - I had my eyes open and I saw lights that were red. [VH is miming this with her hands as she speaks]
- 3a:392 **TW: Have you all seen sort of flashing...**
- 3a:393 VH: Yes.
UA: If you look at a light and close your eyes you can see the after-image of it.
- 3a:394 **TW: After imaging. Yes, and what causes that then?**
- 3a:395 DL: Deterioration? Or is it that it sort of gets stuck in the eye? [TW smiles with DL and laughs] Not sort of stuck in the eyes but...
- 3a:396 **TW: But the light goes gggggg [TW mimes light being stuck in the eye]. It is not light getting stuck, that is what it might feel like [UA has hand up - TW indicates with her hand that he can speak]**
- 3a:397 UA: Is it perhaps that it is the last image the brain actually saw? Then when...
- 3a:398 **TW: It is not the whole image though is it. [GS and VH put their hands up] What is it about the things that cause the after images? What type of things cause these after images? These flashes?**
- 3a:399 GS: I think because you - you know a lot of things so may be if you're thinking of something else then you look at a light, maybe you - because it is dark and maybe you have a little light on something and you close your eyes and you see other lights. It is because you're thinking of lots of different things and you're also looking at light, so it is like you're staring into space.
- 3a:400 **TW: I really like that idea. It sounds quite poetic. But actually it is kind of simpler than that. It is not to do with your thought processes, it is only to do with your eyes. What type of things cause the flashing? [VH puts her hand up]**
- 3a:401 VH: Because it was too light. Because if it was green and dark...
TW: Mmm. [TW nods]
VH: ... I couldn't see.
- 3a:402 **TW: So what do we call these kind of things? They're very...**
UA: Bright.
TW: [TW puts her hand out flat towards UA as she repeats:] Very bright. So if I stared at that light [indicating with her hands a light in the ceiling] and shut my eyes I can still see it. And it is because we say they over-stimulate your eyes. There are particular cells in your eyes that recognise light, and they keep going, "Oh, I can see light, I can see light!" even after...
UA: It is dark.
TW: ...it is dark again. Yes. It is quite poetic what you said GS, but it is not quite right [said quietly]. Also I was going to sort of wind up now. Is that OK? [To JR who nods] I am really impressed, not only have you - obviously you have behaved beautifully and so on - but you've come up with such interesting ideas and you've been able to explain them to ourselves, and to each other. You've, you know, especially UA coming up with questions you can ask other people. Thank you very much for that. Is there anything you want to ask before we let you go to maths? [Pause]
- 3a:403 DL: Do we have to go to maths?

3a:404 **TW: [Laughing] Yes DL, you have to go to maths.**

3a:405 [Practical details to do with letters to the teachers to apologise for being late, thanks from JR and chocolate for participants are discussed here]

3a:406 *JR: Can I ask one very quick question, the arrow on that one? [JR goes round the table to GS who has drawn an arrow pointing out from the eye first on his whiteboard and then crossed it out and put an arrow going into the eye]. You know with the change in the direction of the arrow. Can you just quickly tell me about that. What you were thinking?*

3a:407 GS: The light goes on the teddy bear. So when it is reflected it reflects back to your eyes.

3a:408 *JR: And putting it the other way first. Was that just an idea that you changed or...*

3a:409 GS: Well, first I did it here and then I did it back like this.
JR: Yes.
GS: I changed my mind.

3a:410 *JR: I see. Thanks ever so much. And is there anything else you'd like to ask me about this work, about - are you all happy about this? [DL, KG, LM and VH all nod]. Many thanks.*

3a:411 [Some discussion of notes for teachers etc.]
UA: We've only got ten minutes left miss.
TW: Oh no. [UA laughs] I should put 12.15 [on the note] then shouldn't I. Oh well. We probably should have just kept them. Well you can go and find out if you've got any homework can't you!
UA: Um. I think... OK. [Said in a tone implying UA has no intention of finding out what the homework is]
TW: That is an integral question.
[Discussion about PE lessons that afternoon]
[End 3a]

Interview 3b

3b:1 *JR: Excellent. Thanks very much indeed for agreeing to do this. I really appreciate that. [JR looks at questioning route] So I'd like to invite you please to um watch each video and then think aloud. By that I mean talk freely about anything that comes to mind about the video. I'm interested in how you might 'solve' these problems. What you'd actually do to help children when they think like this. Please just report your thinking as accurately as you can in your own words. You don't have to edit, explain or justify your thoughts. We'll leave how you understand the issues raised to the second part of the interview. Obviously everything you say is anonymous.*

3b:2 **TW: OK.**

3b:3 *JR: There are fifteen video clips, but we don't have to use them all.*

3b:4 **TW: Right.**

3b:5 *JR: I'd be grateful if you'd do some from each of the three topics. So that's here [indicating on the laptop screen the pictures representing the three topics] the cup of tea...*

3b:6 **TW: I see. Yes. [Nodding]**

3b:7 *JR: I'll keep an eye on the time. We'll spend a maximum of thirty minutes on this. Unless you'd like to go on a bit longer. But I'm planning on finishing in thirty minutes.*

3b:8 **TW: Right. Wherever we get to.**

3b:9 *JR: I'll keep an eye on the time, so you don't need to worry about that. After that I'd like to ask you a few questions which will take about another thirty minutes.*

3b:10 **TW: OK.**

3b:11 *JR: Please feel free to say when you've had enough or if you'd like a break. And I'll try not to interrupt you while you're watching the videos and responding to the video clips.*

3b:12 **TW: OK.**

3b:13 *JR: [Smiling] Last little bit. [TW smiles] Please don't worry if you can't make sense of what the children say in some of these clips. Some of the ideas which came up are really*

challenging even for trained scientists like us and since I started exploring children's naive concepts I've discovered many of my own. [TW and JR laugh] Please just say if you'd like to unpack an idea together. I'm aware that you're being asked to do something which is difficult, [TW nods] namely to respond immediately to some very challenging naive scientific concepts. In the classroom we often have to respond quickly [TW is nodding] and it is this thinking that I'd like us to explore together. But it is literally that thinking in the raw.

- 3b:14 **TW: OK. So each clip I'm describing, I'm - is it a clip of the kids or me or both?**
- 3b:15 *JR: Both. [unclear - said at the same time as 3b:16]*
- 3b:16 **TW: So am I explaining what I was doing at the time or what I would do next? I'm not...**
- 3b:17 *JR: Any thoughts that come to mind. Literally your thinking [indicating with my hand thoughts]*
- 3b:18 **TW: I think I need to see a clip to sort of... try.**
- 3b:19 *JR: And actually, I think what other participants have found is sometimes it takes two or three to sort of get into what this is about.*
- 3b:20 **TW: Yes. I'm not quite sure. I need to see the clips.**
- 3b:21 *JR: Hopefully it will make more sense as we go along. But if it is not making sense, please just say.*
- 3b:22 **TW: OK. Shall we? [JR nods]**
- 3b:23 **TW: OK. I press this [TW clicks on the link on the laptop to start the first video clip]. Right [TW moves her chair forward - just afterwards JR does the same].**
- 3b:24 *JR: Is that OK?*
- 3b:25 *CLIP 1: experiments [ID 3a:12-24] 3a:12 ... What does science make you think of?*
- 3a:13 *UA: It makes me think of understanding.*
- 3a:14 *DL: Everything?*
- 3a:15 **TW: Ooo. [Looking round towards VH and LM]. Any other ideas?**
- 3a:16 *VH: It makes me think of experiments and [pause]*
TW: Experiments [looking round the group], that came up a lot when you were discussing why you liked science, that is probably why you think of it. Anything about science that you [KG] think of?
- 3a:17 *KG: Solids, liquids and gases.*
- 3a:18 **TW: OK. [Looking round at LM]**
- 3a:19 *LM: Everything about Earth.*
- 3a:20 **TW: Wow. Can you think of a situation where you've actually had to change your mind about something or someone has changed their mind about science, because of an experience?**
TW: [TW starts speaking here - see 3a:26 below]
So maybe an experiment you've done or something that happened to you. That made you change your mind about something to do with science. [Slight pause] That is an interesting question isn't it. [UA puts his hand up and TW is looking at him] You might need a couple of minutes to think. Have you got one already UA?
TW: [TW pauses the video here and says 3a:27]
- 3a:21 *UA: Um, when I was younger I asked my mum to buy me a Bunsen burner [TW nods] and I was in my room playing with it and I actually found I could change the flame, but accidentally when I changed the blue flame to the blue flame I had a knock on my door so I turned and it actually burnt my clothes. [TW has her mouth open in a shocked expression] So now I know to make sure I turn the Bunsen burner off before I do anything else.*
- 3a:22 **TW: That is quite an experience [with an impressed tone of voice]. I did not know that you could have Bunsen burners at home. How does the gas supply - does it come with its own little gas supply?**
- 3a:23 *UA: Yes.*

- 3a:24 **TW:** *How interesting. Well I'm glad you've learnt that lesson without harming yourself.*
- 3b:26 **TW:** *Am I supposed to talk over it [whilst clip continues to play in the background].*
- 3b:27 **JR:** *You can, and you can just pause it if you press it. And then replay. [Clip continues to play in the background].*
- 3b:28 **TW:** *Because I thought this is the hardest question out of all of them. Actually the first ones were. And I don't think they understood the question. And I think I hadn't quite got into what we were doing yet. Because things like 'what is science' - scientists can't necessarily answer, and I think they kind of stuck to 'what is a science lesson'. Because that is their only experience of science. And I was, I didn't really explore their answers very much, I just wanted to get everybody talking at that point. [TW has paused the video whilst she says this. She now restarts the video at, 'UA: When I was younger...' [see above]].*
- 3b:29 **TW:** *['UA: I was in my room playing with it [the Bunsen burner]] Quite funny. [TW and JR laugh]*
- 3b:30 **TW:** *[Laughing] And that's the end!*
- 3b:31 **JR:** *That is the first one.*
- 3b:32 **TW:** *But that was... yes, I wasn't really sure that they understood that. I think that was almost too big a question to go into. I almost think that that question, if we'd maybe done it at the end we would have been more able to explore it. But I was keen to get onto, I don't know, something a bit more tangible than 'what is science'. [Pause] Yes. [TW looks at JR] How do I go back?*
- 3b:33 **JR:** *To go back to the menu use always the house in the corner [of the laptop screen]. That should take you back to there [the menu screen]. When it has gone red it means you've done it.*
- 3b:34 **TW:** *OK.*
- 3b:35 **JR:** *OK? [TW nods]*
- 3b:36 **CLIP 2: condensation [ID 3a:30-34] 3a:30 TW:** *... But now, we're going to think about these two things [indicating the cup of tea and bowl of ice cubes on the table]. Now we've got a hot cup of tea. And that is quite impressive, because sir has brought that with him and that is still quite hot. And in there we've got ice cubes. Do you want to pass them round. Try not to spill anything. This is obviously very warm, probably not hot enough to burn you but be quite careful. [Ice cubes go one way round and the tea the other way round. Each student feels them both] So my question to you - I'll let you feel them all first [Pauses - noise from the sliding cup]. I just want you to be thinking about the hot tea, thinking about the ice. Careful as you pass them round. [Pause] Everyone has had a look. Not something that you've not seen before. Right, but. Now we need to think about what is happening, right now, to this hot cup of tea and to these cold ice cubes? [UA, GS and possibly KG with hands up] OK, shall we go round again. Do you want to start UA and then we can go round. See if we can add as much detail as possible [said in an animated way with hand gestures] so if they've said something [indicating DL and UA] you can sort of nod along that you agree, and if there is anything you want to add you can add to it.*
- 3a:31 **UA:** *In the ice cubes, the ice is slowly melting so that is going to create more water in the bowl. [TW nods] And with the hot cup of tea, because, I'm not sure, I don't think it is boiling but there is steam coming from it.*
- 3a:32 **TW:** *What would you like to add to that DL?*
- 3a:33 **DL:** *The ice cubes are melting and if you were to put a - like if the steam, if you were to put a cover over the top it would be condensating [sic] - on the side of the glass.*
- 3a:34 **TW:** *Oh yes. So we could do our own little experiment here and produce some condensation [on this last word TW turns her head once more towards DL]. Excellent.*
- 3b:37 **TW:** *[Pause - TW has a puzzled expression as the clip stops] I'm intrigued as to why you've chosen that clip. I'm not sure if I gave too much away by just describing the things as I passed them round. Because already I was making them think about hot*

- and cold and all the rest of it. And I don't think they could talk about both. I think if I was teaching that in a classroom I would have done one and then the other. I think if you've got something hot you've got to talk about what is going on there. And I was very concerned that they always think about cold getting into things rather than heat getting out of things. And I think later on GS went into a whole thing about cold getting in and we got into a bit of a pickle about it. Um [Pause] I think they get melting. I think they find ice melting quite straightforward, but I don't think they necessarily understood what goes on with something being warm. But I think we kind of battled it out in the end. [TW laughs] I think it was a kind of long-winded one this one. And I had an overwhelming urge to talk to them about particles, to break it all down, before you've even get anywhere near talking about temperatures. [Pause] [TW shrugs] I don't know what else to say about that one.
- 3b:38 *JR: If at any stage you'd like me to say, you know, things about it that I like, that I was interested, I'd be very happy to say [unclear - TW speaks]*
- 3b:39 **TW: Yes. I don't know what?** [TW points at the screen]
- 3b:40 *JR: I found - I found the way you used the resources really interesting. The fact that you passed...*
- 3b:41 **TW: Did you? That everyone had to touch it. I think you've got to feel things. Especially if you're talking about something like energy that you can't understand. You've got to be able to touch it. "What is cold?" Well there's cold [TW mimes passing something cold to a child]. "What is hot?" You've got to start somewhere haven't you. But otherwise you can't look at something and not [pause] I don't know how else to describe hot and cold without touching them. That was... um OK [TW is nodding - she appears to be acknowledging the point made in 3b:41]. My gut feeling.**
- 3b:42 *JR: And there was - DL uses the word 'condensating' at one point. And then straight afterwards you use the word 'condensation' - I found that bit at the end [pause]*
- 3b:43 **TW: Is it about sort of highlighting what they've done well in their answers?**
- 3b:44 *JR: Were you correcting her in some way?*
- 3b:45 **TW: Did she say it wrong and I corrected her?**
- 3b:46 *JR: She said condensating. And you said condensation.*
- 3b:47 **TW: Ah. That's naughty [TW is smiling]. You're not supposed to correct without explaining are you. I don't know if I misheard her.**
JR: Yes, yes.
TW: ... or whether I was really explaining it to the others. I can't remember at this moment what I was doing. But usually it is about - for me - pulling out the word they've used that is correct and that we should use. I wouldn't normally intend to correct her, and would have wanted to use what she used and say, I like that word, so I'm going to use it myself. [Pause] But I can't remember if I was correcting her or not.
- 3b:48 *JR: I realise it was a long time ago [interview 3a took place approximately three weeks before this interview].*
- 3b:49 **TW: Shall we? [i.e. go on to the next video] Is there anything else?**
- 3b:50 *JR: No, thank you.*
- 3b:51 **TW: It is hard to...**
- 3b:52 *JR: It is hard to get going isn't it. But this is exactly what I meant though.*
TW: This is what you want. OK.
JR: If that is OK?
TW: Yes. No, that is fine.
JR: And I know it is difficult.
- 3b:53 **TW: [Just after the clip has started to play] [unclear - but could be 'I remember about this one']**

- CLIP 3: heat and air [ID 3a:38-45] 3a:38 **TW:** ... *Look at the ice. Is there anything else you can tell me about it? [Long pause] There is a word I thought we might have used by now. Are you going to use it GS? Let's see.*
- 3a:39 **GS:** *Melt. Melting?*
- 3a:40 **TW:** *Ah no, UA has already used that. That was a very good word.*
- 3a:41 **GS:** *Freezing.*
- 3a:42 **TW:** *OK, why might we use that word?*
- 3a:43 **GS:** *Because it was - it froze to an ice cube, it was actually a liquid. And it froze to an ice cube. But because the atmosphere and our body temperature is quite hot and mixed with the ice cube it melt into water.*
- 3a:44 **TW:** *OK.*
- 3a:45 **GS:** *It is coming a bit - it is coming is going to come colder in time because there is nothing to cover it and all the air is coming in to it. And it makes it colder.*
- 3b:54 **TW:** [Long pause] *So that was the misconception wasn't it [TW points at the laptop screen] about the air coming into it rather than heat being lost to it. And, I think that there is a slight problem, when you have a very open question then he was tying himself up in knots as he kept talking. He started off quite accurately and it kind of got looser and looser. Um, I hope I went on to kind of address that and - I don't know if it comes up later, but... I think they should have a certain amount of time to talk, which is why I let him go, but then I probably - you know - in a classroom situation would have been writing down the words as he used them and then I'd go back and unpick each bit. Whether I managed that or not I don't know.*
- 3b:55 **JR:** *I know it is a really weird thing having little snippets from this. And of course a lot of the things that you sorted out really really well at the time made a lot of sense when I was coding it. So I didn't always feel it was necessary to...*
- TW:** *Fine.*
- JR:** *... bring here. I suppose what I'm bringing are some of, you know, the most murky, you know, "What's going on here!"*
- 3b:56 **TW:** *So this one here, I was probably letting him talk, in the hope that he'd - I also did that terrible thing that is, "Guess what is in my head." You know, "There is a word that I would have expected you to use." I can't remember now which word it was I was expecting them to guess out of my head! [TW and JR laugh] I just wanted them to...*
- 3b:57 **JR:** *You [unclear - could be 'talked about'] temperature later and energy later.*
- 3b:58 **TW:** *It might have been temperature yes. Temperature or energy. Um, I might have been looking for something, but I can't think now, so how they were supposed to guess what was in my head. And I think that was letting him just waffle on really. I was... mmm... I wasn't too wild about this bit. I didn't think it went that well. Um. [Pause] I preferred the card sorting bit. I think they were like, "Well we said it is melting it is done." I felt they were a bit, "Why is she still going on about this?" [TW and JR laugh] Anyway, so I'm not really sure where I was going with it either. But, I think we needed to talk about temperature, and I was trying to get to a point where we weren't thinking about air moving in [TW mimes this with her hands] or temperature - cold getting in. It was about heat loss. But I think maybe I'd gone on a bit too much. [Pause] Shall I get rid of that one [TW clicks on the home button and chooses the next video on the laptop].*
- 3b:59 CLIP 4: boiling [ID 3a:54-64] *What's changing? [GS has his hand up] DL.*
- 3a:55 **DL:** *The temperature.*
- 3a:56 **TW:** *That's the word. [TW: That's the word I was looking for! [TW and JR laugh] Now you were all discussing it, I think you might have mentioned it GS, but the kind of changes we're talking about are temperature changes. [Emphasises the word temperature with voice and says it more slowly than other words in the sentence] So let's try to stick to that idea now.*

- TW:** [TW pauses the video and says 3a:60 here]
Can we make a link. Can we make a link between the temperature and the other changes? [Pause] UA nods. [Said with feeling] Go on then UA!
- 3a:57 *UA: The change in temperature you can link to say like to water. If you say like 100 - if it is over 100 in temperature it has become to its boiling point. So that could create gas.*
- 3a:58 **TW:** *Ah. Who talked about gas earlier?*
- 3a:59 *DL: [unclear - but appears to be something like 'I talked about condensation']*
- 3a:60 **TW:** *Oh. Is condensation a gas?*
- 3a:61 *DL: [unclear because said very quietly, but seems to be:] It is gas sort of turning into liquid on a cold surface.*
- 3a:62 **TW:** *Yes, that is exactly what condensation is DL. Well done. Someone did mention that they thought there was some gas coming off this [holding the cup]. If I just got it from the kettle, what do you think you would see?*
- 3a:63 *Several students simultaneously: Steam.*
- 3a:64 **TW:** *That's the gas isn't it. Yes? So if a liquid changes to a gas UA has explained the change that must happen, there must be a temperature change and for water that is over a hundred.*
- 3b:60 **TW:** [TW pauses the video] *Because the other thing I wasn't quite clear on at the beginning was whether I was allowed to stop and actually teach them. Or whether I was just generating questions. Because normally when someone has dug themselves in a hole I'd go, "Right, let's stop with the questions and you trying to have a go and lets actually talk through the science." I think maybe I waited too long to do that. I don't know. [TW goes to un-pause the video, but the next video starts to play] It jumped.*
JR: I think it might have gone onto the next one. So could you go back to the menu please.
TW: *I don't know if that one was just really really short.*
JR: Yes, I think we just went onto...
TW: *I don't know how I did that then. Sorry.*
- 3b:61 [CLIP 4: boiling - plays again from the start. Please see 3a:59]
- 3b:62 **TW:** [Pause - after the clip stops] *I'm not sure what to say about that one. [Pause] I don't know, have you got any questions?*
- 3b:63 *JR: With that one, [pause] I really liked how you helped DL articulate the condensation. Her answer there is just awesome isn't it. You know, she knows full well that this is not a gas, and that she needed the prompting there [TW is nodding] and I think one of the things I really enjoyed in looking at these dynamics in the group are the way [pause] are the way that you're leading them around. [TW laughs] I wanted to discuss about this. About the way that you're guiding them. I would be interested in your thoughts about guiding the group in their understanding.*
- 3b:64 **TW:** *Um.*
JR: Sometimes in very subtle ways. You know, just a little, you know [JR mimes nudging with his hand]
TW: *It is a sort of nod to get them to answer each other's questions. In an ideal world I wouldn't say anything. And they'd bounce around [TW indicates the conversation bouncing between pupils with her fingers] - they just need a bit of poking, and just a reminder when - she [DL] wasn't far off - but she was about to say that condensation was a gas. When she might have known that it wasn't, but the others [TW indicates the whole group with her hand using the picture on the laptop] might not have. So you have to just nudge them into re-explaining it. Um. [Pause] I think there is something I try and do all the time, because I think it is more powerful if they get it from each other than it is from me. Um. [Pause] I don't know what else to say about that. [TW laughs]*
- 3b:65 *JR: That is really helpful. Thank you. [TW and JR laugh]*

- 3b:66 CLIP 5: molecules (short) [ID 3a:92-132] 3a:92 **TW: ... *If something has got a higher temperature do you actually know what it has got more of?***
- 3a:93 **UA: *Has it got more of...***
- 3a:94 **TW: *So for example a gas would have more of this than a solid.***
- 3a:95 **UA: *More molecules?***
- 3a:96 **TW: *It is not more molecules, but it is definitely to do with the molecules.***
- 3a:97 **LM: *Particles [unclear as said very quietly]***
- 3a:98 **TW: *Molecules or particles. Yes. That is a good word. [TW nods as she says this] [Pause] What do gas particles do that solid particles can't?***
- 3a:99 **GS: *[Has hand up and really wants to come in] Miss you know particles in a [solid?] - in - it is quite close to each other.***
- 3a:100 **TW: *Mmm. [Nodding and leaning forwards]***
- 3a:101 **GS: *So in a solid it is just close together, so when it melts it vibrates I think and it goes...***
- 3a:102 **TW: *There is a good word. Keep going...***
- 3a:103 **GS: *It goes apart to a liquid [TW is nodding] and when it goes to its boiling point it starts um... going [TW nodding]***
- 3a:104 **TW: *Right, so someone, a person maybe, not even a particle, is mov...***
- 3a:105 **GS: *Going hyper.***
- 3a:106 **TW: *...is going hyper. Or running around. What have they got more of?***
- 3a:107 **GS: *Energy***
- 3a:108 **TW: *Someone said it. [TW points with index fingers of both hands] I think maybe one of the girls said it as well. GS, [sitting back in seat] excellent. Energy [Said with considerable emphasis and lengthening the word]. So when something has got a high temperature, really we're thinking about how much energy it has got. So if this is getting cooler [indicating the cup] where is the energy going? [TW crosses her arms as if stumped by this question]***
- 3a:109 **KG: *Is it into the air miss?***
- 3a:110 **TW: *Sort of, yes. Keep going with that idea.***
- 3a:111 **UA: *Does the energy go along with the steam?***
- 3a:112 **TW: *Tell me more. [TW leans her head on her hand in a 'listening' posture]***
- 3a:113 **UA: *Maybe because the steam is showing the energy of the particles in the tea and it is so hot the particles need to get away so they're turning into gas to escape?***
- 3a:114 **TW: *That was a really nice word. They actually escape [emphasises the word escape] when liquid boils. It is like a particle [TW mimes running with her arms], "I'm free, I'm free!" Whoosh! [TW indicates something flying off with her arms] They shoot off, because now they're not confined to the cup [TW touches the cup]. The kettle or whatever. What were you going to say GS?***
- 3a:115 **GS: *I was going to say the top bit [GS is standing up and reaching towards the cup] it stays at the top bit. When it gets to its boiling point - because if it was a kettle it goes really really quick up in the air. So the particles just go really quick. [TW is nodding] Like I said [unclear but may be 'and frees itself in the air'] [TW nods and smiles]***
- 3a:116 **TW: *But we've actually got the opposite happening here haven't we. Because our cup of tea is sadly not boiling. It is not that the particles are going to get [indicating with her hands particles moving into the atmosphere] out, get free. What is going to happen to their energy? [TW looks at DL]***
- 3a:117 **GS: *[Puts his hand up and says 'Oh' - TW continues to look at DL as if not noticing GS - VH has her hand up slightly but not as enthusiastically as GS]***
- 3a:118 **TW: *[Pause] It is something to do with... KG, can you just remind us what you said? [GS puts his hand down]***
- 3a:119 **KG: *I said that if the temperature in the room is much cooler than the temperature that the tea is at that is why it is getting colder.***
- 3a:120 **TW: *You also told us where the energy was going to go.***
- 3a:121 **KG: *In the air.***

- 3a:122 **TW:** *In the air. [Pause] OK. Not just in the air, where is that energy going to go? [Pause] [KG puts his hand up then brings it down again. GS puts his hand up]*
- 3a:123 **GS:** *We're going to breath it in.*
- 3a:124 **TW:** *We might yes! That is really nice isn't it. I was doing it earlier when you're a bit cold [holding the cup of tea in both hands] you always see teachers hugging their cups of tea when they're out on duty. Why do we do that?*
- 3a:125 **DL:** *Because the heat transfers from - if you have your hands on the cup [TW pauses the video here - see below] like you feel like your nerves. Your nerves like pass the heat on. Sort of thing.*
- 3a:126 **TW:** *Does anyone know what it is called when the heat transfers?*
- 3a:127 **UA:** *[Puts his hand up] I think it is called conducting.*
- 3a:128 **TW:** *Excellent. So if that goes through from that liquid, through that cup and to my hand it is conducting through. And actually it will take it away. You actually take the heat away. So of course that liquid is getting colder and colder because the energy is, in this case, going into me. Or in this case, [TW puts the cup on the table] ... where is it going?*
- 3a:129 **VH:** *Table.*
- 3a:130 **TW:** *Table or the air. Some will come out here [indicating heat coming out through the side of the cup with her hand]. Some will go that way. It is all about energy transfer.*
- 3a:131 **GS:** *You will put some of the heat from your hands into the cup.*
- 3a:132 **TW:** *That is true, I don't think I actually have any today though [TW feels her hands]. I've got such cold hands, even though I've been holding that, I've got such cold hands. You can see they're really pale today. But you're [GS] right [TW picks up the pace with which she is speaking this last sentence].*
- 3b:67 **TW:** *There is tremendous high level science going on here.*
JR: *Stunning.*
TW: *Because the energy - all that stuff. The difference between temperature and energy and actually understanding that temperature is simply a measure of how much energy each particle has [unclear - 'relative to volume'?]. I don't know why I kept going on with it because I think I would have probably given up if it was a normal classroom - I would have felt, "OK, they're only in Year 7. We won't go." But they got there and I felt they could get there. At least three or four were totally on board with it. And they were understanding it and they were keeping going. I'd like to say the girls understood, but I'm not sure - especially now I can see their faces more clearly, exactly how much of that they took. Those two girls [TW indicates LM and VH on the laptop screen]. [Pause] But it was just trying to get them talking about energy. I think earlier I was trying to get them to talk about temperature and energy, but I think they will have very recently done a topic about solids, liquids and gases. So they were only really interested talking about melting and freezing and condensation [TW is smiling as she says this] and I wasn't really interested in that. And this was the bit where they started talking about what I thought was important. And I had an overwhelming urge to explain the difference between conduction, convection and radiation! [TW and JR laugh] But thankfully I stopped at that point. But that was where - and it was so nice because you get so few pupils who you'll get to really unpick it and go - why? It is about energy. Whereas you could do a whole lesson on that and never really talk about energy. Um. So I think that was what I was going for. And I just got quite excited when they started getting it right. You can tell by my [TW takes a big sigh]. Yes. Is there anything else you want me to comment on.*
JR: *[I indicate with my hands that I am happy] That is great.*
TW: *No. Going on.*
JR: *This is exactly it. Just thoughts. Almost through the tea! [TW and JR laugh]*

- 3b:68 CLIP 6: heat reacting [ID 3a:132-142] 3a:137 GS: *Because my hand was quite warm, I put my hand on the metal handle, so it is conducting heat from my hand onto the metal handle.*
- 3a:138 TW: *Yes... [TW's tone invites GS to go on] [Pause] Anyone want to add to that? That was a nice description GS [TW looks over at UA who has his hand up. KG also has his hand up].*
- 3a:139 UA: *And erm, so before GS put his hands on the door knob, because there was no heat touching or reacting to it before - it was cold, but the second GS put his hands on it the energy transferred.*
- 3a:140 TW: *Well sort of. I mean there is no real thing - there is no such thing as cold. There is only the absence of hot. That's a bit complicated [This last sentence is said in a quieter voice than the one before]. But the reason it feels cold is because it is actually stealing from you. [Pause] When you touch metal it is stealing from you. What was it stealing?*
- 3a:141 DL: *Your heat.*
- 3a:142 TW: *Your heat. It is stealing it. It is taking it away. Because it takes it away quickly it feels cold to your touch.*
- 3b:69 TW: *I really like that example. I remember when I first started having to teach physics - I didn't know anything about physics, I'm a biologist through and through [TW laughs] - I just found that to be absolutely fascinating. So I bring it up all of the time! [TW laughs] I think as soon as, again, when you feel something and you know what it feels like for it to be cold, then it - it makes you understand the absence of heat. I mean I'm not sure again - that is something they'll need to keep coming back to each year before they're finally - it really touches the syllabus maybe a little bit in Year 11. But, em, [pause] I don't know. I bring that up all the time because I just enjoy it as a piece of science and I enjoy that they got it. And they understood it. GS nearly got it perfect just before I'd said anything didn't he. Um. Yes. But we're just moving on from - OK we've talked about tea and stuff. OK let's relate it to something else. It was just widening their examples I suppose.*
- 3b:70 TW: *Right. Card sort. I'm trying to remember all the things we tied ourselves into knots with this one instead [TW and JR smile]. However [with a sigh].*
- 3b:71 CLIP 7: river [ID 3a:154-160] 3a:154 TW: *... How did you start going about doing that UA. You seemed very confident. You've just gone boom boom [miming placing cards confidently] Splitting them all up. Did you have an idea in your mind [indicates thoughts swirling in the head with her hand]?*
- 3a:155 UA: *Yes. I had an idea. Some... I thought some things, well say, let's take the river for example. Because it has got erm - because the area around it, it feeds off the area around it - so I thought it could be considered living.*
- 3a:156 TW: *OK, so you've gone through it, you've used some sort of criteria to judge. OK. There is no rush by the way. [DL just finishes] Did you [DL] have a criteria? How have you thought about it?*
- 3a:157 DL: *Erm. I just think that all the plants are living. Mushrooms they grow, so they must be living. Like a bike doesn't grow. An embryo is a baby. Lions grow. Everything [unclear - could be 'on living?'] really can get bigger. And like, I think, yes... [DL trails off]*
- 3a:158 TW: *That's OK. We'll remember that word, because that might be useful to us in a bit. Are there any words you don't know? The pictures are pretty helpful aren't they. Is there anything on there that you don't recognise? There is a very difficult word embryo [TW holds up this card]. Do you know what it is?*
- 3a:159 DL: *Yes*
 UA: *It is a baby that is being formed in the mother's womb. [Said very quietly]*
 TW: *Say it again for me. [TW cups her hand round her ear]*
 UA: *Yes. It is a baby that is being formed in the mother's womb.*
- 3a:160 TW: *OK, so very early stage it is called an embryo. It doesn't look much like a baby yet does it.*

- 3b:72 **TW:** So the first thing what I was doing was - well UA had obviously finished, so I thought he - I'd never leave a child who has finished an activity. It is just an opportunity to engage in discussion. Same with DL, but also to reassure the others that they didn't have to hurry up because UA was finished. So I'll keep him busy while they're still thinking. They might be listening at the same time, but they were all pretty busy. And I didn't question what he said. It wasn't about discussing whether he was right or not, it was just getting him to talk while we got set up really. Or not set up, but you know everyone finished the activity and had enough time [said with emphasis]. Same with DL. And by talking about the criteria they were using, I thought it might give others ideas - you know, just to have a little system. It could be anything, but especially when you've got to split things into two piles, you've got to be thinking, why. [Pause] Why you're putting them into two piles. And then it suddenly occurred to me they might not necessarily know what everything was. Both LM and VH are not first language English. They're both [from an eastern European country]. It suddenly occurred to me that there were a few words they might not have recognised. Most of them were quite straightforward, but that is why I went into 'embryo'. [TW looks at JR and then goes on].
- 3b:73 CLIP 8: bicycle [ID 3a:178-185] 3a:178 **TW:** ... *GS, what was the one you've just decided to move. I think it is interesting that you've decided to move it.*
- 3a:179 *GS: Bicycle, because on this bicycle there is just a bicycle bicycle. But on this one there is actually a person on the bicycle which...*
- 3a:180 **TW:** *LM you're nodding.*
- 3a:181 *GS: Because a person is living, they're using their energy on the bicycle to pedal, it makes it [the bicycle?] living.*
- 3a:182 **TW:** *Oh, OK. So, you talked about three different cards there [TW holds them up so students can see them]. KG do you agree? Where have you put these three?*
- 3a:183 *KG: Well, now from what GS has said I'm changing my mind and I'm putting the person on the bike on living because - I don't really -*
[TW starts to speak at this point - see 3a:76]
I don't know miss [lifts and drops his hands in a sign of resignation?]
- 3a:184 **TW:** *You sound like you've been convinced.*
- 3a:185 *KG: I wasn't sure where to put it, because it says just bicycle and I wasn't thinking - I was thinking just bicycle. You know, living or non-living. But after what GS has just said is making me think like it is true. Someone is riding on a bike.*
- 3b:74 **TW:** I thought it was really interesting that they were listening so intently to each other that they were then changing their mind because of it. Not in a kind of, "I'll do what you are doing." But in a, "Oh no, that's quite a - that makes sense, I'll move it [TW mimes moving a card]." So I really liked that bit. [TW plays the end of the clip]
- 3b:75 CLIP 8: continue to play. [TW smiles during this]
- 3b:76 **TW:** That is the whole point of the thing. It made him think [repeating KG's words - TW laughs]. Oh, I did it again. [TW has clicked on something on the laptop she had not meant to press.] Woops.
 JR: I think that was probably...
TW: Oh, was that the end? Is that why. OK. So I just that was probably my favourite bit. [Video starts to play again from the beginning and TW stops it]. I won't go back. I think that was probably my favourite bit actually. Because, and I hadn't noticed, I don't know if that was deliberate on your part having two cards the same but one with a person on and one not. [JR nods to indicate that this was deliberate] I presume it probably was, and to make them discuss the absence of the person. And I liked that. [Pause - TW clicks on the next video clip]
- 3b:77 CLIP 9: tree (short) [ID 3a: 195-232] 3a:195 *GS: ... It has got to have some form of intelligence. [TW looks upwards as if thinking about this] [TW: We wrapped ourselves*

- up in knots on this one!]** *It has got to have some form of knowing what it is doing for it to be alive.*
- 3a:196 **TW:** *Has it? Does a tree know what it is doing?*
- 3a:197 **UA:** *[Pause] Well, [pause] well, if you think about it the cells that make up a tree the nuclea [sic], the nucleus, it gives out instructions so it must know what its instructions to help the tree survive. [TW looks over at VH and LM]*
- 3a:198 **TW:** *What do you [VM] think? Do you agree? Do you think a tree knows what it is doing?*
- 3a:199 **GS:** *No.*
DL: *No. [unclear as very quiet]*
- 3a:200 **TW:** *You've [LM] put it in living. So have you [GS].*
- 3a:201 **GS:** *Yes it does, because if it doesn't know what it is doing it won't grow. Because you need to have some sort of brain which would make be able to have the intelligence to grow.*
- 3a:202 **TW:** *Does it take intelligence to grow?*
[TW pauses the video at this point]
- 3b:78 **TW:** *I don't know what the answer is to this one is. [TW laughs] I mean I know scientifically the answer is "no", but - and I kind of - I was just fascinated by what they were saying. I was absolutely fascinated by their reasoning, and their application of logic to something that can't be logical. It doesn't have a brain, it doesn't know what it is doing, but it is really nice that they think it is. And I think it is a very - I think like you said, it is a naive concept isn't it. Trees must know what they are doing, otherwise why would it not happen? It is kind of the assumption some people have that there must be a God, because otherwise why would all these things occur? Something must be controlling it. Um. I really enjoyed this bit. But I don't know that I guided them that well, because I'm not sure that I wanted to take it away from them. Do you know what I mean? [JR nods] I remember actually really upsetting a child once because I said - I jokingly said you couldn't talk to trees, and this child was nearly inconsolable, because apparently he talked to trees all of the time. I think there is a line between teaching science and is it OK for them to think at 11 years old that a tree cares what it is doing? There is a tiny little line - and I don't know whether I actually got to the end and said, "No, it doesn't actually have a brain." Depends how cruel I was! [TW and JR laugh]*
- 3b:79 **CLIP 9:** *continued*
- 3a:203 **GS:** *No, it doesn't take intelligence - it needs to have some [DL has hand up] sort of intelligence to grow. It doesn't have a brain, but it must have something in it - maybe... I don't know what it has in it but it has something in it to make it grow.*
- 3a:204 **TW:** *You're working with some very difficult ideas here [The tone this is said with is lower and conveys respect for the ideas being discussed]. There is not necessarily a right answer to this. You're doing really well guys. DL.*
- 3a:205 **DL:** *I think it doesn't know what it is doing. I think it just takes food and then it is like - it is like humans. If they don't have a brain, it wouldn't really matter that much. [TW laughs while watching at this moment] The world wouldn't be the same, but they would just eat and they would just do what they do [GS, VH and LM all have their hands up - GS very high, VH and LM much lower] - It wouldn't...
*[The video at this point cuts to here]**
- 3b:3a:209 **UA:** *As GS said about the brain, as I said about the nucleus, that could be considered considering the number of cells that make up a single tree the amount of nucleuses could [TW smiles] be considered the brain of it - of the tree.*
- 3a:210 **TW:** *So would you say that a tree would be cleverer than a daffodil, because it is bigger? [TW laughs whilst watching this bit]*
- 3a:211 **UA:** *Um.*

- TW: I think at that point I was just having fun! [TW and JR laugh]. I was just messing with him there [laughing]. I made it go away now. I messed it up again.**
 JR: That is the one we've just seen.
TW: OK.
- 3b:80 JR: Can I just mention that we're about half an hour in. Now I'm...
TW: Oh are we, what do you want me to do?
 JR: I'm absolutely fine to carry on if you are?
TW: Yes, no I'm quite enjoying it.
 JR: I'll cut the second bit back a bit to fit this in, but that is... Is that OK with you?
TW: If that is alright with you, if this is useful.
 JR: This is really really useful for all sorts of bits that are really helpful.
TW: OK.
- 3b:81 **TW: [Pause] I want to know what your hypothesis is! [TW laughs - question appears to be rhetorical]**
 JR: Which I will be sharing.
- 3b:82 CLIP 10: leaves [ID 3a:233-239] 3a:233 LM: ... and then when it is winter it actually dies because it is too cold.
 3a:234 **TW: Does it die completely?**
 3a:235 LM: No, but it doesn't have leaves.
 3a:236 **TW: Ahh. What happens to the leaves?**
 3a:237 LM: They fall off the tree. And then when it is spring again, it comes alive like - it is still a process.
 3a:238 **TW: Mmm. I like the idea of it being a process. [TW indicates GS can speak]**
 3a:239 GS: I think the tree - the tree by itself, only the leaves is the thing that dies. The tree could go on for ever, but if you cut it maybe not. ...
- 3b:83 **TW: [With a puzzled expression and her arms crossed] I'm not sure if I came back to LM to explain that a tree is not dead in the winter. But I think again the 'dead', 'living', 'leaf' - and assuming just because the leaves are dead the tree is dead - [Pause - TW again has a puzzled expression on her face] I don't know why you chose that clip. [TW turns to JR] I'm not sure what you were after. But I didn't go back to her maybe.**
- 3b:84 JR: Sometimes it is as I'm coding I'm [pause] you know the codes are often parallel - there are often between 5 and 10 different things all going on at the same time, I think.
TW: Crikey.
 JR: And sometimes it is really to hear your thoughts.
TW: Which one - what I thought was going on. [Said simultaneously with JR's words below]
 JR: From this interview, would there be any support for the thoughts that I'm having in terms of an interpretation? But sometimes it is really peculiar things - you know, I think this this idea of looking out the window and seeing trees without leaves and concluding that they're not alive - not living...
TW: Perfectly logical isn't it.
 JR: ...is an interesting thought.
TW: It is a fairly common language thing - we talk about everything coming alive in the spring don't we. It is where your common language and your scientific language isn't matching up really. [Pause]
 JR: She does say 'alive', she doesn't use the word 'living'. You know, is there differences there?
TW: Oh, I see.
 JR: Tricky isn't it.
TW: I sort of left it didn't I. I don't know.
 JR: But of course often you are. After the video clip you're not stopping.
TW: Mmm, mmm.

- JR: Please don't feel... I felt you dealt with this really really well.
- 3b:85 CLIP 11: fire [ID 3a:258-289] 3a:258 **TW: ... UA, [who has his hand up] do you want to tell us about another card?**
- 3a:259 *UA: Yes. I was wondering about fire.*
- TW: This was to me a bit like the... what did we just talk about? The bike. The living person and the... And they had all of these fantastic reasons why fire was living, but it just isn't. [TW and JR laugh] And it was like, and it is again, how far you with it. It is not. And I don't know what I ended up doing. [TW lets the video carry on playing] It was fascinating to listen to them.**
- 3b:86 CLIP 11: continued
- 3b:3a:260 **TW: Uhu.**
- 3a:261 *UA: How, how easily the cells can overpower other cells.*
- TW: Oh and he had the idea that they have cells. Which it just doesn't, but it would be much more logical if it did.**
- UA: And which the fire can consume but not actually take the cells. Um.*
- 3a:262 **TW: What would the cells be in in that example? What is on fire in your example?**
- 3a:263 *UA: Um, so say like a leaf on fire. At least [unclear] on fire. The fire um the fire takes hold - that is the only way I can think of - the fire takes hold of the leaf and the cells on fire slowly - um slowly take over the cells. I'm not really sure the scientific word for saying that - and I - it takes over the cells and because of the he... because of the heat and the vibration - is that why the leaf would either um A still burn or B disintegrate?*
- 3b:87 **TW: [Pause] I don't think I know the answer to his question. I've never thought about cells burning. I don't know what I did next as to whether I tried to answer it or whether I asked the others what they think. But he has just gone into some really complex ideas. I'd never thought about those two things together I don't think, so it was an eye opener to me. [Pause] I just let him talk it through.**
- 3b:88 JR: And you seem to have - you know there were ideas also at this point playing around from GS who was - I think if I remember correctly - he was thinking that the fire was living, and you also had this kind of [unclear - 'argument?'] from UA, a very different idea.
- TW: I was sort of waiting to be convinced. [Said simultaneously with JR]**
- JR: You seemed to have different... people saying very different ideas all at the same time I suppose was one of the reasons why I was bringing this out.
- 3b:89 **TW: So GS said what he said about living, and then I kind of wanted to [unclear - 'hear what UA said?'], and then UA just didn't stop, and I was trying to put it in, and then he had this idea that cells were on fire and I think he just got me thinking. And I'd like to think I then went on to pull it all together, but I'm not sure whether I did or not. I actually went back and addressed it as being more of an energy. [Pause] Sometimes I think it is useful to hear like different - I mean you might do it more for something that is more opinion based than fire being living. I think I was just fascinated by what they were coming up with - just at the very idea that fire was living - it just hadn't occurred to me.**
- 3b:90 CLIP 12: light [ID 3a:340-349] 3a:340 **TW: It does interest me that you've all drawn lines. You could have drawn it [DL, UA and GS all put their hands up] as a wiggly line or all sorts of different things. [TW turns to DL] DL?**
- 3a:341 *DL: If you go into a dark room your eyes immediately open up more so that you can't trip up over things. They open up more to let light in [TW nods]...*
- TW: That's true.**
- DL: ...so when you shine the torch on, your eyes sometimes close down because they've got too much light. So that is why you can actually see the teddy. The light beaming back into your eye.*
- 3a:342 *GS: Because light travels in a straight line.*
- UA: [Sits back - clearly frustrated and gives a big and very audible sigh]*

- 3a:343 *GS: Light travels in four directions. This way [indicating up by pointing with his finger], this way [left], this way [right], this way [down].*
- 3a:344 **TW: Just four?**
- 3a:345 *GS: And... [peters out]*
- 3a:346 **TW: Can light go that way? [TW indicates backwards and forwards with her hand]**
- 3a:347 *UA: In any straight line.*
- 3a:348 *GS: Any straight line yes.*
- 3a:349 **TW: Yes. That's right. ...**
- 3b:91 **TW: [Pause] Um. I'm just amazed that a group of 11 year-olds knew about how to draw line diagrams [JR nods agreeing] to show light travelling. I can only assume because that is because the majority of them will have done their science here last year and we've sort of 'upped' what they know. Although it is in Year 6. [Pause] But then immediately he started - it seemed to me like he was talking about the points of a compass. And I wasn't quite sure - and then UA corrected him. So I just sort of nodded along really. They were just - they were like, "Yes, we know this one. This one's easy. All the other questions were really difficult, we had to think, this one, they travel in straight lines, this is how you draw it. Job done." They were a lot more...**
- JR: We'll have no wiggles here. [TW and JR laugh]*
- TW: It was kind of like that [TW mimes a pupil crossing their arms] at the end of it weren't they. But um, I was surprised, I thought they'd find that a lot harder.**
- 3b:92 *CLIP 13: eyes [ID 3a:356-362] 3a:356 TW: ... So you told me that the light bounces into my eyes. Does anyone know what happens next?*
- 3a:357 *UA: I think - I think there's. I'm not sure what it is called but I think there is something in your eye that allows the light to sort of - yes. As I say - bounce back. But when it bounces back to the original space so you're able to see where it was.*
- 3a:358 **TW: So it bounces back. So light bounces on my eye and then bounces back to you? [TW mimes light coming to her own eyes and then bouncing off her eyeballs] So is there light coming out of my eyes? [TW looks around as if demonstrating light coming out of her eyes sweeping the room]**
- 3a:359 *DL: No.*
- UA: No.*
- 3a:360 **TW: I'd have monster eyes! ZZZZ. [TW mimes something streaming out of her eyes like a very realistic monster and smiles]**
- 3a:361 *UA: No. The light source that comes - when that hits it - when that hits an area the light bounces into your eye so you can actually see where it is.*
- 3a:362 **TW: Oh, I see! ...**
- 3b:93 **TW: I was just messing with him again. But he then explained it more clearly afterwards. And that is a standard misconception that people draw line diagram and light comes out of their eyes. So I was just trying to get him round to - and he knew the answer, he got it there in the end. But um, I was just highlighting the inaccuracy. [TW shrugs] That is kind of it.**
- JR: Thank you.*
- 3b:94 *CLIP 14: nerves [3a:362-374] 3a:362 TW: ... [pause - TW drums fingers on the table] how do I know what my eyes see? There's a question. Let's think about that for a minute. [UA has hand up. GS puts his hand up]*
- [TW and JR laugh whilst watching]*
- TW: I was like, I have to think what the answer is for a minute! How do I know what my eyes see?**
- 3a:363 *GS: Because of your brain. Your brain tells you what you can see. So um... [trails off]*
- 3a:364 **TW: Who tells my brain?**
- 3a:365 *DL?: Nerves.*

- GS: Nerve systems. [Simultaneously]
- 3a:366 **TW: Ooo. Nerves. Interesting GS. Does anyone want to kind of summarise that? [TW indicates with her hands bringing something together?] So what must there be in your eye? [UA has hand up. KG puts his hand up]**
- 3a:367 **KG: Eye socket that can like send - like the brain sends messages to the eye [KG indicates something going from his brain to his eye with his hand].**
- 3a:368 **TW: Change that word slightly from sockets. Borrow his [GS's] word.**
- 3a:369 **KG: Oh. Nerves like... [trails off]**
- 3a:370 **TW: [TW nods and smiles]**
- 3a:371 **DL?: The optic nerve.**
- 3a:372 **TW: Keep going [KG]. So the...**
- 3a:373 **KG: Basically, the nerves travel through the sockets [indicating something moving from his brain forward] and they basically visualise what I see [KG's hands move to enclose something]**
- 3b:95 **TW: I think they had found the bit about the rays so easy that I toddled off into my area which is biology and it was particularly the eyes. And I love talking about the eyes and so - I was really impressed with KG actually because every now and then - I don't really know him I would say that well, and every now and then he just perked up and said something and you're like, "Wow, that is quite impressive." And that was a nice example of that. Um. And they clearly knew there had to be communication between two different parts of the body. And they handled what is a ridiculously complicated question that just erupted out from me. Um. And they did it really well actually. I don't know if you kept the bit - did I go on and on about your eyes actually seeing upside-down and stuff?**
- 3b:96 **JR: You do talk about that with them at one point. Is that in the... I don't think I've got that clip here.**
TW: I don't know. But it was just again, talking about things that occur to me as being fascinating, and if I'm fascinated well [laughing] I tend to assume that other people will be.
- 3b:97 **JR: I love that [miming image on the back of the eye being upside-down]. [JR and TW laugh]**
- 3b:98 **CLIP 14: After-image [ID 3a:394-402] 3a:394 TW: After imaging. Yes, and what causes that then?**
- 3a:395 **DL: Deterioration? Or is it that it sort of gets stuck in the eye? [TW smiles with DL and laughs] Not sort of stuck in the eyes but...**
- 3a:396 **TW: But the light goes gggggg [TW mimes light being stuck in the eye]. It is not light getting stuck, that is what it might feel like [UA has hand up - TW indicates with her hand that he can speak]**
- 3a:397 **UA: Is it perhaps that it is the last image the brain actually saw? Then when...**
- 3a:398 **TW: It is not the whole image though is it. [GS and VH put their hands up] What is it about the things that cause the after images? What type of things cause these after images? These flashes?**
- 3a:399 **GS: I think because you - you know a lot of things**
TW: Oh, bless GS.
so may be if you're thinking of something else then you look at a light, maybe you - because it is dark
- 3b:99 **TW: I noticed this today. Oh, I don't know what I've just done [TW has paused the video] I noticed this a lot today with GS. He is really quite good at science, but he keeps getting science muddled up with, I think, what his parents talk to him about religion. Because today we were talking about something, whether you have to have children or not, PSHE lesson, and he basically said you have to. And it is clearly told to him, and sometimes I think there is a crossover between - I wouldn't be surprised if something about the living nature of fire wasn't to do with that as well. It may tell**

us more about his background than it does about his science. Because his logical brain is definitely trying to marry up what he is being told with the science, because he is clearly very good at science. And there, [in the video] I just love that idea that you know all this stuff so light flashes. But then is he thinking up to when, you know in cartoons when a light bulb goes on? But he hasn't got to the point where he knows the structure of the eye and cells at the back of the eye. And I really enjoyed that bit as well. He is so cute. GS. I don't know if there was more? Much more after that.

JR: I think that was about it.

TW: OK. That was the last one!

3b:100 JR: Thank you so much for doing that. I'm really grateful.

TW: I hope that was useful.

JR: It is really really useful.

TW: It is really hard to... because I'm desperately trying to guess what you want me to say! [TW and JR laugh] Much like the children were trying to do for me through that. Because you - I think that is the one thing that puts children off open questions isn't it. Because they don't know what you want.

JR: Yes.

TW: And they don't know that sometimes it is the discussion of it and the thought processes.

JR: I can't tell you how grateful I am you playing along with that one. Because I realise it is a really hard thing I'm asking you to do. Because you know, I could - this could have started with me saying, "Well, this is what I think."

TW: Yes, but you can't say that.

JR: But I'm desperately trying to resist that, because that is, I think, a lot of the way researchers approach the issue of what you do in your job, and actually what I'm interested in is trying to build up the theory based on...

TW: Rather than, "I think you were doing this, were you?"

3b:101 JR: Would you like a break? Because I realise that was about three quarters of an hour we've had there.

TW: I wouldn't mind just using the...

JR: Of course. Can I just leave that [the video] running and I'll just... [TW and JR laugh about something - unclear what]

3b:102 [Pause]

[End 3b]

Interview 3c

3c:1 **TW: OK?**

JR: Are you OK to...

TW: Yes. Carry on.

JR: It is five past twelve now, I know we've got lunch at half past, when would be good to stop?

TW: Sometime between now and half past. Whatever...

JR: Please say when you... I realise this is quite a lot to ask of you.

TW: No no, it is fine. I'm just talking. I'm good at that! [TW laughs]

JR: Thank you. If you're OK.

3c:2 JR: This next bit is really - you know I've got a few questions to guide us, but if there is anything that has been coming out from this I'd like to talk with you about it. Anything that you'd like to raise about the whole process. Or any thoughts that you've had while watching the videos that you might not have expressed yet.

3c:3 **TW: Not specifically.**

- 3c:4 JR: Shall I go with a couple of sort of - um. First one I wanted to ask you was what was it like for you - how did you feel while you were watching those video clips? Could you tell me a little about your...
- 3c:5 **TW: Well generally quite pleased, because I enjoyed it. So obviously looking back on it I found it quite enjoyable again. A couple of times I was like "Ogh, [TW grimaces], I should have done that." Or I should have perhaps picked up on that a bit, or, you know obviously critiquing...**
JR: Yes.
TW: ...what you did. But, no, on the whole I was pleased with how it went. I was really pleased with the kids. I thought they were brilliant. [Pause] Yes, I really just felt very positive and it just made me think I'd like to do more of this type of thing. More questioning and stuff.
- 3c:6 JR: How similar is that to what happens in the classroom? That sort of context. I realise it is a bit artificial.
- 3c:7 **TW: Do you mean my classroom?**
- 3c:8 JR: Your sort of normal teaching life.
- 3c:9 **TW: Yes, so I would say that I do that quite a lot because I like questioning and I like - I think there were a couple of [unclear 'video clips'?] where you see me deep in thought because they've made me think about something, and that's the lessons I enjoy the most. So I do that quite a lot. I mean actually the first lesson today with that class, with PSHE, and it was [unclear] - there was (don't tell anyone) there was no particular lesson plan let's say.**
JR: [JR smiles at the video camera - TW and JR laugh]
TW: There was post-it notes. I know, someone will be in here shooting me! They wrote post-it notes and they had questions and that was what I structured the whole lesson around. What is unfortunate is when you've got thirty kids instead of six you can't necessarily go back and capture every single misconception. I'm not sure that I did with those six. [TW points to the laptop screen] But there is so much more lost unfortunately, so you can only hope that they're guiding each other through. And then when you do the feedback that you're jumping on anything major. But I think that is a fair representation of what goes on in my classroom, but on a much smaller scale unfortunately, so it is much more detailed. And I would say out of every lesson, a more common lesson that what I had today, it would be maybe ten to fifteen minutes of each lesson was - would be hard core questioning and the rest might be doing the practical or doing something else.
- 3c:10 JR: That is really helpful. Thank you. I'd like to ask you a bit about what you anticipated and what you didn't. You know because...
- 3c:11 **TW: There is loads of stuff I did not expect! [TW laughs]**
- 3c:12 JR: There were things that came out in that interview that, you know, I've been a teacher a long time, never heard children talking about, never even thought about... You know, the trees one [JR points at the laptop] blew my mind. Can I ask you, were there particular things that you thought, "Yes, that is pretty normal." and other things that you didn't.
- 3c:13 **TW: With heat and temperature, it was fairly standard. They don't really understand energy. They weren't necessarily applying it to temperature. As I said earlier, they were expecting it to be about solids, liquids and gasses and then move on. That one - and I know from always having to teach the p... - and because of the expression of the English language, "Don't leave the door open, you'll let the cold in." We constantly use language in the wrong way, so we bring up a whole group of children who don't understand the science of it. So that one I felt was quite expected. Nothing that they talked about with the card sort did I expect. And I think that is probably why it was my favourite bit. And why I reckon I could do that all day long with all children they'd probably get as far as - I really liked that activity. You must email it to me.**

- 3c:14 JR: Yes. You'd be most welcome [unclear 'to have it?']
- 3c:15 **TW: [Pause] I was always disappointed because there was so much more we could have done. We could have done literally for days and I don't think anyone would have got bored having that constant argument. Is it living, is it not? And I almost - like I said earlier I think it spoils it when you have to bring science in and say, "Well actually science says no." [TW smiles] I always think that kind of limits it really and we were very much in the realms of philosophy in that section. I wasn't expecting that at all. And then for the last section I wasn't expecting any of them to be able to draw line diagrams. I wasn't expecting all to get it so thoroughly. I was almost disappointed. "Oh, no misconceptions?" [TW mimes a disappointed air] I almost had to sort of point out some really finicky bits just to get them talking about something. But no, certainly the middle bit I wasn't expecting at all, that was why it was so fun. I think that is why teaching is fun.**
- 3c:16 JR: I liked how you were saying there that when the misconceptions don't come up it is almost not as fun as when they do.
- 3c:17 **TW: Well, if everybody just knows the right answer - this is what we talked about earlier, if everyone is sitting there behaving beautifully and understanding that is lovely, I suppose it is what we all aspire to, but at the same time there isn't very much for us to do. It is not challenging our skills. Whereas where you have got challenging behaviour or concepts which we're not sure any of us have grasped because nobody has ever thought about whether a tree had a brain because all of its nucleuses or something! I'm not really sure where UA was going with that. But, um, [pause] I don't know then. It is fun. It is fun to really deeply think. And they were really deeply thinking. They could have been adults having that debate down the pub or something couldn't they.**
- 3c:18 JR: The interactions between the students. I know you brought that up earlier when we were doing the first interview. I thought that was fascinating the way they were [TW nods] feeding each other ideas and questioning each other. I know you complemented UA at the end for the way he had been asking questions of the others which I think in Year 11 students - 11 year-old students is...
- 3c:19 **TW: It is quite a high level isn't it. I think it is very interesting that that group do philosophy. Because I think that will encourage that as well. That's where we'd like all pupils to get to. I wonder if a different group would have been able to do it as well. Or whether it was just the nature of sitting round a small table with a teacher that inspired it from them. I don't know, I think given the opportunity most children would ask loads of questions like that, but it is so - it is a shame that there aren't more opportunities to do it. I have quite a few. I have some special children in most classes [TW smiles] who like to say, "What if...?" And I love those questions, and it does make it more difficult to go over an exam paper or something, but you have to just channel it. No, they're my favourite bits.**
- 3c:20 JR: Just generally, students during those videos had been expressing all sorts of concepts that could be described as naive concepts, and that is not meant in any way pejoratively, are there general techniques that you might use for dealing with children's naive concepts?
- 3c:21 **TW: I think it would depend on the particular concept. But I think touching, feeling and doing. Because if you've got a thought in your mind. If you've always been told that something, you know like the tree dies in winter, then why would you change that thought unless something came across [pause] - someone just telling you that that is not right isn't going to tell you a lot, well that is what everyone is told, maybe what your mum has told you every day. Why would this silly teacher woman be any better than my mum? Or whatever. So I think the experience of doing and actually seeing that it is still alive. Now I can't think of an example of how you do that with a tree, but for other things. That would be the most useful way. But letting them work**

it out themselves. **Right, you all think that - I can't think of an example now - oh I know, that light comes out of people's eyes and you set up some kind of experiment with lasers or something where you see that it is going in the other direction or something. So, but almost by not telling them - letting them explore it themselves that would be my general thoughts on it. Or just questioning them [TW mimes something which indicates questioning in cycles or over and over again] about it until their logic falls apart. "Are you sure about that. Well, what about this?" Or, "what about that?" or "What about the other?" Until they go, "Oh, that can't be true because it doesn't work. It doesn't fit."**

3c:22 JR: Just there you used that word, "Not telling." Are you conscious of things that you're not telling them deliberately.

3c:23 **TW: Oh I'm deliberately not telling the lots of things. Because you have a desperate urge to just go, "No, no a tree isn't living." Or no. Because you want them to have the science right. In the back of your mind you're always thinking, not in this case, but generally, "Oh, they're going to have a test soon". Or they're going to have an exam soon and they can't be writing that a train - a tree (or a train) has got a brain, because that is wrong. However, the process they're going through is more valuable than any test will ever pick up on. So I'm acutely aware of - and it is not an accident that I haven't just gone, "No, you're wrong." But I don't think at any point I said no - I hope I didn't. I'm sure I said it... I think on occasion if something is absolutely wrong you do have to point that out, because you're not doing anyone any favours by going, "Think that still." But it doesn't create learning to just go, "No, that's wrong. This is what you've got to do."**

3c:24 JR: And in sort of parallel with that question, not showing something, do you think sometimes teachers might show things they know not to be right as part of the...

3c:25 **TW: Oh yes. I think... yes there is that whole thing... a test paper said this the other day. You drop a hammer and a feather at the same time, which, if either [TW says 'if either' with a sly expression on her face], will hit the ground first? Based on Galileo's thing. Well it is a trick question. And the kids are all saying, "Is this a trick question?" Because they've seen one or two trick questions. You do because then you can have a whole discussion on, "Well, actually..." And so on and so on. But yes, teachers do deliberately... I don't think they're trying to mislead, because they would never then go, "Carry on thinking that." They'd always address the misconception, but there are sort of stock things that we get wrong in language in particular... So yes, I think teachers definitely do that. [TW laughs].**

3c:26 JR: That is really helpful. Thank you. [Pause while JR looks at the questioning route] I'm not going to do all of these by the way, I'm just sort of you know bouncing round a few questions. Is this OK? Not getting too cold?

3c:27 **TW: No. Chilly, but I'm fine actually.**

3c:28 JR: Could I talk with you a little bit about children's problem solving strategies.

TW: OK

JR: I think sometimes children's problem solving strategies are very similar to adults' problem solving strategies. You know, sometimes we have ways of solving the sorts of issues that are coming up here. But sometimes they're different. I wondered if you had any experiences of, you know, almost naive techniques. So not naive concepts, but naive...

3c:29 **TW: I think one of the naiveties that comes up there is firstly that everything they're told must be true. It is a bit like, you've seen it in a newspaper so it must be true. So there is that. But there is also, 'there must be an answer'. Or that there is a right answer. I think that is probably the biggest difference, as you get older you go, you accept that you're not always right, or people are not always right, or there isn't always a perfect answer. Particularly in science, although science is kind of billed as having the answers to things. I think that is probably the most stark difference. I**

- think it goes back to what GS was saying, he was desperately trying to make everything that he knew fit together, which is kind of adult in one way, it is quite a mature idea, but he couldn't quite reconcile the different things. [Pause] I suppose that is more naive... more adult actually [said in a reflective tone]. But um, [pause] I think the desperation for a correct answer or that there is - but I think we school that into them. Because there are right answers at school and you get ticks and crosses if you get it wrong. And then you're tested and you will pass. So we teach them that there is only one right answer and then throw questions like that at them and go, "Well, there are many answers." [TW sits back crossing her arms imitating the teacher and laughing] "What? There can't be." [TW imitates a pupil] Um. Yes. [Pause] That is all I can think of on that really.
- 3c:30 JR: Thank you. That is really helpful. Um. If you'd been doing three topics like that in the sort of normal class, as part of the normal school year, can you tell me a little bit about how it might be similar and how it might be different?
- 3c:31 **TW: OK. So heat and temperature would all start off being practical. I wouldn't talk about words like freezing, melting, heating - anything until we'd started doing it. And so then they've got - so then you do a lot of observations and they have to describe things, and then once you've built up your bank of words, like melting, freezing, condensation, and so on; then you try and link them all together. So it would, they'd see it and feel it all first before you try to have the words for it. Because I think they are still so complex. So that would be quite different from that point of view - obviously they did get to touch the hot tea and the ice. That might have been quite useful starting point. You might do a discussion, and then do some practical. But I err towards the practical first. Um. The card sort was almost exactly how I would use it in lessons. I probably would have had less cards.**
- 3c:32 JR: It is a stupidly big pack isn't it. [JR laughs]
- 3c:33 **TW: Well, we could go on for ever. But also there are some there that would relate to a physics lesson, there are some that would relate to biology, and so on. So. No I fully intend to use those in lessons in exactly that way to promote discussion, to promote collaborative learning, and just to get people thinking and justifying. I can think of a million different ways I would use that in the classroom. Actually. All different topics. And I wouldn't change it apart from limiting the number of cards given at one time. And the last one. Again I think I would have done a lot of experiments with light so they could see it bouncing off mirrors, see it bouncing off - there are quite a lot of animations you can show about light flowing and so on. And that wasn't particularly different, I can imagine that being a standard question. I probably would use it as maybe a plenary part of a lesson. So OK we've done these experiments with ray boxes, we've looked at light, we've looked at this animation. Here's a scenario, draw me what happens. And I often use mini whiteboards and pens in lessons. So that is fairly standard as well.**
- 3c:34 JR: Thank you. How are we doing? [JR looks at the clock] So we've got ten minutes. [JR looks at TW] Are you wilting?
- 3c:35 **TW: I'm fine. [TW laughs]**
JR: A little bit more?
TW: Yes.
- 3c:36 JR: If a student or students disagree with you over ideas, how do you... do you persuade them? Are there techniques you might use to persuade them?
- 3c:37 **TW: It depends what it is. Um. And it depends how significant it is. If it's... if it's... I don't know... If it is non-syllabus related and they happen to think Manchester United are the best football team in the world I probably wouldn't give it much thought. It doesn't occur to me to be very interesting. [TW and JR laugh] But if it is something very fundamental and particularly if it is a misconception that is going to stop them passing an exam, even then. I mean the big one in this school is evolution.**

So there are certain things - there was nothing I could say to convince a large group of our pupils that evolution is correct or certainly is the theory that scientists adhere to. Because of the way they're taught their religious teachings. So there - I mean of course there is also an ethical issue there. I can't tell them that their religious teachings are wrong, so I will give them as much information as I can, I would tell them what people think. But I have to leave them make their own minds up. As much as I want to tell them [pause]. As long as they are thinking and as long as they're approaching it and as long as they know what they have to write in the exams, I have to leave it at that point. And then really leave it to their parents I suppose to decide how their children are brought up. [Pause] If it is something more, I don't know, [pause] if someone is convinced that it is cold coming in rather than heat going out, then I think I would spend a lot more time persuading them, because that is syllabus related and so on. You can teach evolution without [pause - TW blows air in a silent whistle] I don't know how to say that. You're not teaching creationism. You're not teaching it as an alternative theory. You're teaching it as the theory that scientists agree - but I can say, "You don't have to agree with me, but you have to know about it and you have to learn...". The pupils don't have a problem with that actually. So, I think 'sometimes' was my answer.

3c:38 JR: Thank you. [Pause while JR looks at the questioning route] I think I'll just finish actually with just one last question. From the whole experience taken together of that group interview, and the two interviews we've done here, is there anything else you'd like to say? And please don't hold back if there is anything that is niggling or that might be difficult to say.

3c:39 **TW: No. I quite enjoyed it. It is nice to sit and think about teaching, about science. No, it has been fun [TW smiles]. I can't think of anything else I'd like to say.**

3c:40 JR: Well thank you very much. I can't tell you how much I appreciate you giving your time like this and sharing your experience.

3c:41 **TW: That is fine.**

[End 3c]

Interview 4a

4a:1 **TX: Do I have to sit down?**

JR: *That would be fine, just there. [JR points to a seat]*

TX: Because I don't usually sit down. That's the problem.

JR: *[Unclear] catching you on the camera.*

TX: [OU and TX smile]

4a:2 **TX: [To KL] Are you nervous?**

4a:3 KL: No.

4a:4 **TX: Are you [DA] a bit nervous?**

4a:5 DA: Yes.

4a:6 **TX: Are you [DM] a bit nervous? [TX says this quickly and the effect is humorous and KL, DA and DM smile]**

4a:7 JS: No.

4a:8 **TX: Don't be nervous right. Just be [JR drops something which makes a loud sound]...**

JR: *Sorry.*

TX: Just less of the [TX mimes dancing]. If you [DA] want to do that, you do that. Shall we start Mr Riordan? OK. Thanks you lot for coming today. It means a lot. What we're going to do is we're going to talk about ideas in science. It is not going to - there is no right or wrong answer. There is no right or wrong answer. It is just about how we have ideas of science and how as we go through our lives [TX mimes

- this with his hands whilst speaking] our ideas of science change. OK? And you lot - I mean how many years on the planet [turning to JS]?**
- 4a:9 JS: Twelve.
- 4a:10 **TX: Twelve years. So you've been learning lots about science in that twelve years. How have you been learning science in the last twelve years?**
- 4a:11 DM: Living it.
- 4a:12 JS: Science lessons.
- 4a:13 **TX: Living it. [Said with feeling]**
- 4a:14 **TX: Science lessons. ... How have you [DA] been living science? How have you been gaining science knowledge?**
- 4a:15 JS: Experimenting with new things.
- 4a:16 **TX: New things. It is about trying new things out.**
- 4a:17 OU: The world around us.
- 4a:18 **TX: The world around us. How do you get the world around us? How do you take it in?**
- 4a:19 OU: Like look and see it and -
JS: Exploring.
- 4a:20 **TX: Exploring.**
- 4a:21 TW: Curiosity.
- 4a:22 **TX: Curiosity KL. What has made you curious recently?**
- 4a:23 TW: [Shrugs] Um. [Laughs]
- 4a:24 **TX: [Unclear - TX smiles and puts his hand to his chin - his action gets everyone smiling - seems to be 'What has made you go mmmm!']**
- 4a:25 DA: [Unclear - but clearly a joke - everyone laughs]
- 4a:26 **TX: What we're going to talk about, so there is no right or wrong answer, if you change your mind about any of the things that you're talking about. So if you think, 'Oh, I didn't really mean to say that.' You can say that. OK. You're allowed to say that. Erm. But tell us during the interview about whatever has changed in terms of your ideas of science. So if you had an idea, [TX mimes holding this idea in his hand] and from what we've done today it has changed, can you tell us if any of your ideas have changed? Is that OK? [Several students nod]. OK. We'll start with you KL. First question is tell me how do you feel about science? Tell me who you are and what you feel about science.**
- 4a:27 TW: I'm TW, and it is really cool because it is a lot better than other subjects like anything else. Because it is not like, "Sit down and work." It is like experiments and other stuff.
- 4a:28 **TX: Other stuff? What kind of stuff?**
- 4a:29 KL: Um. Like... [TW shrugs] I don't know [TW and DA laugh - TX smiles]
- 4a:30 **TX: OK. Come back if there is anything that comes into your head about stuff [TX points to his head]. OK. AJ?**
- 4a:31 AJ: I like the fact that you do loads of experiments and that science is coming like into the [unclear]. And I just 'cause in English or Maths you'd have to do loads of writing and in science you have to do some writing, but it is mostly like graphs and stuff.
- 4a:32 **TX: What kind of graphs are you drawing? What do graphs show?**
- 4a:33 AJ: Your results.
- 4a:34 **TX: Your results. OK. DA? How do you feel about science?**
- 4a:35 DA: It is my favourite lesson [DA laughs]. Um, I got - I've always got like awesome teachers like you [DA and TX laugh] we get to do loads of practicals and [unclear - DA laughs as she says this] and stuff like that.
- 4a:36 **TX: Okeydokey. What do you feel you've learnt most this year? What is the thing that has really stood out that you have learnt most in science this year?**
- 4a:37 DA: Oh, ... what is it called? ... Evolution!
- 4a:38 **TX: Evolution.**

4a:39 DA: Yes.

4a:40 **TX: OK. Who came up with that idea? [Asking DA]**

4a:41 DA: Charles Darwin.

4a:42 **TX: Yes. And what are his three ideas? Do you remember? [Pause]**

4a:43 JS: Variation in a population. Natural selections. And...
DA: Oh right, yes.

4a:44 OU: Mutations.

4a:45 JS: Mutations.

4a:46 **TX: Okeydokey. JS, do you want to say who you are and what you think about science?**

4a:47 JS: Well, I like science. It is like, you get to explore something that you wouldn't really do in like English. That is just like writing and answering questions about grammar, but this is like experiments to find new things out that people like use.

4a:48 **TX: What have you found out that is new that you've enjoyed this year?**

4a:49 JS: Well, we've done dissecting animals. And like learning about all the guts and cells inside them and stuff that was fun.

4a:50 **TX: Good good good.**

4a:51 AJ: I like it when we get the animals out and measure the ratios - that was fun.

4a:52 **TX: DM.**

4a:53 DM: My favourite thing - I like science because it is always something new and it could save a life someday - science. And it can change the world in so many ways. And it is just like so fun.

4a:54 **TX: Good. OK. Change the world. Are you [DM] going to change the world?**

4a:55 DM: Maybe.

4a:56 **TX: Excellent. And OU finally.**

4a:57 OU: I really enjoy science because I like experimenting with things and yes.

4a:58 **TX: What do you feel you've experimented on this year?**

4a:59 OU: Um. We used the um... [long pause] we did this. I can't remember what it was. [OU puts his hand to his forehead] ...

4a:60 **TX: We'll come back to it. Have a think about it. Right. I'm going to ask you now can you tell me what the first thing that comes into your head TW, I'll give you a few thinking seconds, when you hear the word 'science'? That is going to be my next question [TX indicates with his hand that this will go round the group clockwise]. So when you think of the word 'science' what is the first thing that comes into your head?**

4a:61 TW: Space.

4a:62 **TX: Space. [TX reaches out a hand on the desk towards AJ to indicate that it is her turn]**

4a:63 TW: ... Electricity.

4a:64 DA: [TX reaches out palm downwards towards DA] Chemicals.

4a:65 **TX: Chemicals.**

4a:66 OU: Cells.

4a:67 **TX: Cells.**

4a:68 DM: Opaque.

4a:69 **TX: Opaque.**

4a:70 JS: Time travel. [Everyone smiles]

4a:71 **TX: Time travel. Tell me about any experiences you've had where somebody has changed your mind about an idea in science. So you've come in [TX mimes holding an idea in his right hand] and you've had an idea. And then something, or someone [TX mimes this with his other hand] or something has happened and you've changed your mind about that idea. Maybe you thought it worked in a certain way, and then something has happened to make you think, 'Oh, it doesn't work in that way. It works in a different way.' Do you get the question? [Several students murmur that**

- they do] **OK. So you've been on this planet twelve years. You've learnt lots about science and the world around you. So what has happened, or someone, has helped you change your ideas that you've had and have made you think in a different way? OK? Who wants to go first on that one? AJ?**
- 4a:72 AJ: When I went to America I went to the Kennedy Space Centre and I always thought that astronomy and space was quite boring. But then when you like go round and you see where they launched all the rockets and everything it is really interesting. Fascinating.
- 4a:73 **TX: And what changed? What changed in your head and science from that visit.**
- 4a:74 AJ: Well, how - um ... I don't really know. I just thought it was like really - not sure.
- 4a:75 **TX: It was just being there.**
- 4a:76 AJ: I always thought like it was really like boring, and it didn't really like have anything fun to it, but when you get to like see the rockets and everything it makes you change your mind. How cool it would be to go in a rocket.
- 4a:77 **TX: So actually the whole point of you being there was your experience of what it would be like to be an astronaut. And going through that whole process. Cool. OK. Anybody else [OU puts his hand up]? OU.**
- 4a:78 OU: Well I always thought like weight was m- kilos. But then we've been doing recently mass and weight and then I learnt that mass is actually kilos and weight is newtons.
- 4a:79 **TX: And have you noticed, now that you're really happy [TX indicates his head] with that idea in your head. Have you noticed how many times in the press and the media people talk about weight - and they actually talk about kilograms. And they're completely-**
- 4a:80 OU: Wrong.
- 4a:81 **TX: Wrong. Weight watchers.**
OU: Yes.
TX: You go to weight watchers to lose weight, but you're really losing-
- 4a:82 OU: Mass.
- 4a:83 **TX: Mass. So we should really change it to mass watchers. [Everyone laughs] It doesn't sound as good though, does it.**
- 4a:84 KL: I'll need to correct my Mum there.
- 4a:85 **TX: Mass watchers. Your mum goes to mass watchers KL. OK. JS? [Who has his hand up]**
- 4a:86 JS: Um. Like I actually thought science was a really boring thing until I went on a plane on holiday and then I just started to wonder how they actually stay in the air. As they're really really heavy.
- 4a:87 **TX: How did you think they stayed in the air beforehand?**
- 4a:88 JS: I used to think that there was a giant invisible hand that held them. [Everyone laughs. TX mimes this - Al picks up a pencil and places it on his hand].
TX: OK.
JS: But then - Yes. But then I just. But then my Dad said it is all scientific forces like up thrust and lift from the wings and stuff. And that changed the view I had.
- 4a:89 **TX: And from this year in science, how has that up thrust changed even further in your head? From what you've done this year?**
JS: Well.
TX: The idea of forces. How has it changed again this year?
- 4a:90 **TX: ... Has it changed?**
- 4a:91 JS: No, not really.
- 4a:92 **TX: You're comfortable with up thrust and -**
JS: Yes.
TX: And gravity and down thrust. OK. Anybody else? TW?
- 4a:93 TW: I used to think that gravity always pulls you down, so I was really confused when like Australia! But it actually pulls you towards the centre of the Earth.
- 4a:94 **TX: That's right. Yes.**

- 4a:95 DA: I used to think that too. I actually thought that everyone was upside-down when they were at the bottom [DA indicates with her hands what could be the bottom of a globe] I was like - I was saying to my Mum, and I was like - 'Would they get loads of headaches standing on their head?' [DA laughs] ...
- 4a:96 **TX: So what actually changed? What actually caused that change to happen? That change in the idea.**
- 4a:97 DA: Well, because I think we were in the library or something, and there was a globe. And I said, 'Mum, why on the other side of the world are they upside-down? Why don't they just come to the top so they don't get headaches?' And then Mum said, 'They're not, the gravity goes to the centre.' [TX nods]
- 4a:98 **TX: Cool. DM?**
- 4a:99 DM: Well, I used to think that all animals were equal. That no one - nothing had a competitive advantage or anything like that. But then in the lessons that we've been having I've been finding out all things that help them have a competitive advantage in the wild and stuff like that.
- 4a:100 **TX: And has it made you change the way you look at nature programs and when you look at nature?**
- 4a:101 DM: ... Quite a lot.
- 4a:102 **TX: In what way?**
- 4a:103 DM: Well there is has made me think what happened - what would happen if a mutation went the other way. ... [TX nods]
- 4a:104 **TX: And if it didn't give it a selective advantage?**
- 4a:105 DM: Yes.
- 4a:106 **TX: OK. What - So in terms of science this year, do you all feel you've made progress?**
- 4a:107 OU: Yes. [Others nod]
- 4a:108 **TX: And do you feel science is something that you ever stop learning?**
- 4a:109 DM and OU: No.
- 4a:110 DM: Because it is all round the world and everywhere you go.
- 4a:111 **TX: And you're learning it all the time?**
- 4a:112 DM: Yes.
- 4a:113 **TX: OK. [TX turns round towards JR] We're going to look at some objects now. Mr Riordan is going to give us two objects. [JR places cup of tea and bowl of ice on the table - students lean in to look]. There is a bowl of ice and cup of hot tea. OK. Have a look at those for a few seconds. Touch them. Smell them. [Several students smile] Get the whole experience. We're not allowed to drink the tea.**
JS: Oh!
TX: You can touch the cup, touch the bowl.
TW: Can we touch the ice?
TX: Yes, you do whatever you want. OK? Experience the ice and the tea. [JS and DM start putting cold water on each other] Right, here is the question you lot. Again, just throw out answers, one at a time that's all.
- 4a:114 **TX: Tell me what you think is happening to the hot tea, and the ice cube in as much detail as possible. OK? So I want to know what is happening to the ice cubes [TX reaches out and touches the bowl] and to this hot tea [TX touches the tea] in as much detail as possible. One at a time, that is all I'd like you to do. [JS has his hand up] OK? JS, you start off.**
- 4a:115 JS: Well, the thing that is happening to the ice is the room temperature round it is like twenty degrees Celsius, that is about twenty degrees hotter than ice's like melting point, so that is melting and getting warmer in this temperature until it reaches room temperature. So that is going to melt into a liquid. Whereas the hot tea is going to cool down until it reaches the room temperature because of the colder surroundings. [JS's voice gets very quiet towards the end here]

- 4a:116 **TX: Because of the - sorry?**
- 4a:117 JS: Because of the surroundings at room temperature is cooler than the temperature of the tea it is going to cool down. [TX sits up straighter]
- 4a:118 **TX: OK. Thank you for that one. DA, you had your hand up.**
- 4a:119 DA: The ice is going to melt because - yes, it is going to melt into a liquid because freezing temperature is zero degrees, and room temperature is going to make it melt. And the tea is cooling down because ... Well it was boiled at a hundred degrees and then it is just cooling down. And it is not going to stay at a hundred degrees throughout. [DA's tone implies this last line is obvious]
- 4a:120 **TX: Why is it cooling down?**
- 4a:121 DA: Because of the -
TW?: Gas.
- 4a:122 **TX: Tell me about the room temperature.**
- 4a:123 DA: It is not as hot is it?
- 4a:124 **TX: It is not as hot as the -**
- 4a:125 DA: Tea. [TX sits up] [DM has his hand up]
- 4a:126 **TX: Tea. [TX is looking at DM] So where is the heat going?**
- 4a:127 DM: Up. What is happening is the solid ice is now becoming a liquid because it's freezing temperature is now changed to a different temperature. [Tone used is one of explanation] In the room. And it is not at the freezing point and so it will melt into a liquid because of the heat.
- 4a:128 **TX: Why is it not at freezing point?**
- 4a:129 DM: Because the room temperature is twenty degrees or something like that.
- 4a:130 **TX: But I've still got ice here. [TX picks up an ice cube]**
- 4a:131 DM: Because it will take some time to melt because it is not - if it is really hot it will melt quicker whereas at room temperature it will be quite slow.
- 4a:132 **TX: Can you think of a hypothesis that you might want to use to test that?**
- 4a:133 DM: The hotter the surrounding the faster the ice will melt.
- 4a:134 **TX: Thank you. ... TW, any ideas?**
- 4a:135 TW: Well basically what everybody else has said. ... Just that the tea is cooling down because of the room temperature and the ice is turning into liquid.
- 4a:136 **TX: Where is the heat going from the tea? [TX indicates the cup]**
- 4a:137 TW: Up.
- 4a:138 **TX: Why is it going up?**
- 4a:139 TW: Um. Because heat rises.
- 4a:140 **TX: Heat rises. [DM and JS play with the ice] And where is the heat going in the ice?**
- 4a:141 TW: Um. I don't know. [Laughs]
- 4a:142 **TX: You said something very interesting. You said, heat rises, yes. So -**
- 4a:143 AJ: [Unclear - very quiet - something about heat going into the bowl]
- 4a:144 **TX: So heat is going into this bowl. [TX picks it up] So tell me about that. How is the heat going into the bowl?**
- 4a:145 DA?: You said [another name]
TX: Sorry AJ!
- 4a:146 AJ: Um. Because it is surrounded - if there was something covering it [AJ indicates some sort of lid with her hand] maybe - I don't know, because this [the water in the bowl] is quite - this isn't like freezing. And that would cool it down. And the air in the surroundings is warmer so air goes everywhere, so it will sort of go in and like air is going into the tea which is like warm and the heat is coming out because it has nowhere to go.
- 4a:147 **TX: So if the heat is going out [TX indicates something coming out of the top of the cup] what is causing - what is happening to the air around it? ... So if you're saying that the heat is coming out of the tea, what is happening to this air around the tea?**

4a:148 AJ: It is not able to get in. The air isn't able to cool this [the cup] down. So when all the heat is gone it will be freezing. Well not freezing, but cold.

4a:149 **TX: OK. What temperature will this tea go down to, if it carries on cooling, what will it go down to?**

4a:150 JS: Room temperature.

4a:151 **TX: Why is that? Why room temperature?**

4a:152 JS: Because if it goes below the room temperature then the hotter room temperature will start to warm it back up again, until it like stays even at room temperature.

4a:153 **TX: So where do you think the heat - What is happening to the heat in terms of its movement? Is there a pattern to where heat goes?**

4a:154 JS: Well, hot heat tends to go up and cold like heat tends to go down.

4a:155 **TX: Okeydokey. You've got hot heat and cold heat. [DM and others smile and then laugh] OK. No. What is the difference between hot heat and cold heat?**

4a:156 JS: Well like hot stuff, the steam will tend to go up. But if you get like an ice lolly, the steamy stuff that comes off it goes down.

4a:157 **TX: OK. OK. So going back to AJ's point. What has happened to the air then in these two containers?**

4a:158 DM: One is travelling up.

4a:159 **TX: Which one?**

4a:160 DM: That one [pointing to the tea]. It is -

4a:161 AJ: Because there is nowhere else for the heat to go. [AJ touches the side of the cup] Because it is [unclear - on the side?] You can feel the heat around the cup [said very quietly, so unclear].

4a:162 **TX: OK. So where is the heat going then once it is on that cup?**

4a:163 AJ: Up.

4a:164 **TX: So it is going up. So it is going up from the tea?**
DA?: Yes.
TX: The cup?

4a:165 AJ: The tea. Because I think when this [feeling the side of the cup] gets to the temperature of the tea so the heat goes up [AJ mimes this] because it has no space.

4a:166 **TX: And what happens to the heat when it goes up? What is happening to it?**

4a:167 DM: Separating into little particles isn't it?

4a:168 **TX: So heat is particles?**

4a:169 DM: Yes.

4a:170 **TX: OK. So what does heat do to particles?**

4a:171 DM: [Looking to the side and perhaps thinking about this?] Heat separates them? Then they travel up. And then they'll be like really small little particles going up into the air separating. Whereas when it is colder they are closer together.

4a:172 **TX: And then where do they go?**

4a:173 AJ: They go into the air. If you had like the whole table full of tea the room would be warmer.

4a:174 JS: This might sound silly [other students smile], but it is sort of like the higher up in the Earth you go it sort of gets colder and the lower down you go it is warmer. It is like the cold air is going down to the bottom to get warmer and the hot air is going up to cool down. I just thought of that.

4a:175 DM: Because of the magnet in the centre of the Earth. [TX smiles]

4a:176 **TX: Any other things about the ice and the hot tea?**

4a:177 DA: Is cold air denser than hot air?

4a:178 **TX: Tell me about density then. What is 'denser'? What does that mean?**

4a:179 DA: Well, there is like oil. It goes on the top because it is less dense ... than water is.

4a:180 **TX: OK. So what is density then? Why can't the oil get into the water?**

4a:181 DA: Well they don't really - is the word 'resist'?

4a:182 **TX: OK.**

4a:183 DA: Is that the word?
 DM?: Not yet.
 JS: I'm confused.

4a:184 AJ: They don't mix together. They just don't.

4a:185 KL: Is it something to do with the particles, whether they are further away or closer?

4a:186 **TX: OK. Carry on KL.**

4a:187 KL: No, it is just like air - with the particles they are like all spread out [KL mimes this] and air is less dense than water. Because water the particles are closer together, that is why it is harder to move through water. So would that be the -

4a:188 **TX: So what is the heat doing to the density [pointing to the tea] of the air?**

4a:189 KL: Isn't it adding more particles?

4a:190 **TX: It is adding more particles? [TX's tone has a very slight question in it] ... OK.**

4a:191 KL: I don't know.

4a:192 **TX: Where are the particles coming from?**

4a:193 KL: The tea.

4a:194 **TX: The tea. ... So how are the particles from the tea kind of going into the air?**

4a:195 KL: Because - I don't know.

4a:196 **TX: [Pause] Any ideas? [Question directed at the other students] [Pause] What has happened now, in the last ten minutes we've been talking?**

4a:197 Everyone talking at once: The ice has melted a lot more.

4a:198 **TX: A lot more. A lot more water.**

4a:199 OU: Because it is like - it is coming closer to the room temperature.

4a:200 **TX: OK. So what is going into this? [the bowl of ice]**

4a:201 DA: Heat.

4a:202 **TX: Heat. Heat is going in there. OK. Let's talk about this idea of particles. Because KL started talking about particles and you talked about density of particles. You talked about the particles either being closer together or -**

4a:203 KL: Further away.

4a:204 **TX: Further away. Tell me about the particles then that make up this bowl of ice.**

4a:205 Several students start speaking: [unclear]
 JS: Well, in the ice it is like the frozen water and because it is a solid all the particles are really close together [TX lifts an ice cube out of the bowl]
 AJ?: They're closely packed
 JS: Yes. They don't move. But in the watery bit they're all like spread out and you can like just stick your finger in.
 DM: Stick your finger in.
 JS: and that [the ice] is all hard and you can't really [unclear 'move'?] the particles.

4a:206 **TX: OK, just go through that again JS. So what you've got there in that solid ice [TX holds up the ice cube] -**

4a:207 JS: Is um like the particles are like stuck together really cramped together packed up

4a:208 OU: That is what makes a solid.

4a:209 JS: Yes, that is what makes a solid and you can't move it.

4a:210 **TX: OK.**

4a:211 JS: But in a melted liquid, it is like the melted part of it the particles have melted - well unstuck together
 DM: Separated.
 JS: And now they're like yes separated and not they're a lot easier and basically move around.

4a:212 **TX: OK. What has caused, what has caused these particles to move?**

4a:213 DM: The heat.

4a:214 **TX: The heat. And then where has the heat come from?**

4a:215 DA: The air.

4a:216 DM: The room.

- 4a:217 **TX: The room temperature. OK. And going back to your [DM's] hypothesis -**
- 4a:218 DM: The hotter the room temperature the surroundings the faster it will melt.
- 4a:219 **TX: OK. So now let's talk about the particles in the cup of hot tea.**
- 4a:220 OU: They're spread out because it is a liquid.
- 4a:221 **TX: So we've got a liquid. OK. But what have we given that liquid?**
- 4a:222 OU: Heat.
- 4a:223 **TX: We've given it heat. So talk about the particles then in the hot tea?**
- 4a:224 JS: The steam that comes out of the tea when it has just been made, fresh - this might have cooled down a bit, those particles have gone from slightly spread out to really spread out and they're like floating around in like a gas kind of thing. So it is like three stages. It is like really really compact, slightly spread out and then all spaced out [JS mimes this with his hands] kind of - yes.
- 4a:225 KL: Is it kind of like when you heat up the liquid don't the particles like move around faster and that is what causes it to turn to gas. [TX nods]
- 4a:226 **TX: When did you first learn about particles?**
- 4a:227 KL: [Laughs] Year six.
DM: Year five.
JS: Year four.
- 4a:228 **TX: OK. Cool. [Turning to JR] Shall we move on to the next stage? Is there anything else you want to say about tea and ice before we finish? [JR removes the tea and ice and brings the card sort activity]**
- 4a:229 JS: [Unclear - makes a joke and everyone laughs - I think it might be about drinking the tea]
- 4a:230 DA: It would be nice with some biscuits.
TX: It is a bit cold now JS. And now why has it gone cold?
- 4a:231 JS: Because the room temperature has cooled it down.
- 4a:232 JR: *[Passing out the cards and mats] So there is a pack each and then there is a living and a non-living mat each.*
- Student?: Mmm!
- Student?: Thank you. One each?
JS: Is it like one between two then?
JR: *One each.*
- 4a:233 **TX: [Noise as students sort out their mats] So you've got to separate - you've got to separate the cards into living or the non-living. ... Now don't look at your neighbours OK. Just on your own.**
- 4a:234 AJ: Do you have two? [AJ has only one mat]
JR: *Sorry [gives AJ a second mat] Sorry about that.*
DA: I've got two non-living.
JR: *Oh, sorry. Here we go [JR passes DA the other type of mat] Does anybody else have -*
DA: Have you [asking the other students] got two living?
OU: Why has it got two [unclear - possibly 'bikes']
- 4a:235 JS: This is like a puzzle [unclear].
- 4a:236 **TX: OK? OK, so what you've got to do is sort the cards into the spaces on the two mats quickly, do it very quickly just a gut feeling.**
- 4a:237 KL: With the leaf, is it attached to the tree or not?
- 4a:238 DM: Yes.
- 4a:239 **TX: Yes, don't talk about it, just do it on your own. OK. We'll talk about it later - just your gut feeling whether it is living or non-living. Try not to look at your neighbour. OK, because we're trying to understand what the word living means.**
- 4a:240 OU: There are two the same. [There are two pictures of a bike, one with a person on - so moving, and the other without a person on]
- 4a:241 **TX: You can change your mind later, but at the moment it is just your gut feeling. What do you think it alive and what is not.**

4a:242 JS: Spider! ... Fire!

4a:243 JS: [Long pause] Tree. [Long pause] [TX gets a set of cards and mats for himself] [Long pause] [TX turns to JR]

4a:244 **TX: Shall we discuss the reasons for it?**

4a:245 JR: Yes. [unclear - TX and JR whisper whilst the students continue to sort their cards]
 JS: Embryo
 DM: What is an embryo? [Unclear - DM talks quietly with JS about this whilst TX and JR talk]

4a:246 **TX: So I then create a master one?**
 JR: *If you want.*

4a:247 JS: [Long pause] I have two bicycles. One has a person riding it and the other doesn't. What is the difference? [unclear]

4a:248 OU: What is embryo?

4a:249 **TX: It is a developing fertilised egg. It grows into an embryo, before it becomes a foetus.**

4a:250 JS: I put egg in living because it could have a chicken inside it.

4a:251 **TX: Are we all done?**

4a:252 DA: I can't decide [unclear]

4a:253 **TX: Just a few more minutes. A few more seconds. Have a look through. Just check that you've gone through each of the cards - where you think if they are living or non-living. And then we're going to discuss some of these. Are you all ready? AJ, are you OK?**

4a:254 AJ: Yes.

4a:255 **TX: Just getting those organised. [JR removes a the last plastic bag from the table] Right let's start with - I want to start with 'tree'. [TX places his own card above his own mats in the middle] Where have we got tree? So if you think it's - if you've put it in living do thumbs up [all students immediately do thumbs up] and if you think it is non-living thumbs down. So then we can quickly see all what we think. Yes? Is that alright? Living [TX holds his thumb up] or - [TX holds his thumb down]**

4a:256 DM: Non-living.

4a:257 **TX: Are you ready? [said in a loud voice] So tree? OK, we all agree that tree is living. Why is that KL?**

4a:258 KL: Because like MRS GREN. [KL laughs] That is what it makes me think of.

4a:259 **TX: What does MRS GREN stand for?**

4a:260 KL: Um, Movement, Respiration, Sensitivity, Growth, Reproduction
 JS: Reproduction [simultaneously] Excretion
 KL: Excretion [laughs], Nutrition.

4a:261 **TX: But does a tree move? Does it pick its roots up and move? [TX is smiling and looking round - clearly challenging the group]**

4a:262 KL: No.

4a:263 JS: It does photosynthesis. And the plants like breathe - like the leaves in it.

4a:264 DM: It is living. ... And it grows.

4a:265 JS: It breathes in carbon dioxide and breaths out oxygen.

4a:266 **TX: OK. So we're already starting thinking about what makes something living. You're saying [TX points at KL] you're saying MRS GREN.**

4a:267 KL: Yes.

4a:268 **TX: So it has got to be MRS GREN. But is the tree moving? [The tone of the question has changed - it now has a slightly more serious tone] [Long pause]**

4a:269 Several students talk at once: [unclear]
 KL: It is growing.

4a:270 **TX: Yes [turning to KL]. OK. So talk about it then. So it is growing. So it is this big one year [miming a small sapling]**

4a:271 JS: And the next year it is that big [miming a huge tree]

4a:272 **TX: OK. So has it moved?**

4a:273 AJ: Yes.

4a:274 **TX: Yes. How has it moved? By -**

4a:275 DM: By growing.

4a:276 **TX: By growing. Dead leaf [TX shows the card up] What have you got? Let me see, hands up. [TW, JS and OU put thumbs down confidently. DM is looking at the others - he has a broken arm - he hasn't put a thumb out yet nor has DA and AJ] Thumbs up, or thumbs down. We've all put it in the non-living. Why have you put it in non-living?**

4a:277 Everyone together: Because it is dead!

4a:278 **TX: So it used to be alive?**

4a:279 AJ: Yes.

4a:280 **TX: OK. [TX goes as if to take a new card, then stops and says the next bit] What makes it dead then?**

4a:281 JS: [Said simultaneously with DM - see below] It is like all shrunk up and fell off the big tree it like lived on. It doesn't really breath anything anymore it doesn't really do photosynthesis.
DM: It is not growing.

4a:282 KL: It doesn't get any nutrition.

4a:283 **TX: It doesn't get any nutrition.**

4a:284 OU: It doesn't grow.

4a:285 **TX: It doesn't grow anymore.**

4a:286 OU?: It sort of shrinks.

4a:287 **TX: OK. Seed? Let's have seed then. Thumbs up, thumbs down. OK, we're all going for living on that one. OK, DA, why seeds?**

4a:288 DA: Because - because it is just like a tree but it is just like... Yes, it is just like the beginning of the tree when it is packed with all the nutrition. It is just like oh.

4a:289 **TX: OK. But what about these seeds that are like thousands and thousands of years old that haven't germinated. Is it still alive? These seeds - we find them ... in glaciers - they are thousands upon thousands of years old. Is the seed still alive?**

4a:290 JS: Well these ones are packeted [sic], and they should be alive. [Everyone laughs]

4a:291 **TX: Yes, yes, we saw a packet of seeds. How long does a packet of seeds last for though [question directed at JS]?**

4a:292 JS: It wouldn't last long because it is all dark in the packet.
DM: No light will get to it.

4a:293 **TX: And they need light to -**

4a:294 JS: Live [unclear]

4a:295 **TX: Start growing. So is it alive then as a seed?**

4a:296 JS: Well seeds do normally start in the ground. They grow roots and then the big shoot comes up.

4a:297 **TX: But a seed that is not growing? [TX slows the pace with which he says 'not growing'] Because you [TX points towards KL] were saying that growth is part of MRS GREN. If a seed is not growing and it is in a packet, is it still alive?**

4a:298 DA: But it is coming out of the packet! [DA laughs as she says this]

4a:299 JS: [Unclear as DM says something, also unclear, at the same time] and then they grow up. That must mean they are alive in a way.

4a:300 **TX: OK. Candle. [TX shows the card up]**

4a:301 AJ: They're not. [Everyone puts thumbs down]

4a:302 **TX: Where does a candle come from?**

4a:303 JS, DM and AJ: Wax.

4a:304 **TX: What makes the wax?**

4a:305 Several students: Bees.

4a:306 **TX: So bees are -**

4a:307 DM: Alive.

4a:308 **TX: So they're making a product, and the product they're making -**

4a:309 DM: Isn't alive.

JS: Is wax.

4a:310 **TX: What about the flame on the candle? Let's go for fire. Who's got fire as alive or dead - non-living. [Students rather hesitantly put their thumbs down indicating non-living - they look at each other's thumbs as they do this] So fire is non-living. Why is that? AJ?**

4a:311 AJ: Because you use matches or sticks to start a fire. Something that is living starts naturally.

4a:312 **TX: Starts naturally. But lightning hitting some dry twigs starting a fire is quite natural.**

4a:313 JS: It sort of feeds a bit. Because like when there is a piece of wood next to it it will spread onto that and then it will burn it all up like it is eating it. Then it will spread to something else.

4a:314 **TX: So you're saying that it is like MRS GREN then.**

4a:315 JS: Yes. It sort of gets to nutrition from pieces of wood and stuff for fire.

4a:316 **TX: Okeydokey. So let's go back to MRS GREN then. So does a fire - a flame move?**

4a:317 JS: They spread.

DM: Yes.

4a:318 **TX: They can spread. What was the 'R'?**

4a:319 KL and other students: Respiration.

4a:320 **TX: That is taking in oxygen. Does it take in oxygen?**

4a:321 OU and other students: Yes.

JS: Yes, to burn.

4a:322 **TX: To burn. OK. What about 'S'?**

4a:323 KL: Sensitivity.

4a:324 **TX: Is it sensitive?**

4a:325 JS: If you put water on it it goes out.

4a:326 **TX: OK.**

4a:327 DA: ... It is not like it can feel anything.

4a:328 **TX: Yes. Does it feel anything? If you went up to a fire and said a bad word to it would it be upset? [Everyone laughs] Would it be upset?**

4a:329 OU and others: No.

4a:330 **TX: Does it reproduce?**

4a:331 Several students: No.

4a:332 **TX: Does it have babies? [Several students laugh] Does it make more of it?**

4a:333 OU: Yes.

DA: It spreads.

4a:334 **TX: So it spreads. [the tone indicates some surprise] So is that like reproduce?**

4a:335 JS: It becomes like one really big fire.

4a:336 DM: It is a bit like growing.

4a:337 **TX: So that is like growing. Or -**

4a:338 DM: Or -

4a:339 **TX: Spreading.**

4a:340 JS: And then you sort of kill it with water.

4a:341 **TX: OK. What about -**

4a:342 AJ: If like - if like it does go out though if something hits it like wind or -

4a:343 **TX: So it is sensitive? [TX smiles]**

4a:344 AJ: Yes.

JS: Wind blows and it goes bluuhhh [JS is miming a fire being blown by the wind]

4a:345 DM: It won't get upset though.

4a:346 **TX: OK. And what is the last one of MRS GREN. 'N'. Nutrition, feeding.**

4a:347 JS: In a way it could be sensitive to a wind. Because if you like blow carbon dioxide - you know our breath on it, it sort of like goes over it and it gets a bit bigger. Like it is getting annoyed. [DM laughs]

4a:348 AJ: But when it is your birthday you like - [AJ mimes blowing out birthday candles on a cake]

4a:349 JS: But then they're tiny little candles. If there is one like that [miming a big fire] and you blow it it will go shhhh [indicating a fire getting bigger].

4a:350 **TX: So has your opinion of fire changed? Are you all still happy that it is non-living?**

4a:351 OU: I think it is kind of both.

4a:352 **TX: A bit of both.**

4a:353 JS: Yes, you could put it like that [JS puts his fire card mid-way between the living and the non-living mats - DA does the same].

4a:354 **TX: So this one is worth re-looking at. If we're thinking about what living means and about what non-living means do you think we really need to look at this one in a bit more detail?**

4a:355 DM and others: Yes.

4a:356 **TX: OK. Let's go for another one. A ball falling.**
Several students: No.
TX: Thumbs, come on. Thumbs. [Everyone puts their thumbs down] So we're putting that in the non-living. OK. DA why is that one?

4a:357 DA: It is not really alive. It is not living - it doesn't breath. It doesn't get food on its' own.

4a:358 AJ: [Unclear - speaking at the same time as DA above]
 KL: It is not actually moving itself, but gravity it just pulling it down.

4a:359 JS: And it doesn't get nutrition. It doesn't excrete. It doesn't reproduce. It doesn't grow. Unless you pump it up. [DM and OU laugh]

4a:360 **TX: So we're not going to go back and look at that one.**
DM: No.
TX: OK. Clock? Thumbs up down. [Everyone thumbs down] All non-living. [TX puts the card on his non-living mat] OK.

4a:361 JS: Well, man-made things - the ball is man-made, but fire could be created on its own, but a ball can't. We have to like shape it into a sphere, pump it up with air, and then it stands.

4a:362 **TX: OK.**

4a:363 KL: It works on electricity.

4a:364 AJ: [Unclear - said very quietly - something about batteries?]

4a:365 **TX: OK. So it does meet some of MRS GREN.**

AJ: Yes.
TX: Which of MRS GREN does the clock actually match?

4a:366 DM: Movement.

4a:367 DA: That's about it.

4a:368 **TX: That's about it. OK. What about 'plant'? Living or non-living? Can I have your thumbs? [Everyone has their thumb up] We're all going for living. Go for it OU.**

4a:369 OU: Er, because it does photosynthesis. And it like creates sugar. So -
 JS: Same as a tree does.
 OU: And its roots kind of like almost like drink water.

4a:370 KL: It is still a plant. [Unclear - spoken very quietly]

4a:371 **TX: OK. And does it move?**

4a:372 OU: Yes. It grows towards the sun.

4a:373 JS: It is literally the same as the tree.

4a:374 **TX: And why is it growing towards the sun?**

4a:375 OU: Because it needs sunlight to live.

4a:376 **TX: Okeydokey. Let's go for another one. Let's go for 'car'. Thumbs up or down. [Everyone thumbs down] OK. Non-living. DM?**

4a:377 DM: Well it don't move on its own. It's not-

4a:378 JS: You need to push a pedal [JS mimes this] to make it go Jjjjjj. [Everyone laughs]

4a:379 DM: It doesn't reproduce. It doesn't - yes - it just doesn't follow MRS GREN.

4a:380 **TX: OK. Let's go for a different way than our thumbs up and down [TX puts his thumb up then down]. Because I want more information from you. If you're really confident that it is dead, put three fingers down. If you're really confident that it is alive put three fingers up [several students repeat the word 'up']. So if you're not sure that it is alive then you could do two or one [TX mimes this using index and middle and then middle finger with the back of his hand towards the students - several students smile at this]. And likewise two or one [TX mimes the fingers pointing downwards]. So if you're really confident that it is definitely non-living do three down. And if you're really confident that it is living do three up. OK. So now I get more information about what you think. [TX looks at his cards]. Let's go for this one, embryo. Are you all happy what embryo is?**

4a:381 DM: Yes.

4a:382 **TX: You've all given me three up. So you're all very confident that that is alive. Why is that? [TX glances towards JS]**

4a:383 JS: Because like it is sort of like the sort of thing you get in a dinosaur egg or a pregnant woman kind of thing. It is like the start of a baby or a dinosaur egg. It like comes out of that tiny little thing and then it grows and grows until it like -

4a:384 **TX: So we're going back to this idea of MRS GREN. How many MRS GRENS do you think?**

4a:385 JS: Well it doesn't really excrete at that stage. [DA comes in at this point - see below] It gets its nutrition from its mother.

4a:386 DA: But I don't think -

4a:387 OU: [Holding up two fingers - he was holding three up before] I think it is two. Well it is not properly alive yet really because it is like -

4a:388 AJ: And if it is like in an egg -
OU: Yes

AJ: - it can't move, it can't eat. As for when you're pregnant -

4a:389 DM: It could move [DM mimes an embryo wiggling inside an egg - JS appears to be agreeing with DM].

4a:390 **TX: How will it grow?**

4a:391 AJ: It -
DM: It gets its nutrition from its mother.
DA: Well the mother sits on it and keeps it warm.

4a:392 AJ: ... It depends on what it is. Is it a child or is it -?

4a:393 **TX: OK. You don't know what type of embryo it is. So are embryos alive?**

4a:394 JS: Yes very much. [JS nods as he says this - the others seem less sure and don't say anything straight away]

4a:395 **TX: Very much. Because - ?**

4a:396 DM: Because it has all the rules - well most of the rules of MRS GREN.

4a:397 AJ: I don't think - which one? - I don't know if it is. [AJ shrugs towards TX as she says this and shakes her head]

4a:398 **TX: Well let's have a discussion about the rules of MRS GREN.**

4a:399 Several students speak at once: [Unclear - but AJ might be saying something about not moving - see below]
DM: It can move [DM wiggles his shoulders whilst looking at AJ]
JS: I've forgotten what MRS means. I know what GREN means. But I've forgotten what the MRS means.

4a:400 AJ: But this is like really really young, and it can't like - it is still in its [shell]
DM and JS: [whilst AJ is saying the above line DM and JS appear to be clarifying between them the meaning of MRS - unclear but DM says Movement and sensitivity]

4a:401 DA: It is [unclear] really.

4a:402 KL: It is just like an animal version of a seed. So I - I don't know. [KL laughs]

4a:403 **TX: OK. So it is an animal version of a seed. What is the seed doing? Where did you put the seed KL?**

4a:404 KL: In living.

4a:405 **TX: So you're saying it is an animal version of the seed. So what is the embryo doing? [Pause] If it is an animal version of the seed.**

4a:406 OU: ... I think it is living.

4a:407 **TX: ... What is it going to turn into?**

4a:408 OU: [Unclear - because DA and TW are speaking at the same time]
 DA: [Unclear]
 KL: [Unclear]

4a:409 **TX: How is it going to change?**

4a:410 DA: It is going to grow.

4a:411 **TX: It is going to grow. Is that part of MRS GREN?**

4a:412 Several students: Yes.

4a:413 **TX: Are we going to leave embryo where it is [on the living mat]?**

4a:414 Several students: Yes.

4a:415 **TX: Are you confident? Let me see your three fingers. [OU waits and looks at DM's fingers before he puts his own up and then puts three fingers up] They're all pointing up, so we're saying it is living. ... Are you [AJ] sure?**

4a:416 AJ: I'm not sure. Because I don't think it is like alive yea. Because - it looks so young. And it doesn't really look like -

4a:417 DM: So you're saying that a baby looks quite young - [DM smiles as he says this]

4a:418 AJ: No. It isn't. A baby is like an egg when it starts off, if it's an egg it is not exactly living yea. [Tone is quite strong here] Because it hasn't started -

4a:419 JS: Well it has a beating heart.

4a:420 DM: Yes. [DM and JS laugh]

4a:421 **TX: ... OK. The embryo might potentially turn into a person [TX is holding up the person card]. Is a person alive?**

4a:422 Several students: Yes.

4a:423 **TX: Go on, give me your gradings.**

4a:424 DA: Me?

4a:425 **TX: All of you. Go on, give me your gradings.**

4a:426 DA: I'm alive.

4a:427 DM: I'm doing a four!

4a:428 **TX: So you're definitely clear on that one. OK. You're saying four DM. OK.**

4a:429 *JR: We're just getting to about ten to ten. Do we have to stop dead on ten?*

4a:430 **TX: We have to - well, we'll have other classes coming in.**

4a:431 *JR: In which case we probably need to move on to the next one.*

4a:432 **TX: Okeydokey. Let's relook at fire. Give me your gradings on fire you lot? Is it alive, or is it non-living? [DM puts one finger up and then changes to three fingers. OU puts one and then increases to two as he looks at other students. DA and AJ have one finger up. Unclear JS and KL from this angle (see other video camera recording)] OK. Has it changed [TX looks at JS then at the others]? Has your opinion about fire changed?**

4a:433 DM: Yes. Because you get used to the other side of things kind of. Because you may just think about one little thing about it.
 JS: [Unclear - simultaneous with DM - but some sort of joke as OU and DA laugh]
 DM: But it is not like a human living - people could be thinking like that. It is not like a human or an animal, so it is not living. But actually it could be living because it moves, [DM counts these off with his fingers] -

4a:434 AJ: Yes, it [fire?] only moves by the wind.

- 4a:435 DM: No, it moves by spreading as well.
- 4a:436 Several students speak simultaneously: [unclear - DM and JS seem to be joking about something]
- 4a:437 **TX: Has your - give me your fingers [TX mimes this] in terms of what you thought fire was at the start then, and tell me your fingers now afterwards [TX mimes using his other hand to show this]. On your left hand give me your fingers what you were whether you thought it was alive or non-living. [Everyone has fingers downwards - DA has two fingers down, KL one, OU nothing yet then puts two fingers down. AJ has two fingers down. DM has three fingers down]. At the start. And then with your right hand give me your rating after the discussion. [OU: left hand one finger up and right no fingers, fingers down, DA has left two fingers down right three fingers down, DM has left unclear and right one finger up, AJ two fingers down both hands, JS three fingers down right and left unclear, KL has two fingers down right hand and left three down]. So you've all changed. AJ you haven't changed.**
- 4a:438 AJ: I haven't.
- 4a:439 **TX: Why haven't you changed?**
- 4a:440 AJ: Because it is not living. Because ... it spreads, but that is by adding more wood. If it didn't have anything to spread to - [DM interrupts here]
- 4a:441 DM: It spreads like I was adding more food.
- 4a:442 **TX: ... OK. DM -**
- 4a:443 AJ: But we don't spread and grow. But you don't grow by putting out a [unclear - DM and JS joking about something - unclear what] It will grow constantly.
- 4a:444 JS: [Mimes an arrow shooting]
- 4a:445 AJ: You don't grow like straight away once you've eaten.
- 4a:446 DM: No but -
JS: It takes a while.
- 4a:447 DM: You're virtually always growing though.
JS: [Unclear]
- 4a:448 **TX: DM, your opinion changed. Can you tell me why your opinion changed?**
- 4a:449 DM: Because I just learned that maybe there is another side to these, like it could be like the stuff [JR has indicated the need to move to the next activity - TX looks at the questioning route at this point whilst DM continues to speak] just changes really. Because I've seen different views [TX and DM look at each other] of people and it has helped me realise that that is part of MRS GREN.
- 4a:450 **TX: OK. So your definition of living is - What is your definition of living?**
- 4a:451 DM: It is the -
- 4a:452 **TX: For something to be alive it has to -**
- 4a:453 DM: Move, have sensitivity, grow, reproduce, respiration, nutrients [DM counts these off on his fingers] - and [laughs nervously] -
- 4a:454 **TX: OK. Are you all happy with that? Are you all happy that that is a definition for living? Is that your definition for living? Anybody got a different definition for living? ... Anybody got a different definition? ... OK. Thank you for that you lot. We're going to move on -**
- 4a:455 *JR: I'm so sorry to rush you on that one.*
- 4a:456 **TX: There was a lovely -**
JR: Fascinating discussion. Can I suggest that I just take those [mats] like that [one on top of the other without tidying]. Don't worry about sorting them out. I can do that afterwards. If you just literally pile them up like that I'll take them off the table and then we'll carry on with the next one straight away.
- 4a:457 **TX: OK. We're going to have a teddy bear and a torch.**
- 4a:458 DM: Weee! Teddy bear. [Several students smile]
- 4a:459 **TX: OK, you have a teddy bear and a torch and a piece of paper. [TX is giving out the paper whilst giving these instructions] Grab a pencil you lot. ... OK. I'll give you**

the instructions. **OK. Shut your eyes and imagine this. Shut your eyes and imagine that you're walking into a completely dark room. Alright. You're walking into that completely dark room with a torch on. And you see the teddy. Can you make a quick sketch showing the torch, the teddy and your eye.**

4a:460 AJ: With our eyes shut?

4a:461 **TX: No, you can open your eyes. That was just to help you see it. [DA and KL laugh] A quick sketch showing the teddy, - don't draw yet. Wait until I've finished the instructions. Make a quick sketch to show the torch, the teddy and your eye which explains to me how you can see the bear. ... [Students start to draw] OK, so you're drawing an eye, a teddy, and a torch in this room. And I want an explanation how you can see the teddy. ... Don't worry about the person. You don't have to go - stick people are absolutely spot on. ... The eye, torch, and the teddy. Explaining how you can see. [Long pause] [TX turns to JR and says something quietly - unclear - JR's reply is also unclear as it is a whisper].**

4a:462 **TX: I'll give you one more minute. And then we can have a chat about each of our drawings. [DM looks over at JS's drawing and then continues with his own] [Long pause]**

4a:463 DM: [Shows something on his drawing to JS - unclear what - he smiles - DM whispers something to JS - JS picks up the teddy and wiggles the arms as if the teddy is waving to DM - DM smiles - JS then makes the teddy do a forward flip]

4a:464 **TX: JS, are you OK to go first, to share your ideas? [JS nods]**

4a:465 DM: [JS has looked at JR. DM places the teddy back in the middle of the table, then picks teddy up as if teddy is attacking JS and then places teddy back in the middle of the table]

4a:466 **TX: All done?**

DA: Yes.

TX: Good, good. [Said quietly, then in a louder voice TX continues] Right JS, over to you. Let's see your drawing, and if you could talk us through your drawing please.

4a:467 JS: Well, err, -

TX: Hold it up to everybody. [JS does this]

JS: The light rays come out of the torch and go along the dark line [JS may be indicating a line on his drawing? He is obscured in this camera shot as TX has moved] - and then the light rays bounce off the teddy bear and go back up into the eye and you see the teddy bear [see appendices for drawing 4a:467 JS - JS uses a sing song voice at the end of this explanation].

4a:468 **TX: OK.**

DM: [Unclear - appears to be something like 'It is the same as mine' but said so quietly that it is unclear]

TX: OK, go for it.

4a:469 DM: [Showing up the drawing - 4a:46 DM - light rays do not have arrows on in DM's drawing, unlike JS's, and some appear to be bent] Basically there's all the light rays and they're bouncing off the teddy and into my eye.

4a:470 **TX: So lots of light rays. You've drawn lots of light rays. Look at the direction of your light rays. Can you describe those light rays?**

4a:471 DM: Well, most of them go straight.

4a:472 **TX: Most.**

4a:473 DM: Yes. Some [unclear! Ahh!]

4a:474 **TX: OK. OU.**

4a:475 OU: [Lesson beeps sound] There's me. [OU shows his drawing up - see 4a:475 OU in the appendices. The light returning from the teddy appears in the drawing to change direction] There is the torch. These are light rays and the arrows are showing the direction of the light rays. So basically the light comes out of the torch, it hits the teddy and then light reflects back into my eye.

4a:476 **TX: Then back into your eye. Can you tell me ... what err... what is happening to the light coming out from the torch. Describe that pattern that you've drawn.**

4a:477 OU: What, the arrows?

4a:478 **TX: Well, just describe the pattern of the light coming out. And DM put the torch down so we can all listen to the ideas. [DM puts the torch down] Go for it.**

4a:479 OU: Well it is kind of like coming out in all directions. It is kind of like not really controlled. Like loads are hitting the teddy [KL is drawing] so -

4a:480 **TX: Just hitting the teddy?**

4a:481 OU: And like, say there is like a wall behind him, behind the teddy, it would like be hitting that wall as well.

4a:482 **TX: OK. And when it hits that wall.**

4a:483 OU: Again, it bounces back into our eyes. [OU mimes this]

4a:484 **TX: Okeydokey. DA? Let's have a look at yours.**

4a:485 DA: Um. [DA holds up drawing 4a:485 DA. The only ray with an arrow on is the one that hits the teddy and then goes back into DA's eye in the drawing. Other rays are drawn as fairly straight lines. Rulers were not provided] The light from the torch goes like everywhere. Well not everywhere. Yes it goes like ... it just shines [DA mimes this] and then it reflects off the teddy in lots of other directions. And then some of that light goes into our eyes.

4a:486 **TX: Okeydokey. Some of the light. So where does the rest of the reflected light go?**

4a:487 DA: It goes [unclear - said very quietly]

4a:488 **TX: OK. Go for it AJ.**

4a:489 AJ: [AJ shows her picture up 4a:497 AJ. She has not drawn arrows. There does not appear to be a ray of light entering her eye in the drawing. Her explanation suggests says that "I can see the teddy because the light bonces [sic] of [sic] the wall and refelect [sic] to my eye"] Well the light from the torch reflects and bounces off the wall and the teddy. And like bounces around. And then it comes back to my eye [unclear 'like it does the sun'? very quiet]

4a:490 **TX: OK. So go through that again. The light comes from the torch -**

4a:491 AJ: Onto the teddy. Or if there is a wall there onto the wall. And it bounces off the -

4a:492 **TX: So it doesn't just go onto the teddy?**

4a:493 AJ: [Nods]

4a:494 **TX: OK.**

4a:495 AJ: And then it bounces off the wall and the teddy and then into my eye [KL is writing]. ... That makes me see.

4a:496 **TX: OK. ... Thank you for that. Lisa. [TX shakes his head] KL. [Everyone laughs - TX hangs his head in shame]**

4a:497 KL: Um, well pretty much the same as everyone else. [KL has drawn rays with arrows from the torch to the teddy and then coming away from the teddy. The rays going towards her eye do not go all the way to her eye - see 4a:497 KL in the appendices] Light bounces off the teddy. And also, because the teddy is opaque the light doesn't travel through it, it bounces back off it. I suppose some of the light still bounces off if it is transparent. [TX holds the teddy up facing towards KL]

4a:498 **TX: OK. Looking at teddy, which part would most light come off of? [AJ points to the stomach of the teddy using her pencil]**

4a:499 AJ: The belly. [KL points to the same point]

4a:500 **TX: Why do you say that?**

4a:501 AJ and KL: Because it has the largest surface area.

4a:502 **TX: Because it has the largest surface area. Anything else why it might bounce off the belly?**

4a:503 DA: Because that bit [the eyes of the teddy] is darker. Like because if you have a white T-shirt on a sunny day it reflects more of the light and black absorbs the light.

AJ: Absorbs the light.

- DA: So it is more hot.
- 4a:504 AJ: Like if you got a bit of white and black paper and put it directly where the sun is [AJ is miming this] and you held it there the black would like absorb more heat than maybe like the [unclear - AJ's voice trails away and gets very quiet] would take a lot longer.
- 4a:505 **TX: OK. So how would we make this teddy brighter in that darker room then?**
- 4a:506 DA: Paint it in bright colours. [TX leans forward indicating he could not hear what DA has said] Make it white.
- 4a:507 KL: Could you put on a fluorescent jacket? [Several students and TX laugh]
- 4a:508 DA: [Unclear]
TX: Okeydokey? Are you happy with that?
- 4a:509 OU and others: Yes.
- 4a:510 **TX: Anything else you want to say?**
- 4a:511 JS: No.
- 4a:512 **TX: You've all drawn your light. Can you just talk about how you've drawn the light. I'm quite intrigued.**
- 4a:513 JS: I drew arrows to show which way it goes.
- 4a:514 **TX: What kind of lines have you drawn? What kind of sketches have you actually used to show the light.**
- 4a:515 AJ: As light beams.
- 4a:516 **TX: Beams.**
- 4a:517 AJ: Because when there is the sun and and there's like clouds [AJ is miming this] then you see like little beams coming down.
- 4a:518 **TX: You see actual beams of light. KL.**
- 4a:519 KL: It has to travel in straight lines.
- 4a:520 **TX: Why does it have to travel in straight lines? [Students outside the classroom knock on the door. JR speaks with them to explain about the delay. JS, DM, OU all look round]**
- 4a:521 DA: Because light does! [DA laughs]
- 4a:522 **TX: How do you know light travels in straight lines?**
- 4a:523 KL: It can't really like go forwards [KL indicates this with her pencil] and then decide it is going to go there. Because it has got nothing to bounce off.
DA: Nothing to bounce off. [Said simultaneously with KL]
KL: Yes.
- 4a:524 **TX: OK. So you're saying that if we had like a shadow, like this [TX makes a shadow on the desk]. How does that show that light travels in straight lines?**
- 4a:525 DA: Because like the light is travelling from there [DA indicates the window] and then it goes there [she points to her own hand] then into our eyes. And then it then it makes a shadow there [DA indicates underneath her hand] It won't be all the way over here [DA indicates a position far from her hand]. It will be there [underneath] because it travels like [indicating light travelling between her fingers].
- 4a:526 **TX: OK. So you shine the torch on teddy, [pause] so what might be behind teddy?**
- 4a:527 DA: The shadow. I've drawn the shadow.
- 4a:528 **TX: You've drawn the shadow.**
- 4a:529 AJ: I've drawn the shadows [unclear]
KL: I just drew it like -
- 4a:530 **TX: And describe - and explain how that shadow is formed then.**
- 4a:531 AJ: Um, because ...
DM: It depends on the direction which the light is hitting the object. Especially with the sun [DM points out the window]. If you're standing outside -
AJ: Yes, if there was like -
DM: and it is like straight above you [DM mimes this] then there is going to be like not much of a shadow.
- 4a:532 **TX: OK.**

- 4a:533 AJ: If you like had the sun there [AJ is drawing - see 4a:541 AJ] there would be lots of like different - throughout the day there would be different like lengths of shadows. Because it depends on where the sun hits it like there [indicating on her diagram].
- 4a:534 KL: It depends on the source of the light.
- 4a:535 **TX: The source of the light.**
- 4a:536 KL: The direction I mean.
- 4a:537 **TX: OK. Where have you all drawn the torch? ... In relation to the teddy bear. Describe the positions between torch and teddy bear.**
- 4a:538 DA: [Unclear - very quiet] there, the teddy is there. [DA is miming where torch and teddy are].
- 4a:539 **TX: OK. So you've drawn it right [TX mimes torch and teddy in horizontal line] at the same level.**
- 4a:540 DA: Yes.
- 4a:541 **TX: Teddy bear torch. Who has drawn it differently?**
- 4a:542 KL: [Unclear] shines in a straight line.
- 4a:543 **TX: Straight on. OK. Where have you drawn it JS?**
- 4a:544 JS: Basically straight on.
- 4a:545 **TX: You've drawn it straight on. OK. DM?**
- 4a:546 DM: Straight on. Well - kind of. [a joke said quietly - DM smiles]
- 4a:547 AJ: I haven't. I've drawn it like side on.
- 4a:548 **TX: Okeydokey. Thanks for that. About the teddy bear. [TX turns to JR]**
- 4a:549 *JR: Would you mind putting your initials on the drawings please?*
- 4a:550 JS: Just the initials.
- 4a:551 **TX: The initials are fine. We'll sort it out. [TX looks round at JR who gives a round it up sign] So what has been most useful in this discussion? What have you -**
- 4a:552 OU: Fire.
DM: We were looking at non-living and living things seeing if there were different views of people and what they think.
- 4a:553 **TX: Has anybody changed their view [DM puts his hand up] of science as a result of the last hour?**
- 4a:554 DM: I was confused about the fire.
- 4a:555 OU: I wasn't really that sure about the fire, but now I kind of realise it is like got properties of like a living thing and a non-living thing. So it is kind of like a bit of both.
TX: A bit of both.
OU: I wasn't really sure.
- 4a:556 **TX: And when it has properties of both [TX is lifting his hands up alternatively as if massing something] what does that make you think in your head? What do scientists have to do?**
- 4a:557 DM: See things from different points of view. And different ways.
- 4a:558 AJ: And like if - you have to like take into account to the people. So people who think that - like DM thinks it is living and JS think that it is living, but like I don't think it is living. And then you'd have to take all the views into account and think like -
- 4a:559 **TX: Have you enjoyed listening to other people point of view?**
- 4a:560 Everyone: Yes.
- 4a:561 **TX: And when you listen to some of these ideas, how does that make you feel inside? What is going on inside your head when you listen to someone else?**
- 4a:562 AJ: You think 'Well actually that is -'
OU: [Unclear - simultaneous with AJ above] to build up on that idea.
- AJ: Like if like DM was - yea but it could. When he said something about it - something about science I don't know how I'd [unclear] because I knew it happened.
- 4a:563 KL: It makes you think.
TX: It makes you think.

KL: And use reasons. Some people just go, 'Fire isn't alive'. And then you say, 'Why?'
And they say, 'Because it is not.'

DA: It just isn't!

4a:564 **TX:** Do you like that thinking process? Do you like that challenge?

4a:565 DM: Seeing other peoples' views. See what they think.

4a:566 OU: And finding ways to like build onto their views.

4a:567 **TX:** You like that? You like building on their ideas? **OK.** You lot, you've been fantastic for the last hour. You have. I hope you've given Mr Riordan lots of great stuff.

4a:568 *JR: I can't tell you how grateful I am. It has been really fascinating. I hope you've enjoyed it. I certainly have.*

4a:569 **TX:** We're going to have to discuss fire. **[DM and others nod]**

4a:570 JS: That's our next lesson. We'll build on [unclear].

4a:571 **TX:** I think we need to discuss.

[End 4a]

Interview 4b

4b:1 *JR: Thank you very much indeed for doing this. I really appreciate that.*

TX: That's OK.

JR: Can I give you the sort of formal... introduction [JR picks up the questioning route]. So please watch each video clip, and then 'think aloud', by that I mean talk freely about anything that comes to mind about the video. I'm interested in how you might 'solve' these problems. What you'd actually do to help the children when they think like this. Please just report your thinking as accurately as you can in your own words. You don't have to edit, explain or justify your thoughts. We'll leave how you understand the issues raised to the second part of the interview. Everything you say will be anonymous.

There are 16 clips, but we don't have to use them all. Try to do some from each of the three topics. So there is the tea, the living and non-living and the teddy [JR points these out on the laptop screen]

TX: OK.

JR: We'll spend a maximum of 30 minutes on this. I'll keep an eye on the time, so we need to move on just before 12 [JR looks at his watch] - so you don't need to worry about that. After that I'd like to ask you a few questions which will take about another 30 minutes. Please feel free to say when you've had enough or if you need a break. I'll try not to interrupt you while you're watching and responding to the video clips.

Please don't worry if you can't make sense of what the children say in some of these clips. Some of the ideas which came up are very challenging even for trained scientists like ourselves. Since I started exploring children's naïve concepts I've discovered several of my own! Please just say if you'd like to 'unpick' an idea together. I'm aware that you're being asked to do something which is difficult, namely to respond immediately to some very challenging naïve scientific concepts. [TX murmurs assent] In the classroom we often have to respond quickly and it is this thinking that I'd like to explore together.

Is there anything you'd like to check about this before we start?

4b:2 **TX:** [TX's phone buzzes] **I'll just turn my phone off.**

JR: Good point. I'll turn mine off too. [Pause]

4b:3 **TX: OK.**

JR: Many thanks for doing this.

TX: It is OK. You're very welcome.

JR: Is there anything you'd like to check out before we start?

TX: No, that's fine.

JR: *The nuts and bolts [JR shows TX how to control the videos on the laptop] if you click on the link it takes you to the video. There is a little house in the corner when you want to come back to this menu. So please feel free to control this yourself. If you want to pause the video at any point you can press the mouse. And if you press it again it will start from where it is at.*

TX: OK.

JR: *That OK? Thank you. [Pause]*

4b:4 JR: *Normally they play straight away.*

CLIP 1: *headaches [ID 4a:3-97] 4a:93 TW: I used to think that gravity always pulls you down, so I was really confused when like Australia! But it actually pulls you towards the centre of the Earth.*

4a:94 **TX: That's right. Yes.**

4a:95 DA: *I used to think that too. I actually thought that everyone was upside-down when they were at the bottom [DA indicates with her hands what could be the bottom of a globe] I was like - I was saying to my Mum, and I was like - 'Would they get loads of headaches standing on their head?' [DA laughs] ...*

4a:96 **TX: So what actually changed? What actually caused that change to happen? That change in the idea.**

4a:97 DA: *Well, because I think we were in the library or something, and there was a globe. And I said, 'Mum, why on the other side of the world are they upside-down? Why don't they just come to the top so they don't get headaches?' And then Mum said, 'They're not, the gravity goes to the centre.' [TX nods]*

4b:5 **TX: [Pause] I think the key for me in that clip was what changed their thinking.**

That is all I'm really getting from it really. They obviously have come with preconceived ideas. Um. We were talking about those ideas and then what caused them to change - to try and get across that science is a continually changing evolving process. You come up with your ideas and your ideas are valid. Um. So you sometimes you need to um try and work out what that change is. What caused that change - to happen. What experience. It is experiential learning at the end of the day. Um. Which is just as valid as um studying a text book or classroom. You know, it is all part of the experience. ... I think that is all I'm getting from that clip. Is that OK?

JR: *Yes. [TX leans forward to start the next clip]*

4b:6 **TX: I think you've got to challenge the - their current expectations. That was, I mean that was - I think going right back to my PGCE it was the Rosalind Driver work on constructivism where you get the student ideas and then you challenge it, you break the ideas, and then you reform.**

4b:7 **TX: It is quiet isn't it.**

JR: *Sorry.*

CLIP 2: *touching ice [ID 4a:113-127] 4a:113 TX: OK. [TX turns round towards JR] We're going to look at some objects now. Mr Riordan is going to give us two objects. [JR places cup of tea and bowl of ice on the table - students lean in to look]. There is a bowl of ice and cup of hot tea. OK. Have a look at those for a few seconds. Touch them. Smell them. [Several students smile] Get the whole experience. We're not allowed to drink the tea.*

JS: *Oh!*

TX: You can touch the cup, touch the bowl.

TW: *Can we touch the ice?*

TX: Yes, you do whatever you want. OK? Experience the ice and the tea.

[TX pauses the video here for the first time]

[JS and DM start putting cold water on each other] **Right, here is the question you lot. Again, just throw out answers, one at a time that's all.**

4a:114 **TX:** *Tell me what you think is happening to the hot tea, and the ice cube in as much detail as possible. OK? So I want to know what is happening to the ice cubes [TX reaches out and touches the bowl] and to this hot tea [TX touches the tea] in as much detail as possible. One at a time, that is all I'd like you to do. [JS has his hand up] OK? JS, you start off.*

4a:115 **JS:** *Well, the thing that is happening to the ice is the room temperature round it is like twenty degrees Celsius, that is about twenty degrees hotter than ice's like melting point, so that is melting and getting warmer in this temperature until it reaches room temperature. So that is going to melt into a liquid. Whereas the hot tea is going to cool down until it reaches the room temperature because of the colder surroundings. [JS's voice gets very quiet towards the end here]*

4a:116 **TX:** *Because of the - sorry?*

4a:117 **JS:** *Because of the surroundings at room temperature is cooler than the temperature of the tea it is going to cool down. [TX sits up straighter]*

4a:118 **TX:** *OK. Thank you for that one. DA, you had your hand up.*

4a:119 **DA:** *The ice is going to melt because - yes, it is going to melt into a liquid because freezing temperature is zero degrees, and room temperature is going to make it melt. And the tea is cooling down because ... Well it was boiled at a hundred degrees and then it is just cooling down. And it is not going to stay at a hundred degrees throughout. [DA's tone implies this last line is obvious]*

4a:120 **TX:** *Why is it cooling down?*

4a:121 **DA:** *Because of the -
TW?: Gas.*

4a:122 **TX:** *Tell me about the room temperature.*

[TX pauses the video for the second time]

4a:123 **DA:** *It is not as hot is it?*

4a:124 **TX:** *It is not as hot as the -*

4a:125 **DA:** *Tea. [TX sits up] [DM has his hand up]*

4a:126 **TX:** *Tea. [TX is looking at DM] So where is the heat going?*

4a:127 **DM:** *Up. What is happening is the solid ice is now becoming a liquid because it's freezing temperature is now changed to a different temperature. [Tone used is one of explanation] In the room. And it is not at the freezing point and so it will melt into a liquid because of the heat.*

4b:8 **TX:** *I think science is a totally sensory experience. One of the key things I really do enjoy in teaching is the whole stimulus - to get engaged open thinking to start with. I think that is something that is really crucial in getting kids not only engaged and motivated, but to get them thinking about the questions. I think that is really really powerful. You know it is the smell, the taste, the touch - it is the whole experience. I think that is something - We're lucky in science, we have got a wider repertoire of materials to work with. [TX restarts the video]*

4b:9 **TX:** *I think what I'm doing there is DA - I think there is an expectation that students have to kind of add something more. I mean - um - JS started off with quite a coherent answer. Um. And I'm just wondering if there is an expectation that he had to add more to that answer. Um. So really DA - my question there related to, 'OK, what does cooling mean?' It is trying to unpick the concepts behind the kind of key terminology she was talking about. That is where the question was going. [TX moves to restart the video] Oh! [TX has moved onto the next video clip by accident]. Was going. [JR points out the home button] Oh, back to home. Sorry.*

JR: *That will get us back to the clip.*

TX: *Sorry.*

JR: *Please don't worry. Sorry, it is a bit - Sorry about that.*

TX: *It is alright.*

JR: *I think it is that one we're on. Isn't it.*

TX: [Nods]

JR: *Oh, I'm really sorry, I think it is starting us from the start of that clip.*

4b:10 TX: **I think it is the unpicking of that key word from delta [Clip 2 plays from the start again]. To get the understanding of - the cooling.**

JR: *Sorry, it won't [jump ahead]*

TX: **That's alright. [Pause] This is hard! [JR looks at TX and nods]**

JR: *Thank you for doing it. I realise this is very challenging.*

4b:11 TX: **[As the clip continues] Part of me just wants to watch the clip and not even - verbalise it. I'm just trying to try and process it.**

4b:12 TX: **[TX pauses the video again at 4a:115] So in many ways what JS has got there is an idea of equilibrium. He has got the idea [TX mimes weighing something with his hands] that it is going to reach some kind of - the ambient equilibrium temperature of the room. [TX restarts the video]**

4b:13 TX: **[4a:119 is playing and TX speaks over the video without pausing it] Room temperature is going to cause it to melt. ... As opposed to the heat energy. ... [TX listens through to the end of Clip 2]**

4b:14 TX: **[Pause] Is that the end of the clip?**

JR: *Yes.*

TX: **[Pause] I just want to listen to more. [TX and JR laugh] I can't - I haven't - ... I think there's - there's not - they're interchanging temperature and heat. Which is a common misconception - all the way up to Years 10 and 11. Um. ... I'm really proud of JS that he has got an idea of the equilibrium. Because that is a really challenging concept - to get the idea of. Um. I haven't really got anything much else to say. Is that OK?**

JR: *Yes. Absolutely fine. There may be some clips where there aren't things to say at all and please don't worry about that.*

4b:15 TX: **What I'm absolutely - really pleased was the - is the engagement of their body language and the way they're kind of really focused. You can really see the thinking going on in all of them. Um. Which is great. [TX plays the next clip]**

4b:16 CLIP 3: *heat rises [ID 4a:136-141] 4a:136 TX: **Where is the heat going from the tea? [TX indicates the cup]***

4a:137 TW: *Up.*

4a:138 TX: **Why is it going up?**

4a:139 TW: *Um. Because heat rises.*

4a:140 TX: **Heat rises. [DM and JS play with the ice] And where is the heat going in the ice?**

4a:141 TW: *Um. I don't know. [Laughs]*

4b:17 TX: **So what I'm doing there [TX goes to pause the video]**

JR: *That's it.*

TX: **Oh. Was that it. That is just again just a comparison really. Absolutely - Was it KL or DA that came out with it? Or was it AJ actually? In the middle. One of them said, 'Heat rises' They made a fact. So OK, well what I'm doing there is, 'OK, so let's have a contrast.' What's happening in the cold situation? If you're going to give me a fact there, take that a step further. Apply that fact now to what is going to happen in the cold. So it is trying to develop their thinking. Obviously it is - in terms of Bloom's - that answer is either remembered or shows understanding. So it is really to try and develop that understanding and apply it then to the cold situation really. I think that is what I was doing there.**

4b:18 CLIP 4: *air in [ID 4a:146] 4a:146 AJ: **Um. Because it is surrounded - if there was something covering it [AJ indicates some sort of lid with her hand] maybe - I don't know, because this [the water in the bowl] is quite - this isn't like freezing. And that would cool***

it down. And the air in the surroundings is warmer so air goes everywhere, so it will sort of go in and like air is going into the tea which is like warm and the heat is coming out because it has nowhere to go.

- 4b:19 **TX: It is interesting watching other kids while AJ was going on with that answer. [JR and TX smile] They weren't really concentrating on her answer. Can I watch it again?**
JR: *Please. Yes.*
TX: Back to home?
JR: *I think if you right click on it it gives you some options. ... Sorry.*
TX: Shall I just go back to the home?
JR: *Yes.*
TX: I have to click that. ...
JR: *You might need to click.*
TX: OK. [Clip 4 plays again from the start - TX pauses the video]
- 4b:20 **TX: It is interesting. Oh! [the video carries on playing - JR pauses it] It is interesting that AJ said, "I don't know." And then went on to give - It is like - Do students when they say that, "I don't know." It is their kind of precursor to free thought. ... I don't know. But she didn't stop did she? So she felt confident enough to start exploring her thoughts. Which is really encouraging. But that kind of, "I don't know." is like a kind of - lays the card down to saying, "OK, well here's my ideas, here's my hypothesis, here's my understanding ... of the explanation I can give. But - But I don't know." Which is nice. For me that's - You don't listen to things like that in students. The, "I don't know.", but they carry on.**
- 4b:21 **TX: [TX plays clip 5 which has the title 'hot and cold heat'] Hot and cold heat! [TX and JR laugh]**
JR: *I'm sorry. I forgot to set [unclear]*
- 4b:22 **CLIP 5: hot and cold heat [ID 4a:153-156] 4a:153 TX: So where do you think the heat -**
TX: [As the video continues to play] Too many questions, I'm throwing too many questions at them. [TX shakes his head].
TX: What is happening to the heat in terms of its movement? Is there a pattern to where heat goes?
- 4a:154 **JS: Well, hot heat tends to**
[TX pauses the video at this point]
go up and cold like heat tends to go down.
- 4a:155 **TX: Okeydokey. You've got hot heat and cold heat. [DM and others smile and then laugh] OK. No. What is the difference between hot heat and cold heat?**
- 4a:156 **JS: Well like hot stuff, the steam will tend to go up. But if you get like an ice lolly, the steamy stuff that comes off it goes down.**
- 4b:23 **TX: I'm being - I'm being verbose with my question there. I threw too many questions. [The video continues to play - JR stops it]**
JR: *Sorry. I think it has gone onto the next one.*
TX: I've seen that in teachers - I used to watch that in teachers all the time [TX tilts his head backwards and closes his eyes] where they throw - bla bla bla bla [TX mimes this] - three four questions out and then the students don't ... they can't - they don't know what question they're actually answering. I've seen that so many times in lesson observations. [TX sighs and shakes his head] [TX plays the clip 5 again - he pauses it for a second time just after the students laugh in 4a:155]
- 4b:24 **TX: Now you see it is interesting. There - Sorry [the video has jumped to the next one] Am I pressing it too hard?**
JR: *I'm not sure. Please don't worry.*

TX: The ... They - There is a contradiction there isn't there. The hot and cold heat. [TX nods] ... Was I wrong to use that? I don't know. I was just repeating what they were saying to kind of elaborate their thinking on it. And you could see that they were - it was already challenging them by the humour, to kind of diffuse that contradiction. You don't get cold heat. [TX goes to play the clip again] ... Can I watch it again.

JR: *Please [unclear]*

TX: [As 4a:155 plays - TX speaks while the clip continues to play] Just trying to unpick what - hot stuff!

4b:25 **TX:** So again, they're talking about their experiences of - they're bringing their own experiences of - of - of hot and cold into the discussion. ... Is JS - In the next clip is JS carrying on with that?

JR: *I think that is a little snippet -*

TX: Is that it? In terms of what I was doing there it was really just kind of putting back the hot and cold heat thing to them to think about. What were they actually meaning by those terms? ... Um. I'm keen to see what did JS say? [TX and JR laugh] OK. [TX goes to play the next clip] Now this is where I think was the key part - where this key word kind of triggered their thinking.

4b:26 *CLIP 6: heat is particles [ID 4a:166-171] 4a:166 TX: And what happens to the heat when it goes up? What is happening to it?*

4a:167 *DM: Separating into little particles isn't it?*

4a:168 **TX:** So heat is particles?

4a:169 *DM: Yes.*

4a:170 **TX:** OK. So what does heat do to particles?

4a:171 *DM: [Looking to the side and perhaps thinking about this?]*

[TX starts speaking at this point - see 4b:28]

Heat separates them? Then they travel up. And then they'll be like really small little particles going up into the air separating. Whereas when it is colder they are closer together.

4b:27 **TX:** So what I'm doing there ... is I'm - 'heat is particles' - Is that what DM said?

JR: *I think so.*

4b:28 **TX:** Yes. ... So I'm really now - I should have challenged him more on that. Because I then kind of corrected him by the question I said, "What is the heat doing to the particles?". So I was already putting my - kind of my knowledge of particle theory back - it is a leading question for DM. ... Rather than let him explore. ... I wanted the correct answer. I wanted the correct answer coming out [TX laughs] too quickly. And I was preventing him - well let's see if I was preventing him [TX moves to replay clip 6] Oh! I'm sorry JR I'm feckless with this -

JR: *There's different bits of the screen for clicking on and it makes it tricky.*

TX: OK. [TX puts his hands over his mouth for a moment]

4b:29 **TX:** So DM's thinking is pretty sound there again. He has locked onto the particle theory and - he has talked about the space between the particles. I think it was a leading question though. I led it. [TX moves to play a clip] Heat is particles - that is what DM said. "What do you mean by that?" I should have said. I should have said, "What do you mean by that?" Rather than leading him into the question. We do that as science teachers don't we [TX says this quietly and shakes his head slightly. JR nods agreement]. We lead the thinking. Rosalind Driver would turn in her grave. [TX and JR smile] [TX plays clip 7]

4b:30 *CLIP 7: magnet [ID 4a:174-175] 4a:174 JS: This might sound silly [other students smile], but it is sort of like the higher up in the Earth you go it sort of gets colder and the lower down you go it is warmer. It is like the cold air is going down to the bottom to get warmer and the hot air is going up to cool down. I just thought of that.*

- 4a:175 DM: *Because of the magnet in the centre of the Earth. [TX smiles]*
- 4b:31 JR: *I think he says, "Because of the magnet in the centre of the Earth."*
- 4b:32 TX: **[Pause] Mm. I have to watch that clip again. [TX replays clip 7] [During 4a:174 TX says:] So he [JS] is talking about convection. ... So I think [TX smiles] what DM is doing there - he has got some knowledge about the centre of the Earth, and he is just throwing it out there. I'm not - I don't think he is actually linking it in. I don't think there any linkage there to JS's understanding of convection currents. ... Don't know. I'll have to watch the next - Is there more on -?**
 JR: *It is really tricky isn't it that it is just little bits from the whole thing.*
 TX: **I know!**
 JR: *One of the options would have been to show you the lot,*
 TX: **Yes, yes.**
 JR: *but of course - can you imagine! It would mean that we're here for about twelve hours just on one video. So I've selected weird little bits like this, but I realise it is quite strange, and it means you can't see the context.*
- 4b:33 TX: **Something that - even that now we're six clips in, I'm already thinking about the kind of questions that really should have been asked to keep it more open. And how much leading I think has been done. [TX plays clip 8] OK.**
 JR: *I should say - a lot of these you dealt with I felt really really well. And of course I'm not showing you the bits where things were all fine - I'm showing you deliberately the bits where I need your help with interpretation.*
 TX: **Yes.**
- 4b:34 CLIP 8: thumb [ID 4a: 255-273] 4a:255TX: **Just getting those organised. [JR removes a the last plastic bag from the table] Right let's start with - I want to start with 'tree'. [TX places his own card above his own mats in the middle] Where have we got tree? So if you think it's - if you've put it in living do thumbs up [all students immediately do thumbs up] and if you think it is non-living thumbs down. So then we can quickly see all what we think. Yes? Is that alright? Living [TX holds his thumb up] or - [TX holds his thumb down]**
- 4a:256 DM: *Non-living.*
 [TX pauses the clip at this point]
- 4b:4a:257 TX: **Are you ready? [said in a loud voice] So tree? OK, we all agree that tree is living. Why is that KL?**
- 4a:258 KL: *Because like MRS GREN. [KL laughs] That is what it makes me think of.*
- 4a:259 TX: **What does MRS GREN stand for?**
- 4a:260 KL: *Um, Movement, Respiration, Sensitivity, Growth, Reproduction*
 JS: *Reproduction [simultaneously] Excretion*
 KL: *Excretion [laughs], Nutrition.*
- 4a:261 TX: **But does a tree move? Does it pick its roots up and move? [TX is smiling and looking round - clearly challenging the group]**
- 4a:262 KL: *No.*
- 4a:263 JS: *It does photosynthesis. And the plants like breathe - like the leaves in it.*
- 4a:264 DM: *It is living. ... And it grows.*
- 4a:265 JS: *It breathes in carbon dioxide and breaths out oxygen.*
- 4a:266 TX: **OK. So we're already starting thinking about what makes something living. You're saying [TX points at KL] you're saying MRS GREN.**
- 4a:267 KL: *Yes.*
- 4a:268 TX: **So it has got to be MRS GREN. But is the tree moving? [The tone of the question has changed - it now has a slightly more serious tone] [Long pause]**
- 4a:269 Several students talk at once: *[unclear]*
 KL: *It is growing.*

- 4a:270 **TX:** Yes [turning to KL]. OK. So talk about it then. So it is growing. So it is this big one year [miming a small sapling]
- 4a:271 **JS:** And the next year it is that big [miming a huge tree]
- 4a:272 **TX:** OK. So has it moved?
- 4a:273 **AJ:** Yes.
- 4b:35 **TX:** The ... [the clip starts to replay, JR pauses it] - I think one of the things I'm really keen is that it is fully inclusive the whole process. So whole class assessment has been a big thing in the last five six years I've been looking at [TX looks at JR who nods]. In terms of getting whole class feedback to inform learning. And - So the thumb up [TX mimes this], the hands, the rating scales are all kind of really quick tools that I use constantly to gain very quick feedback. And then you then challenge and regroup accordingly depending on what feedback you get from the students. So that is why I did the feedback. Thumbs up [TX mimes this] thumbs down. It then went to three fingers, because you need some kind of gradation on the strength of their - because what came out very quickly from doing that first exercise was their different opinions. And how their opinions were changing - from the conversations that were going on. So that is why we then changed it to the three fingers. So there was a gradation of how confident they felt they could categorise the living or non-living. [TX replays the clip]
- 4b:36 **TX:** I'm going to watch that again. Sorry.
JR: *This is not a great set up - sorry about this.*
TX: No! I think it is great how you link the visual with the kinaesthetic. [Clip 8 plays from where it was paused, i.e. 4a:257] [JR checks his watch - then checks the camera behind him]
- 4b:37 [Someone knocks on the house door and then comes in. TX and JR smile. There is a short conversation between this visitor and TX which won't be included in this transcript before the interview resumes].
- 4b:38 **TX:** I'm going to have to go back. [TX replays clip 8 from the beginning] Sorry about that.
JR: *No problem.*
 [Clip 8 starts again at 4a:257 and TX pauses the video almost immediately]
- 4b:39 **TX:** I think I started with tree because I wanted one that was going to challenge them straight away. Because - um - the tree it constitutes lots of kind of contradictions. I remember doing a piece of work at university where we looked at a small tree and a big tree and what happens to it. Where has that mass, that increasing mass come from? So tree creates lots of thinking - lots of open ended thinking in kids. And that is why I picked tree first. [TX restarts clip 8] Oh!
JR: *I think it should be OK. There is definitely something weird happening on my PowerPoint. I'm sorry about this.*
TX: Click again?
JR: *I think it should play.*
TX: OK. [Clip 8 plays again from 4a:255] Poor DM with his hand up! [TX smiles] ... [TX speaks over the video when it arrives at 4a:261]
- 4b:40 **TX:** So it is just challenging our interpretations of movement. ... [when the video gets to 4a:268 TX speaks again]
- 4b:41 **TX:** So all I'm doing there is just challenging - they've got their - they've got that kind of rubric of MRS GREN - is the classification of living. It is what is on the national curriculum. So really it is just challenging the criteria on each one of those components. And I think movement for plants is a classic - because students' interpretation of movement in animals is much different to interpretation in plants. [TX restarts the clip] And it is the start of MRS GREN. [TX and JR smile]

- 4b:42 **TX: I said yes. So I was kind of agreeing with them. Maybe I should have kept it - not given them the ans - you know not acknowledged their answer. Don't know. ... The movement is a really challenging one - for them, because it makes them think deeper about the categories of MRS GREN. Which was later explored in the fire, wasn't it. [TX goes to play the next clip] Seed. ... Oh.**
JR: It is OK, I think it should - Oh sorry, that was me. So its seed we're doing isn't it.
- 4b:43 *CLIP 9: Seed [ID 4a:287-299] 4a:287* **TX: OK. Seed? Let's have seed then. Thumbs up, thumbs down. OK, we're all going for living on that one. OK, DA, why seeds?**
 4a:288 *DA: Because - because it is just like a tree but it is just like... Yes, it is just like the beginning of the tree when it is packed with all the nutrition. It is just like oh.*
 4a:289 **TX: OK. But what about these seeds that are like thousands and thousands of years old that haven't germinated. Is it still alive? These seeds - we find them ...**
[TX starts speaking at this point. He pauses the clip after a moment]
in glaciers - they are thousands upon thousands of years old. Is the seed still alive?
 4a:290 *JS: Well these ones are packeted, and they should be alive. [Everyone laughs]*
 4a:291 **TX: Yes, yes, we saw a packet of seeds. How long does a packet of seeds last for though [question directed at JS]?**
 4a:292 *JS: It wouldn't last long because it is all dark in the packet.*
DM: No light will get to it.
 4a:293 **TX: And they need light to -**
 4a:294 *JS: Live [unclear]*
 4a:295 **TX: Start growing. So is it alive then as a seed?**
 4a:296 *JS: Well seeds do normally start in the ground. They grow roots and then the big shoot comes up.*
 4a:297 **TX: But a seed that is not growing? [TX slows the pace with which he says 'not growing'] Because you [TX points towards KL] were saying that growth is part of MRS GREN. If a seed is not growing and it is in a packet, is it still alive?**
 4a:298 *DA: But it is coming out of the packet! [DA laughs as she says this]*
 4a:299 *JS: [Unclear as DM says something, also unclear, at the same time] and then they grow up. That must mean they are alive in a way.*
- 4b:44 **TX: I just wanted to kind of explore really - um. She has got the idea of the beginning of a seed. I wanted her to explore, "Is it still alive though it's dormant for an extended period of time?" [TX looks at JR, JR nods] By giving that - throwing that example in really just to get her to challenge her thinking. I think that is what I was doing there. Just to challenge ... her answer. But with a practical example for her to apply it to. [TX plays the video from where it was paused]. [TX laughs at 4a:290]**
- 4b:45 **TX: [While listening to 4a:290] I'm going to carry on with this time thing. [Clip 9 continues to play]**
- 4b:46 **TX: [While listening to 4a:297] Again, just challenging back to MRS GREN. [Clip 9 continues to play]**
- 4b:47 **TX: Yes, it was again just challenging back to MRS GREN ... It is such an easy one to lock onto, that you just want to keep challenging their thinking on it. [TX plays the next clip] I'm pleased I did that. I'm pleased I challenged that.**
JR: Can I just point out the time. We've got about five minutes on this one.
TX: This is a really key - I think this is a really interesting one.
- 4b:48 *CLIP 10: fire [ID 4a:310-355] 4a:310* **TX: What about the flame on the candle? Let's go for fire. Who's got fire as alive or dead - non-living. [Students rather hesitantly put their thumbs down indicating non-living - they look at each other's thumbs as they do this]**
TX: [While Clip 10 continues to play] This is what made me change to three fingers. So fire is non-living. Why is that? AJ?

4a:311 AJ: Because you use matches or sticks to start a fire. Something that is living starts naturally.

4a:312 TX: **Starts naturally. But lightning hitting some dry twigs starting a fire is quite natural.**
 [TX pauses the video here for the first time]

4b:4a:313 JS: It sort of feeds a bit. Because like when there is a piece of wood next to it it will spread onto that and then it will burn it all up like it is eating it. Then it will spread to something else.

4a:314 TX: **So you're saying that it is like MRS GREN then.**

4a:315 JS: Yes. It sort of gets to nutrition from pieces of wood and stuff for fire.

4a:316 TX: **Okeydokey. So let's go back to MRS GREN then. So does a fire - a flame move?**

4a:317 JS: They spread.
 DM: Yes.

4a:318 TX: **They can spread. What was the 'R'?**

4a:319 KL and other students: Respiration.

4a:320 TX: **That is taking in oxygen. Does it take in oxygen?**

4a:321 OU and other students: Yes.
 JS: Yes, to burn.

4a:322 TX: **To burn. OK. What about 'S'?**

4a:323 KL: Sensitivity.

4a:324 TX: **Is it sensitive?**

4a:325 JS: If you put water on it it goes out.

4a:326 TX: **OK.**

4a:327 DA: ... It is not like it can feel anything.
 TX: [TX laughs as he hears this]

4a:328 TX: **Yes. Does it feel anything? If you went up to a fire and said a bad word to it would it be upset? [Everyone laughs] Would it be upset?**
 TX: [TX laughs and then pauses the clip for the second time]

4a:329 OU and others: No.

4a:330 TX: **Does it reproduce?**

4a:331 Several students: No.

4a:332 TX: **Does it have babies? [Several students laugh] Does it make more of it?**

4a:333 OU: Yes.
 DA: It spreads.

4a:334 TX: **So it spreads. [the tone indicates some surprise] So is that like reproduce?**

4a:335 JS: It becomes like one really big fire.

4a:336 DM: It is a bit like growing.

4a:337 TX: **So that is like growing. Or -**

4a:338 DM: Or -

4a:339 TX: **Spreading.**

4a:340 JS: And then you sort of kill it with water.

4a:341 TX: **OK. What about -**

4a:342 AJ: If like - if like it does go out though if something hits it like wind or -

4a:343 TX: **So it is sensitive? [TX smiles]**

4a:344 AJ: Yes.
 JS: Wind blows and it goes bluuuhhh [JS is miming a fire being blown by the wind]

4a:345 DM: It won't get upset though.

4a:346 TX: **OK. And what is the last one of MRS GREN. 'N'. Nutrition, feeding.**

4a:347 JS: In a way it could be sensitive to a wind. Because if you like blow carbon dioxide - you know our breath on it, it sort of like goes over it and it gets a bit bigger. Like it is getting annoyed. [DM laughs]

4a:348 AJ: But when it is your birthday you like - [AJ mimes blowing out birthday candles on a cake]

4a:349 JS: *But then they're tiny little candles. If there is one like that [miming a big fire] and you blow it it will go shhhh [indicating a fire getting bigger].*

4a:350 TX: **So has your opinion of fire changed? Are you all still happy that it is non-living?**

4a:351 OU: *I think it is kind of both.*

4a:352 TX: **A bit of both.**

4a:353 JS: *Yes, you could put it like that [JS puts his fire card mid-way between the living and the non-living mats - DA does the same].*

4a:354 TX: **So this one is worth re-looking at. If we're thinking about what living means and about what non-living means do you think we really need to look at this one in a bit more detail?**

4a:355 DM and others: *Yes.*

4b:49 TX: **So again, all I'm doing there is by putting in um ... a ... statement that ... doesn't contradict, but just gets them to promote their thinking into a more practical approach. Just a different way of thinking [TX mimes redirecting thought with his hands]. To challenge their thinking, that is all I'm doing by giving a practical example of the lightening. [TX plays clip 10 from where it was paused]**

4b:50 TX: **So again, what I'm doing there is I'm challenged - I'm challenging what they mean by feeling [TX smiles]. What sensitivity actually means. [TX goes to restart the clip - the clip has jumped to the next clip and JR has put the laptop back to the menu] Was that the end of the clip?**

JR: *Pretty close yes.*

4b:51 TX: **Interesting that DA went very quiet at that point - after that. [TX goes to play the video]**

JR: *Sorry.*

TX: **If I click on the actual title?**

JR: *I think it is clicking on the video, and there is a difference where it is on the screen or something. I think it might be that. I'll need to check this. I'm sorry about this.*

TX: **It's OK.**

4b:52 CLIP 11: *three fingers [ID 4a:380-390] 4a:380 TX: OK. Let's go for a different way than our thumbs up and down [TX puts his thumb up then down]. Because I want more information from you. If you're really confident that it is dead, put three fingers down. If you're really confident that it is alive put three fingers up [several students repeat the word 'up']. So if you're not sure that it is alive then you could do two or one [TX mimes this using index and middle and then middle finger with the back of his hand towards the students - several students smile at this]. And likewise two or one [TX mimes the fingers pointing downwards].*

TX: **[As the clip continues to play] Just reiterating the instructions. That is all I'm doing there.**

So if you're really confident that it is definitely non-living do three down. And if you're really confident that it is living do three up. OK. So now I get more information about what you think. [TX looks at his cards]. Let's go for this one, embryo. Are you all happy what embryo is?

4a:381 DM: *Yes.*

4a:382 TX: **You've all given me three up. So you're all very confident that that is alive. Why is that? [TX glances towards JS]**

4a:383 JS: *Because like it is sort of like the sort of thing you get in a dinosaur egg or a pregnant woman kind of thing.*

TX: *[TX smiles] Again, that is his experience. [TX pauses the clip here]*

It is like the start of a baby or a dinosaur egg. It like comes out of that tiny little thing and then it grows and grows until it like -

4a:384 TX: **So we're going back to this idea of MRS GREN. How many MRS GRENS do you think?**

- [TX pauses the clip for a second time here]
 4a:385 JS: *Well it doesn't really excrete at that stage. [DA comes in at this point - see below] It gets its nutrition from its mother.*
- 4a:386 DA: *But I don't think -*
- 4a:387 OU: *[Holding up two fingers - he was holding three up before] I think it is two. Well it is not properly alive yet really because it is like -*
- 4a:388 AJ: *And if it is like in an egg -*
 OU: *Yes*
 AJ: *- it can't move, it can't eat. As for when you're pregnant -*
- 4a:389 DM: *It could move [DM mimes an embryo wiggling inside an egg - JS appears to be agreeing with DM].*
- 4a:390 TX: **How will it grow?**
- 4b:53 TX: **That is just him [JS] bringing his experience of where he's met that embryo into - into the discussion. You've got such a wide variety there - from the embryo of the dinosaur right up to - he's obviously seen something in sex education. Well we did reproduction earlier on, so he has seen those kind of - [TX restarts clip 11 from where it was paused] Those clips.**
- 4b:54 TX: **[Having just heard 4a:384 TX pauses the clip and continues] Possibly too leading there with my question. I wanted to bring back MRS GREN, because that seemed to be the big classification tool that the students were using in their mind - their thought process. So again, I suppose I brought it in to bring it back to that classification system - and use it as a kind of challenging tool really, to get them to - put their thinking against. [TX restarts the clip - the clip jumps onto the next one again - TX goes back to the menu] Was it 'three fingers'?**
 JR: *Yes. [Clip 11 plays from the start again]*
- 4b:55 TX: **[While listening to 4a:385 TX laughs] [While listening to 4a:387 TX smiles and then says:] Oh OU!**
- 4b:56 TX: **[Clip 11 ends] I think my question there was, "How would it grow?" So getting the idea from the earlier clip about growth being a part of movement, which they came to the conclusion in the tree - was trying to - that question was just related to. "OK, well how would it grow." [This is said quite quickly] Just trying to get that challenge about the movement thing as well, because it is moving by growing. ... It was interesting how OU came up with that statement. [TX goes to play the next clip] Embryo, part two. Do I click on there?**
 JR: *It should play. [Clip 12 plays]*
- 4b:57 CLIP 12: *Embryo [ID 4a:413-420] 4a:413 TX: Are we going to leave embryo where it is [on the living mat]?*
- 4a:414 *Several students: Yes.*
- 4a:415 TX: **Are you confident? Let me see your three fingers. [OU waits and looks at DM's fingers before he puts his own up and then puts three fingers up] They're all pointing up, so we're saying it is living. ... Are you [AJ] sure?**
- 4a:416 AJ: *I'm not sure. Because I don't think it is like alive yea. Because - it looks so young. And it doesn't really look like -*
- 4a:417 DM: *So you're saying that a baby looks quite young - [DM smiles as he says this]*
- 4a:418 AJ: *No. It isn't. A baby is like an egg when it starts off, if it's an egg it is not exactly living yea. [Tone is quite strong here] Because it hasn't started -*
- 4a:419 JS: *Well it has a beating heart.*
- 4a:420 DM: *Yes. [DM and JS laugh]*
- 4b:58 TX: **I think what AJ has got there is her thought that, "Is it a baby, is it alive?" Because it is still at an embryo stage. I know erm - students are aware - when does life start? They do that in RE - in Year 7. So her concept of living - "It is not alive**

yet. Is it a viable baby? Is it a viable living organism or is it just a ball of cells?" So her conflict there is the idea that the embryo is a ball of cells and each of those cells are alive. I think she has got the idea that the cells are alive, but she is not linking it to 'alive' in the definition of it being a ... foetus, or even a baby [TX mimes holding a baby with his hands] that she can recognise - potentially. [TX goes to play the next clip] **Is there any more on this?**

JR: *I think there might be... That might well be the end.*

4b:59 **TX: Are we alright for time?**

JR: *We're fine if you're OK.*

TX: Yes, yes, yes.

JR: *I can always cut the other [JR mimes shortening the second interview]*

4b:60 **CLIP 13: fire fight [ID 4a:432-447] 4a:432 TX: Okeydokey. Let's relook at fire.**

Give me your gradings on fire you lot?

TX: It was really powerful this bit.

Is it alive, or is it non-living? [DM puts one finger up and then changes to three fingers. OU puts one and then increases to two as he looks at other students. DA and AJ have one finger up. Unclear JS and KL from this angle (see other video camera recording)] OK. Has it changed [TX looks at JS then at the others]? Has your opinion about fire changed?

4a:433 **DM: Yes. Because you get used to the other side of things kind of. Because you may just think about one little thing about it.**

JS: [Unclear - simultaneous with DM - but some sort of joke as OU and DA laugh]

DM: But it is not like a human living - people could be thinking like that. It is not like a human or an animal, so it is not living. But actually it could be living because it moves, [DM counts these off with his fingers] -

TX: Because of the criteria.

4a:434 AJ: Yes, it [fire?] only moves by the wind.

4a:435 **DM: No, it moves by spreading as well.**

4a:436 *Several students speak simultaneously: [unclear - DM and JS seem to be joking about something]*

4a:437 **TX: Has your - give me your fingers [TX mimes this] in terms of what you thought fire was at the start then, and tell me your fingers now afterwards [TX mimes using his other hand to show this]. On your left hand give me your fingers what you were whether you thought it was alive or non-living. [Everyone has fingers downwards - DA has two fingers down, KL one, OU nothing yet then puts two fingers down. AJ has two fingers down. DM has three fingers down]. At the start. And then with your right hand give me your rating after the discussion. [OU: left hand one finger up and right no fingers, fingers down, DA has left two fingers down right three fingers down, DM has left unclear and right one finger up, AJ two fingers down both hands, JS three fingers down right and left unclear, KL has two fingers down right hand and left three down].**

TX: Shall we pause and just have a look at that. [TX pauses here]

So you've all changed. AJ you haven't changed.

4a:438 *AJ: I haven't.*

4a:439 **TX: Why haven't you changed?**

4a:440 *AJ: Because it is not living. Because ... it spreads, but that is by adding more wood. If it didn't have anything to spread to - [DM interrupts here]*

4a:441 *DM: It spreads like I was adding more food.*

TX: [TX smiles] So DM is challenging.

4a:442 TX: ... OK. DM -

4a:443 *AJ: But we don't spread and grow. But you don't grow by putting out a [unclear - DM and JS joking about something - unclear what] It will grow constantly.*

4a:444 *JS: [Mimes an arrow shooting]*

4a:445 *AJ: You don't grow like straight away once you've eaten.*

- 4a:446 DM: No but -
 JS: It takes a while.
- 4a:447 DM: You're virtually always growing though.
- 4b:61 **TX: So KL doesn't look like she has changed at all.**
 JR: *We might be getting AJ's hand there.*
TX: Oh, is that AJ's hand?
 JR: *It is tricky to see all the hands. We could get that from the other - camera angle.*
[Pause]
TX: OU is going from - he was 2 confident at the start with his left hand -
 JR: *To none?*
TX: Is that none!
 JR: *It looks as if he is less confident.*
TX: Yes, so he is [unclear] less confident. I can't see DM's other hand. [TX restarts clip 13] I wish I could remember.
- 4b:62 **TX: I think I just stood back at that point and just let the discussion go because it seemed to be self-perpetuating. I didn't think I needed any input. In there. [TX starts clip 14] Most straight. [TX reads this which is the title of clip 14]**
- 4b:63 *CLIP 14: most straight [ID 4a:469-473] 4a:469 DM: [Showing up the drawing - 4a:46 DM - light rays do not have arrows on in DM's drawing, unlike JS's, and some appear to be bent] Basically there's all the light rays and they're bouncing off the teddy and into my eye.*
- 4a:470 **TX: So lots of light rays. You've drawn lots of light rays. Look at the direction of your light rays. Can you describe those light rays?**
- 4a:471 DM: *Well, most of them go straight.*
- 4a:472 **TX: Most.**
- 4a:473 DM: *Yes. Some [unclear! Ahh!]*
- 4b:64 **TX: I'll have to play that again. [TX plays clip 14 again - when he gets to 4a:470 he says over the video] I just wanted to elaborate the description really - for that question. [The clip stops] ... I said 'most' ... to kind of prompt him [DM] into thinking to try and expand that, but I don't think he did. ... [TX goes to play the next clip - but then says:] I want to know now where did the rest go if most of them were straight [TX and JR laugh]. Some are curvy? [TX plays clip 15]**
- 4b:65 *CLIP 15: light beams [ID 4a:512-523] 4a:512 TX: You've all drawn your light. Can you just talk about how you've drawn the light. I'm quite intrigued.*
- 4a:513 JS: *I drew arrows to show which way it goes.*
- 4a:514 **TX: What kind of lines have you drawn? What kind of sketches have you actually used to show the light.**
- 4a:515 AJ: *As light beams.*
- 4a:516 **TX: Beams.**
- 4a:517 AJ: *Because when there is the sun and and there's like clouds [AJ is miming this] then you see like little beams coming down.*
- 4a:518 **TX: You see actual beams of light. KL.**
- 4a:519 KL: *It has to travel in straight lines.*
- 4a:520 **TX: Why does it have to travel in straight lines? [Students outside the classroom knock on the door. JR speaks with them to explain about the delay. JS, DM, OU all look round]**
- 4a:521 DA: *Because light does! [DA laughs]*
- 4a:522 **TX: How do you know light travels in straight lines?**
- 4a:523 KL: *It can't really like go forwards [KL indicates this with her pencil] and then decide it is going to go there. Because it has got nothing to bounce off.*

- 4b:66 **TX: Again, just trying to pull out where KL's thinking was. [TX plays clip 16]**
- 4b:67 *CLIP 16: a bit of both [ID 4a:555-558] 4a:555 OU: I wasn't really that sure about the fire, but now I kind of realise it is like got properties of like a living thing and a non-living thing. So it is kind of like a bit of both.*
- TX: A bit of both.**
- OU: I wasn't really sure.*
- 4a:556 **TX: And when it has properties of both [TX is lifting his hands up alternatively as if massing something] what does that make you think in your head? What do scientists have to do?**
- 4a:557 *DM: See things from different points of view. And different ways.*
- 4a:558 *AJ: And like if - you have to like take into account to the people. So people who think that - like DM thinks it is living and JS think that it is living, but like I don't think it is living. And then you'd have to take all the views into account and think like -*
- 4b:68 **TX: AJ is on the right track there [TX smiles]. You know she's been very kind of analytical about her answer there. I think she just couldn't put it into words. But she was on the - you know - it was a really nice way that she was exploring that. About science. I haven't really got much else to say about it really.**
- 4b:69 *JR: Fantastic. [Pause]*
- 4b:70 **TX: That was the summing up part at the end wasn't it. [JR nods] About the impact of science. [Pause] I haven't really - ...**
- 4b:71 *JR: Thank you very much for doing that. I realise it is a real challenge isn't it. Especially when you can't see the context.*
- 4b:72 **TX: Yes. Because there's some of the bits I'd have - it would have been really nice to see a bit further on to see where it went. But very proud of them. I'm really proud of them.**
- 4b:73 *JR: Before we go onto the next sort of question interview, would you like a break at that point? [Pause here while TX and JR have a break]*
- [End 4b]**

Interview 4c

- 4c:1 **TX: I'm just trying to - I'm just reflecting so much. So much is going through my head at the moment. I think the key thing I got out of this is how you can put a leading question and how it can really - it really kind of guides their learning [TX mimes this with his hands] but is it the most appropriate time to put a leading question in? Um. I think challenging them with examples I think has come out from looking at my practice there. Challenging with practical examples that they could relate to. Which would challenge their thinking. Um. [Pause] And the rating scale. [TX nods]**
- JR: Shall I start on the... [TX indicates cup of tea] [Long pause for tea - TX and JR chat is not transcribed]*
- 4c:2 *JR: Can you recall what you were thinking during any of the clips - is there anything that might have been playing around in your head that you might not have mentioned so far?*
- 4c:3 **TX: Just watching the clips just now?**
- JR: Yes.*
- 4c:4 **TX: I think I've categorised it in my head as I was watching it. I was analysing my own practice, and I was also looking at the kid's motivation and then thirdly interestingly, I was looking at their science. So selfishly I was looking at my own practice and my questions and then I was looking at the kid's engagement. And then tertiary was the actual science conceptual development. I think that was my three categories I was looking at while watching it.**

4c:5 *JR: Thank you. Please would you tell me what it is like thinking aloud after watching the videos. Do you think like this in the classroom? How does the experience of watching these videos compare with what happens in the classroom?*

4c:6 **TX: I think the thinking aloud - I don't think I did a lot of it during the clips. I don't know what you thought. But I didn't think I did a lot of it. Because I was so interested in what I was watching. In terms of the classroom, I do think like that. I have an internal voice that is going on in the classroom. I'm very aware of that internal voice. Yes. And I'm also very aware of trying to create opportunities for openness and inquiry based learning but get the whole students involved so that can be achieved through different groupings of students. Different practices of um - I'm just trying to think of an example - I gave them a practical to do the other day and they all had - they were in groups - differentiated groups. And there were slightly different parts of the practical they had to do. And then we used an ambassador approach so whatever they learnt from one group they then had to feed that into the next group and circulate it round. So there was a lot of peer teaching going on. Um. Because I want to keep my input into lessons as minimal as possible. I feel I've moved from very much being a teacher who is very much in control and dictating the pace of the lesson, to one where I push it more and more [TX mimes this with his hands] onto the kids. As I get older as a professional.**

4c:7 *JR: Because that -*

4c:8 **TX: Because I think I see the power of - I mean again, there was a component of the fire discussion in the clip [TX points at the laptop screen]. When you give them the right stimulus, the right inquiry, they take ownership by asking the right questions, then the learning is self-fulfilling. The engagement is self-fulfilling. All you need to do then is some sort of quality assurance mechanism through success criteria or through tracking of what is going on - um - that the learning is in the right path. Does that make sense? [JR nods]**

4c:9 *JR: Thank you.*

4c:10 **TX: Does the experience of watching these videos compare with what happens in the classroom [TX reads this from the laptop]. How does it? It is much more analytical - because you can really - I mean you listen to what the kids are saying in class, but you can - I think watching it back like this is much [more?] powerful learning. We did a lesson with Year 10 the other day where we had to do fractional distillation. Which was the most - [TX turns towards JR] well it isn't the most exciting topic on the planet. [JR laughs] Sorry. But -**

JR: I have to agree with you there.

TX: So we did this thing where we watched some clips of different teachers teaching it on YouTube and we - I gave the kids - first of all I said, "You're going to observe these teachers. You're going to be the lesson observer. You're going to be OFSTED, could you kind of come up with some categories to grade these teachers?" So they came up with success criteria, and then the kids re-watched the lessons based on the success criteria. But actually what they were doing each time they re-watched the lesson is they were learning about fractional distillation. And it was one of the most engaging lessons I've ever done on fractional distillation. But it was watching - you know - three teachers with three very different styles on YouTube. ... But that is what the kids were doing. They were analysing what the teacher was doing. So if a teacher was - let's say - moving forwards and back or fidgeting. There was one teacher who was fidgeting with her neck a lot [TX mimes this]. The kids picked up on it. But they also picked up on the fact that she used like the same word over and over and over again. "Are you alright with that? Are you alright with that?" So they're very - I think watching things and then reflecting back on them is a really powerful tool for learning. That is what I'm saying.

4c:11 *JR: And authorising them to play that role.*

- 4c:12 **TX: Yes! Giving them the responsibility. It is like giving out red pens. You give kids out red pens, with success criteria, or a mark scheme - I think the learning is really powerful and it is engaging because they have got that responsibility of the red pen. ... If you're allowed red pens in schools. [Said with irony - JR laughs] There is one school where we weren't allowed to use red pens - it had to be green.**
- 4c:13 *JR: Which questions, or things that the children said, did you anticipate coming up? Was there anything that you hadn't -*
- 4c:14 **TX: The fire. I thought the fire would be, would be challenging - challenging them. I've often used, "If aliens came down to Earth, how would they see the difference between a car and a human being - based on MRS GREN?" That is a technique I've used before to challenge kids' perceptions of just using MRS GREN as a set of criteria. Um. So I thought the fire would have the same effect. The one that threw me was the embryo. That one really threw me. I thought they would just automatically assume it was living. So that really threw me that one.**
- 4c:15 *JR: And threw you at the time?*
- 4c:16 **TX: Yes. AJ's comment - looking back - there's a there's a there's a - something greater to explore there about what our classification of living is.**
- 4c:17 *JR: Does that experience of being thrown by things. Is that something you're familiar with. Does that happen - sometimes - in the classroom?*
- 4c:18 **TX: Yes. Not as often as it should be though. ... Because I think that sometimes we're so outcome focussed in our lessons that that kind of experiential learning - that progressive learning - just challenging your own thoughts. Sometimes we just don't do it enough.**
JR: Thank you.
TX: But that was - that was a challenging one. ... We like challenge. I think challenge is great. That is the great thing about science. If it doesn't make sense, then make sense of it. At the end of the day, what - learning. I think learning is a horrible word
JR. I think 'making sense' is a better word. Better phrase. We present things to kids that don't make sense ... and our brain - us we then interp - we try to make sense of it. Isn't that the driver of our learning? Trying to make sense of the world around us? Isn't that science? Isn't that learning? So if you present things that don't make sense - we try to make sense of it.
- 4c:19
- 4c:20 *JR: I'm thinking about those - psychologists use those butterfly patterns don't they [JR mimes with his hands the Rorschach inkblot test] ink splot splodges, kind of - in order to explore interpretation don't they. And human beings seem to be very good at reading pattern into things*
- 4c:21 **TX: I haven't seen that. Sounds interesting.**
- 4c:22 *JR: A naive scientific concept has been defined by somebody as "non-scientists' everyday understandings of certain bodies of information". It is not meant in any way pejoratively, how do you usually help students who have a naive scientific idea?*
- 4c:23 **TX: You challenge it [Said emphatically]. You have to challenge those naive science ideas. You challenge it with - like we did in the clip, with the seed - the seed comment. About, "OK, we've got seeds that are thousands and thousands of years old. Are they still alive?" "Is the plant - The plant can't pick its roots up and move about. So is it still moving?" It is challenging their understandings. I think that is what we have to do. And I think that is what Rosalind Driver's work is. It is - on constructivism. You break it down - you break down those everyday understandings and you challenge them. The one - the classic one that used to get me right at the start of my teaching career was when Ground Force - Do you remember that programme with Charlie Dimmock and Allan Titchmarsh? Well they'd do peoples' garden's up and Charlie Dimmock and Allan Titchmarsh would constantly say, "I'm going to feed your plants." Feed it with fertilizer - "No! They feed themselves by**

photosynthesis." So but - it is challenging that words - in the classroom. One we've just done on gravity on the planets is the difference between weight and mass. And about how we're starting a campaign to change it to weight - to Mass Watchers. [TX and JR smile] instead of Weight Watchers. So I agree the definition.

4c:24 **TX:** [Reading from the laptop screen] Tell me about experiences you've had with children who've had - What is another one? ... A naive - the feeding one ... is the biggest one that comes to mind. ... Oh! There was one - this was a fantastic one. About three four years ago, where we were looking at evaporation. And about the particles moving from the liquid state to the gaseous state. And a group of students were talking about fizzy pop. And about the bubbles [TX mimes the bubbles with his hands] - you know when you pour a glass of pop and you get the kind of fizz? And they were talking about, "Is that evaporation then?" [TX and JR smile] Because it was going into the air, so if you assume it is going into the air, then it must be evaporating. So that was an interesting one. ... What other naive concepts? ... [Unclear] the planet ones. I'd have to get thinking on that one.

4c:25 **JR:** *We can always go backwards and forwards between things if that helps. Are you conscious of applying specific teaching practices in your everyday work?*

4c:26 **TX:** **Am I conscious?**

JR: Specific things that you're trying to do? As teaching practices, and if so -

TX: **OK. What do you mean by specific teaching practices? Do you mean the actual methodology I use - in the classroom?**

JR: We could explore that route - or particular principles behind what you do?

4c:27 **TX:** **I always start with something that makes - that engages the kids. Something that that they will find relevant to them. It is like a hook to pull them in. You need that hook to start the whole process off. And that hook is often related to the topic - the learning that the lesson is about. The outcome of the lesson. Um. So we had - I'm just thinking of the last lesson we had on Thursday before I went on that trip. Was we were looking at choice chambers and wood lice. So I showed a clip of - on the screen - of some Australian bush people cooking wood lice and eating it. And we started talking about - "Is this - " You know, what did the kids think about eating wood lice. And that was a conscious decision to get them engaged with thinking about woodlice and about their habitat and - There was a bit at the beginning of the clip where they had to hunt the woodlice - to find the woodlice. ... But they were more interested in eating the woodlice [TX and JR laugh]. Which - But at the end of the day that is what I wanted them to think about. Because in the back of their minds - maybe not right at the front of their mind which was the eating of the woodlice, they are looking at the clip and seeing look under dark, damp pieces of wood and rocks. So they're taking that information maybe subconsciously but - The bit that motivates them is the eating of the woodlice. So that hook makes them start thinking about the process and I think that is one of the key features of my lessons, is - there will always be a hook. Um. There has to be outcomes to any lesson. The kids need to know exactly what part of the journey they're on. So I will always plan like a timeline of the lesson. The kids will see where they're at at different stages. And we'll always feedback on that - on that journey. I think that is really important. I think kids who know they've made some progress - As long as you know you've made some progress, then that feeds your motivation and encouragement to carry on the process. You have to know whatever small part it is, you need to know you've made that progress.**

4c:28 *JR: Thank you.*

4c:29 **TX:** **Lots of opportunities for feedback in the lesson. And then share the success at the end. How far along that journey have they been? Does that sound a bit rose tinted? That is how I plan a lesson. It is my core - Do you want specific practices? Like groupings. We could have mixed ability groupings, we could have friendship**

groupings, we could have ability groupings, we could have gender groupings, - we will - other activities. There is a lot of - "Here's an answer, make it better." What I'm trying to focus on in my lessons isn't just the lower thinking skills like remembering and understanding. It is pushing it - constantly pushing it with kids up to the more applying, evaluating, creating. The higher order thinking. Rather than just the lower order.

4c:30 *JR: [Starts to say something]*

TX: And strategies to get kids to make sense as well. I did a lot of work when I started being an AST ten years ago on what do these outstanding teachers do to make sense of information? So they give lots of information to kids, but what do these teachers do to that information to get the kids to make sense of it? And we came up with the Magenta principles. Which were strategies that teachers use to get kids to make sense. So things like 'reduce it'. Taking a large lot of information [TX mimes this with his hands] and reducing it down to the key paragraph. Key sentence. Key word. A key diagram. 'Compare contrast'. So take two things, a whale a submarine, a planet a moon - compare and contrast. What is similar what is different? And give them criteria to compare - compare it and contrast. Deconstruct it. Where you take an idea and you pull it out into its component parts. And then what would happen if that component part you removed it - what would happen? So if you took the circulation system, and you took the heart out of it what would happen to it? What would happen if you took the artery out? If you just had veins instead. Get them to make sense of the component parts by removing one of them. Again, you're pushing it up the HOTS - the higher order thinking skills. You're pushing up to the evaluation, the analytical, rather than just remembering and understanding. [JR starts to say something] And these were twelve principles which I saw lot of teachers - really good teachers do on a regular basis. They were getting kids to make sense. So I then categorised them into these kind of twelve 'strategies'. That the kids did.

4c:31 *JR: Fascinating.*

TX: I'll give you the PowerPoint.

JR: I'd be really interested. And I was interested earlier you said about - "Is that a bit rose tinted?"

TX: That is just what you say. [Unclear - said very quietly]

JR: But ... is there perhaps some difference sometimes between the plan you have and then the reality in the classroom.

4c:32 **TX:** Always. That always happens. You've got to adapt your plan accordingly. But you've still got to have your underlying principles. You've still got to make sure the kids at the end of the day can reflect back and see the progress they've made. Against - you know - criteria. They have to know that. Even if it is just a case of - "You came into the lesson and you knew MRS GREN 4 out of 5 and you left the lesson with 5 out of 5. Make a big thing of that progression. And you use the same techniques from a behaviour management point of view. So you stop the class - they're off task - you get the kids - and they're very honest kids when you ask them kind of research based questions. Always pose it from a point of view that you're doing research. Don't - that you're not emotionally involved. Always point it from the view of - um - how can I verbalise this? ... You're rising above it. You're not emotionally involved. "So OK, you're off task, on a scale of 5 down to 1 [TX holds his fingers up] how on task were you?" They give you this [TX holds two fingers up] and they give you this [TX holds his middle finger up]. And all this. "And OK, well my challenge is I'm going to ask you again in ten minutes and I want you to have at least moved up by one or two. So what are we going to do to make sure that happens?" So you can still get the progression and the behaviour management, but by doing it in a progression way. Because progression is the key to motivator. To

motivation. If you don't feel you're progressing - you know, "Why should I carry on."

4c:33 JR: *So interesting. Thank you. ... Please would you tell me about any experiences - Oh. Are you OK with the time? I'm conscious that we're now up to the hour.*

TX: **It's OK.**

JR: *I'm obviously fine with the time, but...*

TX: **I'm OK.**

JR: *Please say if you're needing a break or anything. Please would you tell me about any experiences you've had with children solving scientific problems themselves. In what ways do you try and influence children's problem solving?*

4c:34 TX: **Well I'm worried after watching that clip that sometimes I ask too many leading questions. But I am pleased with the way I challenged their thinking with giving practical approaches, and bringing in practical experiences that relate to them. Or offering the opportunity for them to discuss their own practical experiences. So I'm really pleased with my practice on that. I think maybe I have to think about my leading questions. [TX reads the question again] Tell me about experiences you've had with children solving problems themselves. OK. Um. ... Just trying to think of what we did last week. They solved their own problems. OK. We were making with Year 9 mayonnaise. We were looking at emulsifiers and we set the challenge that the Tesco's mayonnaise was too runny. So they had oil, they had water and they had egg yolk. And they had to come up with a methodology that they could test and write up to send to Tesco's to work out the optimum ratio of egg yolk, to oil, to water. And what they were given was - I wanted them to model what they are going to be doing after the Easter holidays, which is their coursework where they've got to come up with a hypothesis and their own methodology. So it was really a practice for that. I structured it in terms of, "OK, what's your independent variable, what is your dependent variable and you control variable?" And that is all I gave them. Was the structure and I let them go off into friendship groups to work out the answer. But all I wanted from them was the independent, dependent and um ... control variables. And then we came together after five minutes and we started doing like a mini conference and show-and-tell what the methodologies were. And they started giving them a rating - again five [TX holds up 5 fingers] down to one. Is it repeatable? Because the big thing on the new coursework is we've got to use this word repeatability. So they did the ratings. They went away back into groups and then they came up with their methodology which they then put into practice. So in terms of solving the problem, yes, they all solved the problem ... in groups, but they weren't independent. But they were in groups. But they all contributed. ... And they all came up with an answer. Now after the Easter holidays we're going to look at what they've done and we're going to try and unpick what the good practice was and what the maybe not so good practice was. To try and formulate their practice before they put it into the real life thing of doing the GCSE coursework. So I think it is solving the problem themselves you have to give them some structure to the problem. Rather than being just totally open ended. A technique I use quite a bit is, "Here is the equipment." I've seen a lot of teachers when I go in to support, I see a lot of teachers that just demo everything [TX mimes this with his hands] and you think well what is the point? You know, OK, so your kinaesthetic learners they're going to like it being demoed - I'm a kinaesthetic learner - You know, if somebody doesn't show me how to do something down at the gym I won't be able to do it from a description. But if I see somebody do it, I can copy it. So I see the benefit of the demo, from a learning point of view, but really the power is, "Here's the equipment, here's our outcome, how are we going to do it?" And it is that thinking - that independent thinking. Prior to any demo. Prior to any pulling out of good practice, let's get the kids thinking about what can we do with this equipment. But again, I think teachers are very time**

orientated. They've got an hour lesson, sometimes 50 minutes. And they want the students to get on with the practical and they delve straight into doing the demo. But it actually reduces the quality of the problem solving. I think this is a problem we have in science. We've got 'How Science Works' skills, but we've got time components [TX mimes weighing these with his hands] that often don't merit exploring independent skills. So it is about then trying to really narrow it down into one particular skill in a lesson to develop. So for me with the mayonnaise it was them coming up with a method. I didn't really care at the end of the day if they go runny mayonnaise or not, I wanted them to really explore the independent, the dependent, the control - and from that information pull together a methodology that they could then rip apart after Easter. Does that answer your question?

4c:35 *JR: It does yes. Thank you.*

4c:36 **TX: I've seen teachers be very open, and it just all falls flat. Because they're trying - students haven't got the skills. If it is not structured then it will fall flat. Whereas if they're given structure - to structure their thinking, then you get something more productive.**

4c:37 *JR: And I'm hearing that sometimes the structure is explicit, that you're laying that out before the children, but sometimes not. Am I right? Sometimes that is behind the scenes.*

4c:38 **TX: Yes, ... in terms of, "Here's some equipment, right, what can we do with this equipment. This is the outcome." So there is still structure, here is the outcome that we have to do with this, how are we going to do it? So there is still structure even in quite an open ended task. I still think there is structure.**

4c:39 *JR: But would you be choosing whether you're going to share a structure explicitly, or would you sometimes be -*

4c:40 **TX: That is down to the group and your prior knowledge of that group and their skill ability. That is your - That's the teacher knowing their students.**

JR: Yes.

TX: I've got a Year 9 class that are - you know, I could quite happy just give them a tray of equipment and they could put together a methodology within ten minutes. But then I've got a Year 11 class who've had a very different experience at [Name of the school] and you'd have to basically - not tell them. But you'd really have to structure it. But then challenge that structure. Don't accept that the structure I'm giving you is the perfect structure. Challenge it so that at least then you're developing their problem solving skills, but in a safe - So they've made that little progress. They've put together the test tube [TX mimes this with his hands] with the bung and the delivery tube, and they've collected a bit of hydrogen gas. "OK, well you've collected it into a test tube, how could we make that more precise for measurements?" So challenge it, but in a structured way, so you're focussing on one particular skill: precision. So let's move from a test tube to a 10 centimetre cubed measuring cylinder. Let's move it to a gas syringe. You know, so you're challenging, but it is in a structured way.

4c:41 *JR: Thank you. Would you tell me please about any experiences you've had where your own scientific and or teaching ideas changed?*

4c:42 **TX: [Pause] Um. Yes, it was about ten years ago and it wasn't - has it got to be science?**

JR: No.

TX: It was working with a guy called [Name of this person - MH] and it was the power of peer - peer teaching. And he gave us an exercise where we had to solve a murder mystery - and we all had various bits of information, and we had to solve the mystery. And ... how we all worked together to solve that mystery. And it was just like one of those 'sliding-door' moments - you have to make sense of lots of small bits of information and put them together. And realising as teachers - just giving them the information - giving the kids the information and getting them to learn it isn't - it

is too passive. It is about that active approach to learning. So that was the kind of sliding door moment for me. Seeing the power of it and experiencing it myself. And reflecting on it. That you have to reflect on what you've just done. So if we've had a discussion and we've unpicked DA's answer. We've then got to reflect back and think, "Well, what did we do to ... um ... what did we do to help DA with her answer?" Or if we've made a model, why is a cell like a a cup cake - OK. There is our model. Where's the strengths in the model? Where's the weaknesses in the model. So we don't just say, "Here's a model." End of. Let's unpick it - Why is the cupcake like a cell? What is the strengths, what are the positives, what's the negatives. That is the powerful bit. ... There is so much good stuff in the national strategies that came through from 2002 to 2009. There is some great stuff in it. But it was just overload, there was so much stuff coming through that departments just couldn't disseminate all of this. Have you seen all the modelling stuff?

4c:43 *JR: No.*

4c:44 **TX: Amazing stuff. It is all archived, if you type in 'National Strategies' 'Science' and 'Modelling' - so much great stuff came through.**

4c:45 *JR: If you'd been teaching the three topics to a class, rather than to a small group, please would you describe how it might be different.*

4c:46 **TX: Um. I would have the students leading each group, and that is the plan of action really, to take this further. Because the group have come back buzzed up - I don't know what you added to the Kit Kats [TX and JR smile] - but they want to take it further. So I would use a kind of ambassador's approach, where the kids would lead the activity and I would circulate with some sixth formers. And then we'd have a feedback. I think that is how I would do it. ...**

JR: Um -

TX: I wouldn't reco - I mean that is an approach that I'm comfortable with, but I don't know if other teachers would feel comfortable doing that. But I feel quite confident, with that class, and with the students that you've already used. Leading it would be one: great for their responsibility, their esteem, for their leadership skills. For their emotional intelligence. And I think the students would really enjoy having student leaders. I'd be even tempted to join a group as a student [TX and JR smile].

4c:47 *JR: I'm very conscious of the time. We're well over there. And - before we finish, I just wanted to ask. Is there anything else about this whole process that you'd like to say? Any thoughts you'd like to share?*

TX: About what we've just -

JR: About the whole research.

4c:48 **TX: No. I just feel this research has been very powerful in terms of metacognition ... and looking back at practice and I think it would be - it is such a benefit to all colleagues to take part in this kind of process - reflecting the actual nuts and bolts of their pedagogy. For me - I'm taking away the leading questions. I'm going to be more aware of it.**

4c:49 *JR: Thank you so much for both interviews. I'm really really grateful you giving up your time like this. It has been a real pleasure working with you.*

4c:50 **TX: I hope it has been useful.**

4c:51 *JR: Fascinating. Absolutely fascinating.*

TX: Okeydokey.

JR: Shall we stop there?

TX: OK.

[End 4c]

Interview 5a

5a:1 **TY: While you're scribbling, again, thank you for coming. And like I said last week, this isn't a test, so if you get it wrong that's fine. If we get it wrong we'll probably get it right towards the end. OK? But the key bit is that everyone gets to say what they're thinking about. So is that OK?** [several students nod] **Cool. Shall we give these [the permission letters] back to Mr Riordan [students and TY pass the letters]. [Pause] OK. It looks like I'm cheating a bit because these aren't my questions, they're Mr Riordan's questions, so I have to [unclear - read them?], you'll going to have to let me get away with that one. OK. ... OK [said very gently]?**

5a:2 Everyone: Yes. [several students smile]
AC: Maybe this once. [Said with irony]

5a:3 **TY: Maybe this once. [TY smiles] Thank you. OK, in which case. The first one says: please tell us who you are and how you feel about science. Let's start with AC and we'll go clockwise for this one.**

5a:4 AC: My name is AC and I like science because you get to do lots of experiments and its fun and it is worth your time.

5a:5 **TY: Its-**

5a:6 AC: Its worth your time.

5a:7 **TY: Its worth your time. [TY nods as he says this] Thank you. [TY looks expectantly at PP]**

5a:8 PP: My name is PP and I like science a lot because you can do experiments.

5a:9 DS: My name is DS and I like science because you can learn new things like that you didn't know before [said very quietly]

5a:10 **TY: You can - [TY cups his hands around his ears indicating that he didn't hear what PP said]**

5a:11 DS: [Louder] You can learn new things and you can do experiments. [TY nods]

5a:12 MG: My name is MG and I think science is fun and we also have a fair bit of writing to do, but we all understand that we need to do that.

5a:13 **TY: Is that a good thing or a bad thing?**

5a:14 MG: Yes, it is good. Because then we can evaluate our work.

5a:15 DF: My name is DF, and I think science is good because you get to do fun experiments and to a write-up at the end.

5a:16 **TY: And that bit is good as well? [TY smiles as he says this]**

5a:17 DF: Yes. [TY and DF laugh]

5a:18 **TY: Wow! [Unclear]**

5a:19 SP: My name is SP and I like science because you do fun experiments and it helps us in everyday life.

5a:20 **TY: Cool. Well, thank you everybody. Second one. What is the first thing that comes to mind when you hear the word 'science'? Anybody can answer this time.**

5a:21 AC: [DM puts his hand up] Lots of fun experiments and things exploding. [TY smiles and nods]. That is what I think of.

5a:22 **TY: Thank you. PP?**

5a:23 PP: Lots of writing. [TY laughs]

5a:24 **TY: Oh dear! DF?**

5a:25 DF: Um, experiments and fire.

5a:26 **TY: SP?**

5a:27 SP: Blowing up the lab. [TY laughs]

5a:28 **TY: In a good way? [TY looks at MG]**

5a:29 MG: Before we came to high school I thought it would be like um lots more experiments than we did in primary school, and yes, that is how it is. Lots of fun experiments.

5a:30 **TY: [Nodding] So it is what you thought it would be. That's good. DS?**

5a:31 DS: [Unclear - when I think of science it is] learning new things that you haven't done before about science and the experiments.

- 5a:32 **TY: Lovely. Thank you. OK. Next one. Please tell us about any experiences you've had where you or someone else changed their mind about a science idea. ...**
- 5a:33 AC: When we were doing - organising the sand and the iron filings [AC says the word filings very slowly as if he finds the word difficult to say]. We had to change how we were going to get the iron filings out of the ... sand and water. We had to change the way. We had to think about it and change it.
- 5a:34 **TY: So how did you change it?**
- 5a:35 AC: Um. We tried to reverse it and put it back to how it was. And then we just changed the whole thing.
- 5a:36 **TY: No, I mean how did you change your understanding of your idea?**
- 5a:37 AC: Um. By looking at our mistakes and learning from them.
- 5a:38 **TY: OK. Thank you. Anyone else? [MG puts her hand up]**
- 5a:39 MG: The same one, but we went home and we did research from the internet and books and stuff and we wrote it all down and we came back and we had an idea of what to do to change it.
- 5a:40 **TY: OK, so it was just research that did it for you?**
- 5a:41 MG: Yes.
- 5a:42 **TY: OK. Anyone else? ... You don't have to. ... No? OK. Right. On to the fun stuff then. See if I can get this right. [TY lifts down the bowl of ice from the windowsill next to him and places it on the table. He then takes the cup from the same place which had been underneath the bowl and puts it in the middle of the table.] Have a look. [All the students lean over to have a look] I'm going to read [unclear] what you like. So here we go. Please tell me what is happening to the hot tea and the cold ice cubes in as much detail as you can. And you can have a feel if you don't believe me.**
- 5a:43 SP: The ice cube is taking water from the cold. Because the ice cube is cold and it's going to [unclear - said with a very quiet voice - probably 'help the water get colder' - see 5a:45]
- 5a:44 **TY: [Leaning forward trying to hear] It's going to -**
- 5a:45 SP: Help the water get colder.
- 5a:46 **TY: OK.**
- 5a:47 SP: And the coffee is hot because you poured hot water to make it hot.
- 5a:48 **TY: OK, and what is happening to it now?**
- 5a:49 SP: It will start cooling down.
- 5a:50 **TY: OK. [MG puts her hand up and TY looks at her]**
- 5a:51 MG: The ice is melting into the water and the coffee there's - there probably was steam coming off but now it has cooled down so there is less. ...
- 5a:52 **TY: OK.**
- 5a:53 AC: Because the coffee is hot and the glass [AC touches the ceramic mug] is kind of cold - it was cold probably - there is like condensation going on the edges [MG puts her hand up - TY leans over to look into the mug].
- 5a:54 **TY: Of the -**
- 5a:55 AC: Cup.
- 5a:56 **TY: OK. Yes. I can see that. And how do you explain that?**
- 5a:57 AC: ... The hot air rises and it hits the cold surface and turns into water.
- 5a:58 **TY: So the air turns into water.**
- 5a:59 AC: Yes. No, the surface.
- 5a:60 **TY: The surface.**
- 5a:61 AC: The hot air. [AC nods]
- 5a:62 **TY: Does what?**
- 5a:63 AC: Turns into water. [AC is leaning his head on his hand covering his mouth a little - he laughs a little as he says this]
- 5a:64 **TY: So air turns into water.**
- 5a:65 AC: Yes.
- 5a:66 **TY: When it hits a cup.**

5a:67 AC: Yes. If it is cold.

5a:68 **TY: If the cup is cold then the air hits it -**

5a:69 AC: Hot air.

5a:70 **TY: If hot air hits a cold cup then the air will turn into water.**

5a:71 AC: [Pause - AC looks round at the other students as if for help - MG has her hand up - TY smiles at AC]

5a:72 **TY: I'm only checking. Is that what you mean?**

5a:73 AC: Yes.

5a:74 **TY: OK. Thank you. [TY turns to MG]**

5a:75 MG: The cup is conducting the heat.
TY: Nice word.
MG: So before it was cold. Now it is hot. So the cup is conducting the heat from the cold - [MG shakes her head] from the hot [unclear - cup of tea?].

5a:76 **TY: OK. Where to?**

5a:77 MG: The material of the cup? What?

5a:78 **TY: So you said that the cup was conducting the heat from the tea - you said coffee - from the coffee, and I'm saying, where is it going? Where is it conducting it to?**

5a:79 MG: To the clay part of the cup [MG mimes this with her hand] ... The mug material.

5a:80 **TY: So the mug material is conducting -**

5a:81 MG: The heat from the coffee.

5a:82 **TY: To -**

5a:83 MG: To ... I'm not sure.

5a:84 **TY: OK. That is fine. Thank you.**

5a:85 DS: ... I'm not sure.

5a:86 **TY: Not sure. Not sure at all - any of it? Or is there someone you agree with or disagree with?**

5a:87 DS: [Shakes her head]

5a:88 **TY: Not sure at all. OK. DF?**

5a:89 DF: I kind of agree with what AC said.

5a:90 **TY: Which bit of what AC said?**

5a:91 DF: Like when the when the hotness of the cup condenses and then it goes [DF points upwards] - I'm not [unclear]. When it is hot, I'm not sure, but I think it goes up [DF mimes this].

5a:92 **TY: The cup goes up?**

5a:93 DF: No no, the steam goes -
PP: Rises [Said with a whisper]
DF: rises.

5a:94 **TY: Rises is a good word [TY looks at PP]. OK.**

5a:95 DF: It just goes into the air. And goes round the room.

5a:96 **TY: OK, why does it do that?**

5a:97 DF: Because it is like air. [Said with a very uncertain tone and expression on DF's face] Air is all around us.

5a:98 **TY: What is like air?**

5a:99 DF: The steam.

5a:100 **TY: So the steam is like air. OK.**

5a:101 DF: Not as hot though.

5a:102 **TY: It is hot air. And therefore -**

5a:103 DF: ... It is around us. [Said very quietly, TY cups his hand over his ear] It is around us.

5a:104 **TY: OK. Thank you. We haven't heard very much about the ice yet. I think it was really only SP that told us about the ice. [PP puts his hand up] PP?**

5a:105 PP: The ice bowl is on top of the mug and the hotness of the coffee makes steam and then the steam melts the ice.

5a:106 **TY: How does steam melt ice?**

5a:107 PP: ... [unclear - could be 'Because of'] the hotness.

5a:108 **TY: OK. So what does the hotness do from the steam to melt the ice?** [AC sneezes]
Bless you.
AC: Thank you. [MG has her hand up]

5a:109 PP: Not sure.
TY: Not sure. MG?

5a:110 MG: Um, it conducts heat to the plastic and then into the bowl.

5a:111 **TY: What is 'it'?**

5a:112 MG: The steam - conducts heat to the bowl and erm the ice is in that so it warms and starts to melt.

5a:113 **TY: OK. SP told us right at the beginning then that the ice was making the water cold. Didn't you. So is that the same idea as the idea about the steam coming from the cup? Or is that a completely different idea.**

5a:114 MG: Well I think it is different because we think that - I think that all the water in there is melted ice, not ice trying to cool the water.

5a:115 **TY: OK. But, can SP's idea be true at the same time?**

5a:116 MG: ... Yes, I guess half of it could be water and half of it could be melted ice in that sense.

5a:117 **TY: What is the difference between water and melted ice.** [TY sits back and smiles]

5a:118 MG: Nothing [MG smiles], but water that you've already put in, and water that had been ice.

5a:119 **TY: OK. I don't know the answer to the question, because I wasn't paying attention when Mr Riordan set it up. SP, what do you reckon? Their ideas about the steam melting the ice?**

5a:120 SP: Yes, the steam will evaporate the - no - the steam will help melt the ice and because heat can go through plastic [unclear].

5a:121 **TY: And is there a word that they've used that might describe heat going through plastic?**

5a:122 SP: Steam.

5a:123 **TY: Does steam go through plastic? What does steam look like?**

5a:124 PP: [Very quietly] Gas.

5a:125 SP: Like ... when something is burning ... it is like going up. I can't explain it.

5a:126 **TY: That's OK. OK. So I think what we've said is there are two ideas for the ice. That the ice is cooling down the water [TY looks at SP who nods] and also that the steam from the tea is, in some fashion, conducting - what is it conducting though?** [pause]

5a:127 SP: The water [Very quiet - unclear - TY leans in] The water.

5a:128 **TY: Conducting the water.** [TY's tone invites more answers]

5a:129 PP: The ice.

5a:130 **TY: Conducting the ice.** [DF looks at MG and both smile]

5a:131 AC: No idea.

5a:132 **TY: No idea.** [TY looks at DS]

5a:133 DS: The ice.

5a:134 **TY: OK. Conducting the ice. MG?**

5a:135 MG: Conducting the bowl.

5a:136 **TY: Conducting the bowl.** [TY looks at DF]

5a:137 DF: The ice.

5a:138 **TY: That is really interesting. That is not a word that I would be expecting that you would know yet, but obviously someone knows it - I'm not sure that you all know quite what it means yet.**

5a:139 MG: We learnt it in Year 6, I kind of know what it means.

5a:140 AC: Insulating and conducting.

5a:141 **TY: OK, so insulating and conducting, what is the difference? Can anyone tell me?**

5a:142 MG: Insulating is - Conducting is -

5a:143 AC: We learnt that insulating in electricity and conducting in electricity.

5a:144 **TY: ... OK, but is this question about electricity?**

5a:145 AC: No, but that is what we learnt about con- [unclear] That is what I thought conducting was.

5a:146 **TY: MG might have a different idea.**

5a:147 MG: I think conducting is like letting heat pass through, and insulating is probably the opposite.

5a:148 **TY: OK. So how would you describe the opposite of - ?**

5a:149 MG: Like metal is a conductor, and ... another material might be an insulator meaning you can't feel what is inside like [MG mimes feeling a material] - like rubber. I don't know. But like you can't feel the heat from inside - so it stops it from coming out.

5a:150 **TY: OK. So when I asked what is - I can't remember how I asked it now, we were talking about the heat from the - the steam from the tea melting the ice. And I said, 'what is conducting'? And I think people said the plastic and the steam and maybe some people said the water. Do the answers to that question go with the definition of conducting that you've just told us? ... So if conducting is where heat can go through things, and insulating is the opposite of that, where heat doesn't go through things, is it possible that in the set up that you've described it like this [TY lifts the bowl of ice and places it on top of the cup of tea] is it possible that the steam was 'conducting' or 'going through' the plastic pot? [pause]**

5a:151 AC: I'm not sure. What I think is happening is the steam is going up to the bottom and then it made the bowl underneath warm and because it made the whole bottom bit warm it melted the ice.

5a:152 **TY: OK. And can you do any of that using either the word insulate or conduct?**

5a:153 AC: Probably one of them. Yes.

5a:154 **TY: [Laughing] Do you want to give that a go?**

5a:155 AC: [Laughing] No.

5a:156 **TY: Is there a good reason why not? [Still smiling]**

5a:157 AC: Yes, because I'm not sure.

5a:158 **TY: Are we bothered?**

5a:159 AC: Yes.

5a:160 **TY: Are we? [Eyebrows raised and a surprised tone]**

5a:161 AC: Yes, we should be.

5a:162 **TY: We should be but we're not.**

5a:163 AC: No.

5a:164 **TY: But if we all agreed that it was OK to get it wrong. We really don't care. We'd like to just have a good laugh anyway.**

5a:165 AC: OK. I would say conducting. ... Conducting heat ... [TY turns his hand at the wrist]

5a:166 PP: The heat conducts the bowl which makes the bowl warm and the ice melts - the water makes the - the bowl makes the water warm which melts the ice.

5a:167 MG: I think maybe -

5a:168 **TY: Hang on just a minute. That was really good. I liked the way that you broke it down into steps. That really worked for me. I still think we need to sort out this word conducting.**

5a:169 MG: I don't think it is conducting because -

5a:170 **TY: What is?**

5a:171 MG: I don't think that the steam is conducting the bowl because we don't know if it is warm, we just know that the ice is melting, but the ice could be -

5a:172 **TY: Hang on. We don't know that what is warm?**

5a:173 MG: If the underside of the bowl - the inside of the bowl - we don't know that it is warm, so we don't know if - because we can't check [MG mimes touching the underside of the

- bowl?] either because the water is cold, so that is obviously not - So it might just be that the ice is melting as ice melts. And it is not because of the -
- 5a:174 **TY: Oh, I see what you're saying. So what - I think what you're saying then is you're not sure if AC and PP's idea, that there is heat coming from the tea which is conducting - I'm going to use it how I would describe it - the heat is conducting through the bowl - you're not sure if that is happening.**
- 5a:175 MG: Yes.
- 5a:176 **TY: Or maybe the ice is just melting and it has got nothing to do with the tea at all.**
- 5a:177 AC: Sir can I feel it?
TY: Yes.
AC: Underneath the bowl. [DS has her hand up]
- 5a:178 DS: I think, since that the glass and the bowl was on the window sill, the steam could also be coming from the sun outside.
- 5a:179 **TY: The steam coming from the sun.**
- 5a:180 DS: The heat coming out from the sun to melt the ice I mean.
- 5a:181 **TY: OK.**
- 5a:182 AC: Just out of interest, how long has it been there for?
- 5a:183 **TY: Probably [TY looks at his watch] about twenty bleuh - half an hour.**
- 5a:184 AC: And it was just ice in the beginning?
- 5a:185 **TY: I don't honestly know the answer to that question.**
- 5a:186 PP: When did you make the tea?
- 5a:187 **TY: I didn't make the tea. [TY smiles]**
- 5a:188 PP: When did you put it there?
- 5a:189 **TY: About half an hour ago.**
- 5a:190 MG: [Unclear - 'was it made before?'] and it is still hot.
PP: The steam might have wore [sic] out?
AC: It is still hot.
- 5a:191 **TY: OK, well that is a really interesting idea [TY is looking at PP and sits back in his chair]. The steam might have worn out.**
- 5a:192 MG: And I think -
- 5a:193 **TY: Hold on - I want to hear more about this idea. How can steam wear out?**
AC: [Appears to laugh? Sits back in his chair]
- 5a:194 PP: Because it - the coffee might get cold [TY nods] and the steam can just like go.
- 5a:195 **TY: So are those two things related? Does one cause the other to happen? Or is it just that they happen to happen at the same time.**
- 5a:196 PP: The steam has slowly - like wears out. ...
- 5a:197 **TY: And how does that relate to the tea getting -**
- 5a:198 PP: It is just like - there is hardly any heat going to the - conducting the bowl. To the bowl. And that is how like the water gets warm, but it is not being warm because there is no steam. [TY looks at the ceiling] ... There is no heat.
- 5a:199 **TY: OK, right. So at the beginning of the experiment I think what you're suggesting is that there is a lot of steam, and that the steam melted, or helped to melt the ice, and at the end of the experiment there wasn't a lot of steam and so the melting stopped. ... Is that right?**
- 5a:200 PP: Yes.
- 5a:201 **TY: OK, so tell me about - now forget about the ice melting, [TY removes the bowl from the top of the cup] tell me about the steam and the temperature of the tea.**
- 5a:202 PP: The temperature would have gone down and it would have gone cooler and it would take longer for the ice to -
- 5a:203 **TY: No ice. Just tell me about the steam and the tea. So at the beginning you said there was a lot of steam, and what was, what can you tell me about the tea when there was a lot of steam?**
- 5a:204 PP: The tea was very hot. Then as it got cooler the steam slowly wore out.

- 5a:205 **TY: OK. And what do you mean by 'wear out'?**
- 5a:206 PP: Like it goes.
- 5a:207 **TY: So there is less of it. [AC puts his had up]**
- 5a:208 PP: Yes.
AC: I've made loads of cups of teas myself, [TY smiles] at the beginning you can just see the steam rising [AC mimes this] and you can just see it without having to shine the light on it. But when it gets colder the steam starts going.
- 5a:209 **TY: OK.**
- 5a:210 AC: Because the water is warming and the water isn't that hot. Because it comes straight from the kettle or boiling it. But it gets - the water gets cooler, so the steam might start to go.
- 5a:211 **TY: So it is because the water is cooler there is less steam?**
- 5a:212 AC: Yes.
- 5a:213 **TY: So it wouldn't be true that there is less - that the [TY laughs] because the steam is leaving the cup, that there is less temperature. ... That was too confusing a sentence wasn't it.**
- 5a:214 AC: No, I understand - I understood it, but um... I don't think so. ... It could be possible, maybe, I'm not certain, but it is just my guess [AC looks at TY].
- 5a:215 **TY: OK. But that is all based on experience of making cups of tea.**
- 5a:216 AC: Yes.
- 5a:217 **TY: And observing them. Nice one. DS?**
- 5a:218 DS: It seems that the ice is cold. And when it melts the water might be still cold, so then the heat from - the steam the coffee mug causes the [unclear] coffee to go cooler.
- 5a:219 **TY: So the ice is cooling down the steam? OK, and does that have an effect then on the temperature of the coffee?**
- 5a:220 DS: Yes, the temperature of the coffee will go down.
- 5a:221 **TY: Because the steam is cooler? So it goes in sort of the opposite direction. [DS nods] OK. MG?**
- 5a:222 MG: In Year 6 we - I just remembered we did an experiment with a bowl and it had boiling water in it and cling film on the top and there was ice in that and we - to see what happened with the steam touched that - and something happened to it - it was like - I don't know if it was just condensation but my teacher called it something else. There was another scientific word for it. And that is what happened to the steam. And then - I think we timed how long the steam took to stop.
- 5a:223 **TY: That sounds like a brilliant experiment. And I think AC [TY points at AC] sort of described that right at the very beginning - do you [AC] remember what you said when you looked in the mug?**
- 5a:224 AC: Yes. [TY twists his hand round] The condensation on the sides of the mug.
- 5a:225 MG: So that might be what happened with the steam. It is all going underneath so -
- 5a:226 **TY: And maybe that is why it is wet [TY lifts up the bowl of ice cubes and looks at the underside]. It is either that or the bowl is leaking isn't it. Lovely. [TY nods] SP, one last idea and then we're going to move on.**
- 5a:227 SP: Um. Because the tea at the start when you made it it was really hot, so that as it is half an hour it is going to start to get cooler and then once the - when the bowl was on the tea, because I think it won't be much hot, it won't start melting the ice because if it was - if you put it at the start it would have because there is more steam and -
- 5a:228 **TY: Sorry, if you put it at the start it would have - what?**
- 5a:229 SP: The ice would have melted.
- 5a:230 **TY: OK. And now you're saying there is not a lot of -**
- 5a:231 SP: Steam, because the ice isn't melting.
- 5a:232 **TY: OK. [TY nods] You [PP] just did something really interesting. What did you do?**
- 5a:233 PP: I just felt how hot it was.

- 5a:234 **TY: And why were you doing that?**
- 5a:235 PP: Just checking the temperature.
- 5a:236 **TY: Yes, but why?**
- 5a:237 PP: To see how cool it was.
- 5a:238 **TY: And what did you find out?**
- 5a:239 PP: It was quite hot.
- 5a:240 **TY: Still.**
- 5a:241 PP: Yes.
- 5a:242 AC: I touched it at the beginning and it was really hot. Now I've felt it and it has just gone a bit colder [MG reaches out and feels the cup]. A bit cooler.
- 5a:243 **TY: And what did you use to feel it?**
- 5a:244 AC: My hand.
- 5a:245 **TY: And are your hands the best judge?**
- 5a:246 AC: Yes.
- 5a:247 **TY: Yes? [DS puts her hand up]**
- 5a:248 DS: Because your hand temperature is like different from the first time - your hand temperature might be warmer, and then after a little while your hands might be cooler and you might think it is hotter.
- 5a:249 **TY: [TY gives DS a thumbs up] Cool. Well done DS. That was really interesting. We are actually going to come and talk about some of these ideas in our lessons [TY clears the cup and bowl from the table as he continues to speak] when we talk about the burning tree experiment. So we'll come back to that I promise. [TY smiles] OK, next one then. I like this one as well. Although it is not really a proper science experiment because it is not physics. [TY, AC and JR laugh]**
- 5a:250 AC: Not physics.
- 5a:251 **TY: Let's see if I can get it right. So those are for you [TY hands the mats to AC] and those are for you [TY continues to distribute the equipment]. Can you spread them out so there is one next to each other.**
- 5a:252 AC: This is like what we do for [unclear - perhaps the name of a teacher?]
- 5a:253 **TY: Oh that's a good idea SP - much better [SP hands round the mats in pairs] I think that one is for you [DF]. So you should have two each. ... Yes? If you put them out next to each other [TY mimes this] and there is also a bag for you each.**
AC: Ooo! [This does not appear to be ironic]
- 5a:254 **TY: So just before you have a fiddle, let me get the question read so that we get it right [TY is handing out the bags as he says this]. And I've got a set as well which is nice so I can have a play. So here comes the question. Please sort these cards into the spaces on the two mats. These are the mats [TY holds up his own mats a little]. Quickly. One for living things and the other for non-living things. Try not to look at what your neighbours do, as the idea is to explore the different ways in which we might understand the word 'living'. It is OK to have your own ideas on this. And you can change your mind later if you want. Everyone got it? You know what you're doing [pupils have started to sort the cards]. [Pause] Answer came there none. [Pause] [JR removes the plastic bags from the desk]**
- 5a:255 AC: [AC is sitting next to TY - he shows the two 'bicycle' cards one of which shows a bicycle with the word 'bicycle' underneath, the other shows the same bicycle and word but has a person on the bicycle riding] Why are there two bicycles?
- 5a:256 **TY: Oh I see yes. [Unclear]**
- 5a:257 AC: Oh I see, this one's got -
TY: Shh shh shh. We'll do that in a minute. So just let everyone get theirs done and then we'll start finding out about peoples' ideas. [Very long pause] [TY coughs] [TY is looking at the mats. TY looks at his watch] [MG appears to look at the mat of DF]
- 5a:258 AC: Sir, what's an embryo, I'm not sure.
- 5a:259 MG: You do [to AC]. You do know what that is. You talked about it in science.

AC: You do.
 MG: You talk about it in science.
 AC: Me?
 5a:260 **TY: You've definitely done about that with [name of a teacher].**
 5a:261 AC: I talk about it? I talk about it? [With a very incredulous tone]
 5a:262 MG: You saw a poster on the wall and then you started laughing, so you do know what it is. [AC stares at the card for a moment].
 5a:263 AC: Oh! [MG and TY smile discretely] Yes, I do know what it is. I didn't realise [Pause] [MG moves one of her cards from one mat to the other - unclear which] [DF moves one of her cards - unclear which]
 5a:264 AC: Sir, does the egg have to be before it has been cooked or anything or -
 5a:265 **TY: I think that's what we'll talk about in a minute. [Long pause] [MG moves another card - unclear which] OK? Everyone happy?**
 5a:266 AC: Yes.
 5a:267 **TY: Yes. OK. I think the first thing I want to know is was that easy or difficult? Or give it a mark out of ten for difficulty, say 10 is difficult, 1 is easy.**
 5a:268 DS: Five.
 5a:269 MG: Two.
TY: Hang on. I've forgotten what way round it was. One is easy ten is difficult. And you [MG] said two? Five [DS].
PP: Three.
TY: Three.
AC: Two.
TY: Two.
SP: Three.
TY: Three.
DF: Three.
TY: Three.
MG: You've done me.
TY: OK. Thank you. AC. I was watching people's faces and AC was pulling some funny faces and trying to show them to me [AC laughs] so that maybe I would help, I don't know. Maybe it was just that -
 5a:270 AC: Maybe they was just random. Like a gun firing and a gun silent.
 5a:271 **TY: So when you say random -**
 5a:272 AC: It was just out of the blue. I just don't think it was appropriate.
 5a:273 **TY: Why?**
 5a:274 AC: [Laughing as he speaks] Because it doesn't make sense.
 5a:275 **TY: Why doesn't it make sense?**
 5a:276 AC: Because a gun firing and gun silent, there is no way they can be living, in either way.
 5a:277 MG: There is no difference between them -
 5a:278 AC: There is a difference, something come out of the gun this time -
 5a:279 MG: But not living like.
 5a:280 **TY: Well, it depends how you understand living and non-living doesn't it.**
 5a:281 AC: Because if you - OK, maybe if you think of living as a moving thing, then yes. Then a gun firing probably would be OK. But to me living means that you have a life.
 5a:282 **TY: But how do you judge whether you have a life or not.**
 5a:283 AC: ... Um. ... You do.
 5a:284 **TY: OK.**
 5a:285 AC: You need feeding. You eat.
 5a:286 **TY: So the bicycle eats?**
 5a:287 AC: Oh no, I was thinking of the human on it.
 5a:288 **TY: OK, even though it says bicycle on it.**
 5a:289 AC: Yes, because - I mean. Oh!

5a:290 **TY: No, no, it's fine. There is no right or wrong. I'm just asking.**
AC: That is a mistake. [Said whilst TY is still speaking]
TY: Why is it a mistake?

5a:291 **AC:** Because with bicycles I think maybe it is like the silly thing as in that bicycle is still, that bicycle is moving. That gun is still. That gun is firing.

5a:292 **TY: OK. But there is a difference that you've recognised. [DS is changing cards on her mat] Hang on, don't please change your ideas. Don't forget, this isn't about getting it right or wrong, what we're trying to do is find out why we put them where we put them. Even if we then decide they are wrong. So if you want to talk to me about them say - 'but now I've changed my mind', that is fine. But I'd much rather that we didn't swop around at the minute. SP, what is your favourite one, the one you most enjoyed working out? Or the one you found the most difficult?**

5a:293 **SP:** [Pause] Not sure.

5a:294 **TY: Not sure. Is there one of them you want to talk about? Or explain why you put it where you put it?**

5a:295 **SP:** I put the sun as living because if the sun is like in space and the sun like shines through the planet - planets. Yes.

5a:296 **TY: So you're saying that things are living are in space? Or things that are living shine through?**

5a:297 **SP:** Um. They can be living in space and living [unclear - but possibly 'on Earth']

5a:298 **TY: OK. So if the sun - oops - sorry, if the sun is living how do you - could you set it - could you pair it with something else there that is living for the same reason as the sun is living?**

5a:299 **SP:** Tree.

5a:300 **TY: OK. So how is the same - how is that the same as the sun being living?**

5a:301 **SP:** Because like [unclear] the plant, because the sun is going to help the plant grow.

5a:302 **TY: OK. So it is living because it helps the plant to grow.**

5a:303 **SP:** Yes.

5a:304 **TY: And what makes the plant living?**

5a:305 **SP:** Because - because normally there is always a different - when a plant grows it is getting bigger and bigger, so if it wasn't getting bigger it is probably not healthy.

5a:306 **TY: So things that don't get bigger aren't living.**

5a:307 **SP:** [Laughs and says:] I don't know. [TY laughs with SP]

5a:308 **TY: OK. That's fine. And [AC has his hand up] DF.**

5a:309 **DF:** Um. The plant. [DF smiles and looks down at her mat]

5a:310 **TY: What about it?**

5a:311 **DF:** It was easy because - like - I think - well not the plant, the tree, because you know like - I think it is carbon dioxide
TY: Um.
DF: that goes into the tree. And we breathe that too.
TY: [TY cups his hand over his ear. DF is speaking very quietly] We -
DF: We breathe carbon dioxide I think -

5a:312 **TY: OK.**

5a:313 **DF:** - to live. And because we're living with it, the tree's living. I think.

5a:314 **TY: OK. [AC puts his hand up quickly - MG and DS have their hands up] Hang on just a minute. I'm just really interested, because you started with the plant and then you changed your mind and talked about the tree. Can you tell me what the difference is?**

5a:315 **DF:** I'm not sure if the plant [unclear - DF speaks this in a very quiet voice - it might be 'takes in carbon dioxide']

5a:316 **TY: OK. What happens when the plant gets bigger? ... So that one behind MG maybe. Is that a plant?**

5a:317 **DF:** Yes.

5a:318 **TY: And what is the difference between that one and the one outside? Is that a plant?**

5a:319 DF: No, it is a tree.

5a:320 **TY: So why is that one not a tree?**

5a:321 DF: Because it is small.

5a:322 **TY: So it is a size thing?**

5a:323 DF: Yes.

5a:324 **TY: So maybe the plant doesn't -**

5a:325 AC: It is like an adult and a child.

5a:326 **TY: OK.**

5a:327 AC: Like that [the plant in the corner of the room] is the child, and when it gets older it will become adult.

5a:328 **TY: And how does that make a difference about the carbon dioxide?**

5a:329 DF: I just realised right now that they're the same as living.

5a:330 **TY: Cool. OK. Thank you. I still want to know why they're living though. It is because they -**

5a:331 DF: Have carbon dioxide in it?

5a:332 **TY: So things that are living have carbon dioxide in it?**

5a:333 DF: Some.

5a:334 **TY: OK.**
AC: Sir, can I just say something?
TY: Hang on a minute. MG was first.

5a:335 MG: Because they breathe oxygen. Because that is what it is. They breathe oxygen and carbon dioxide comes out. Not that they breathe carbon dioxide - because - and I think it is because it has an effect on everything else living. So everything that is living has an effect on everything that is living.

5a:336 **TY: So that is one of the tests we could do for whether or not something is living. OK. So pick something on there [the mats] that is non-living and tell me how it doesn't have an effect on anything else.**

5a:337 MG: [Pause] [With a smile] A clock [TY smiles as well]
TY: Mm? [TY cups his hand around his ear]
MG: A clock.

5a:338 **TY: OK. What effect does the clock not have on anyone else or anything else?**

5a:339 MG: OK, a brick [MG smiles]

5a:340 **TY: OK. What if I drop a brick on - lets be kind -**
MG: Let's say AC.
TY: Yes [with a smile - everyone laughs] would it have an effect on him?

5a:341 MG: I don't think there is anything there.
AC: No.
TY: We could argue that couldn't we!

5a:342 AC: It feels on my head - no [unclear]

5a:343 **TY: Well it would probably at least make a dent. Wouldn't it.**

5a:344 AC: Probably not, I have a metal head. [AC and TY laugh]

5a:345 MG: You would feel it. OK. So -

5a:346 **TY: So, in that case, is the brick living or non-living?**

5a:347 MG: Living [said quickly] but, it is not actually living.

5a:348 **TY: OK. So is 'doesn't have an effect' or 'does have an effect on something'. Is that going to be a good test for whether something is living or not?**

5a:349 MG: No. What would be is if it is 'has an effect on all things living' and breathes oxygen. That would [unclear - 'work?']. Well I know you can't really do that because you change one variable [unclear - 'at a time?'].

5a:350 **TY: Yes, but this isn't that kind of an experiment is it. It is not really a fair test type situation, so let's say that we can change whatever we like -**

5a:351 MG: Yes, I'd change - I mean yes. Which ones take oxygen and have an effect on all things living.

5a:352 **TY: OK, so it has to have an effect on all things that are alive and it takes oxygen. Right. Anyone else agree or disagree? [Pause - AC puts his hand up] AC.**

5a:353 AC: What she just said 'it takes in oxygen'. I don't think trees take in oxygen I think they take in carbon dioxide and let out oxygen.

5a:354 **TY: Right.**

5a:355 AC: That is why they say don't cut out rain forests. Don't cut down rainforests and everything because you need to get rid of the CO₂ in the atmosphere.

5a:356 **TY: OK, so does that mean that they are not living?**

5a:357 AC: They're probably living because they're breathing. So that is my little -

5a:358 MG: Maybe just breathing anything [unclear].

5a:359 **TY: OK.**
AC: In most cases they'd have to be breathing.

5a:360 **TY: OK. I'm wondering - I'm hoping the answer to this question is 'yes' - if there is another word you guys mean when you say 'breathing'. I think it is a word you have used before, probably in Year 6. And it probably begins with R [pause] and I reckon this might be the key to fixing the rest of it.**

5a:361 AC: Could you help us out?

5a:362 **TY: It begins with R.**

5a:363 AC: Could you tell us what it ends with like how you do in class?

5a:364 **TY: tion.**

5a:365 **TY: It begins with R and it ends in tion.**

5a:366 MG: R tion. What?

5a:367 AC: Rtion. [AC laughs]

5a:368 **TY: That sounded as if it began with A. SP, I bet you know it.**

5a:369 SP: Redution? [sic]

5a:370 **TY: I think you just made up a new one. It sounds like Harry Potter spell.**

5a:371 AC: Redution! [AC waves an imaginary magic wand and laughs]

5a:372 **TY: I wonder what it might do? No, it is not redution.**

5a:373 MG: Radiation!

5a:374 **TY: No. Res.**

5a:375 AC: Respiration! [Others say the word simultaneously - unclear - several students laugh]

5a:376 **TY: Told you you knew it. So, can anyone tell me about R spiration?**

5a:377 MG: Um. Taking something - breathing something in to - that will help that thing carry on living.

5a:378 **TY: OK. Show me breathing? [The students laugh - AC starts to breathe loudly]**

5a:379 AC: No, no, no.

5a:380 **TY: No! That was good breathing.**

5a:381 AC: OK, it was breathing, but breathing can be done like this. [AC breathes more normally]

5a:382 SP: He doesn't want [unclear].

5a:383 **TY: I can't tell if you're breathing or not. Tell me how the plant over there is breathing? [Pause]**

5a:384 AC: It is breathing, but I don't know how!

5a:385 **TY: OK. Does anyone agree? Is the plant breathing?**

5a:386 MG: The leaves might be moving a tiny bit. [MG indicates a very small amount of movement with her hand] We can't see.

5a:387 AC: But that is probably because of the wind.

5a:388 **TY: So to breathe things have to move?**

5a:389 Several students: [Unclear - but clearly 'no']
TY: Hang on, DF is going to tell us.

DF: No. Um. With the air around the object it somehow - maybe the soil or something - takes it in - goes through the stem of the plant [unclear].

5a:390 **TY: So the soil takes the -**

5a:391 DF: Air.

5a:392 **TY: Air. Through the -**

5a:393 DF: To the roots. Then through the stem.

5a:394 **TY: OK.**

5a:395 DF: And then spreads it around the plant.

5a:396 **TY: OK. Where is there more air going to be? Up around the leaves, or down by the roots?**

5a:397 DF: Up by the leaves. [DF laughs]

5a:398 **TY: Up around the leaves, so might you want to change your idea at all?**

5a:399 DF: [DF starts as if she has just thought of something] The air goes from the top of the plant [DF mimes this] to the bottom.

5a:400 **TY: OK, how?**

5a:401 DF: Um

5a:402 **TY: AC, breathe again. [AC does this] Have you ever seen a plant do that? When a plant has been doing some really hard work out there in the garden have you ever seen a plant do that? No?**

5a:403 MG: Maybe with humans you have to move, or animals you have to move, and plants they just - they can do it secretly.

5a:404 **TY: [Unclear] So it is like magic? And you said humans and animals.**

5a:405 MG: No, just animals. I changed it to animals.

5a:406 **TY: Because -**

5a:407 MG: Because like a dog would move when it was breathing and so on. All things with like a face.

5a:408 **TY: So animals are things with faces. [TY gives thumbs up and smiles] Love it. I love it an awful lot. OK. I don't think we've heard enough form you [DS] from this one. Give us an idea. ... Or tell someone they're wrong if you want. [Pause]**

5a:409 DS: I think the lion and the dog are living.

5a:410 **TY: Because -**

5a:411 DS: Because -

5a:412 **TY: Is it because they have faces? [Everyone laughs] No? OK.**

5a:413 DS: Because they move around.

5a:414 **TY: OK, so the lion and the dog are living because they move around. In which case [TY looks at AC's mat] the bicycle is living.**

5a:415 MG: [Smiles then puts her hands over her mouth]

AC: [Laughs]

PP: The dog and the lion breathe.

5a:416 AC: Oh, but for a bicycle -

TY: And the bicycle doesn't breathe?

5a:417 AC: And the bicycle -

TY: Hang on, because the reason that the dog and the lion were living that we heard from DS [TY points to DS with both hands palms together] was because they move around, so you're saying [AC puts his hand up and shakes his raised hand] - Hang on [TY to AC] - You're saying it is not to do with them moving round, it is because they breathe. So we're going back to MG's idea. So anything that breathes is living and anything that doesn't breathe is not living. And that's it. [TY has his hands crossed with his palms downwards and he uncrosses them quickly as he says this last line].

5a:418 SP: No.

TY: Go on.

SP: Not all the time. It is like ... um, say if -

TY: [Simultaneously] If -
SP: a river is like living. But the river doesn't breathe, so -

5a:419 **TY: OK, what makes the river living?**

5a:420 **SP:** [Pause]
MG?: It doesn't. [Unclear as said in a whisper]
PP: [PP shakes his head - it is unclear if by this he means to disagree with SP or if he is just shaking his head for some other reason. Unclear what is said - 'It just is?']. The wind moves it.

5a:421 **TY: So the wind is living also?**

5a:422 **AC:** [Unclear]
PP: [Unclear - as speaking simultaneously with AC]
TY: Just hush, hush [hand gesture palm downwards] for a minute because SP has to finish his idea.

5a:423 **SP:** The water is flowing so it - [SP smiles and sits backwards] I don't know.

5a:424 **TY: So things that flow are living.**

5a:425 **SP:** In some cases.

5a:426 **TY: In some cases. OK. When would a case of something flowing not make it alive? If that makes sense.**

5a:427 **SP:** [Pause] Um. [SP moves his eyes towards PP] I'm not sure [SP laughs]

5a:428 **TY: [MG puts her hand up] Don't know? OK. MG.**

5a:429 **MG:** You know we said that um everything living affects something else that is living.

5a:430 **TY: You said that.**

5a:431 **MG:** Yes, I said that [MG smiles - TY smiles towards MG]. Um - the wind which is living is affecting the water, so that must make the water living.

5a:432 **TY: OK. You haven't put wind in your living pile.**

5a:433 **MG:** I know. I realise. That was what I was going to change, but you said that -

5a:434 **TY: So now you would put wind in the living pile.**

5a:435 **MG:** I haven't - yet.

5a:436 **TY: No, but you would do?**
MG: Yes.
TY: And you'd do that because?

5a:437 **MG:** Because - err - it affects something else that is living.

5a:438 **TY: And that is the only reason.**

5a:439 **MG:** And it breathes - [MG's tone of voice is very unsure as she says 'breathes'] Yes, that is probably it.

5a:440 **TY: OK. DF.**

5a:441 **DF:** I think that animals and humans are like living. I'm not sure about plants, but I know that animals and humans are living because they have organs inside that moves.

5a:442 **TY: So things with organs inside them that move are living.**

5a:443 **DF:** No, not all of them. Like some of them.

5a:444 **TY: OK. OK. And animals they're different from humans?**

5a:445 **DF:** Well they're the same [DF shakes her head slightly as she says this and smiles].
TY: OK.
DF: Like the same kind of stuff: like heart, lungs - the same stuff.

5a:446 **TY: Thank you very much. One last idea. [TY looks over at AC]**

5a:447 **AC:** You know how they said, because the bicycle is moving it is a living thing. But for the bicycle [AC hits the card on his mat with his finger] to be - for the bicycle to be moving a human needs to be on it.

5a:448 **TY: [Pause] Oo. I don't think that is true.**

5a:449 **AC:** Unless the wind is blowing it.
PP: [Unclear]

5a:450 **TY: What if I took a bicycle up to the top of a step ladder and then let go.**

5a:451 **AC:** Yes, you need a human to take it up to the top.

5a:452 **TY: Ah, but that is not what you said. You said you had to be on it. Didn't he?** [TY looks at SP at this point and the tone indicates that TY is not questioning whether he is right, but is asking SP if he agrees that that is what AC said].

5a:453 AC: OK. A human has to move it.

5a:454 **TY: Just a human? What if I had -**

5a:455 AC: Gravity, human [AC says this quite loudly with a tone that indicates some exasperation and smiles - TY smiles too]

5a:456 PP: Animals.
AC: OK.

5a:457 **TY: Yes, we could have a monkey do it.**

5a:458 AC: [Everyone laughs] A very smart one. Yes.

5a:459 **TY: OK. I'm going to - I'm going to give you [JR puts his hand up]**

5a:460 *JR: I'm really sorry to interrupt. Fascinating! Thank you. Would you mind if I brought the camera just over the desk to have a look at the pictures? Would that be OK with everyone?*
AC: Yes [others nod and all appear to be OK with this]

5a:461 **TY: Can we keep talking while you - ?**

5a:462 *JR: Of course.*

5a:463 **TY: I'm going to give you one idea then. And don't change anything. Because along with that word which began with R, -**

5a:464 SP: Respiration
AC: Respiration.

5a:465 **TY: Respiration. I think that you learnt some other words in Year 6 as well, that went with it [JR is videoing the cards on the mats - SP looks at JR] And probably you remembered them with the name of a lady. [Pause]**

5a:466 MG: Is it like a rhyme or something?

5a:467 **TY: It is sort of - what are they called? - where you line up the words. It's a -**

5a:468 MG: Riddle?

5a:469 **TY: Oh dear! [TY puts his hands on his face] Now I got this wrong with my Year 11s, and since I got it wrong I can't remember the word.**
AC: [Simultaneously with TY] Oh, I know, I know, we did it with Lady Macbeth, what is it, what is it [AC speaks rapidly] err ... where it goes down [AC mimes this] and then you have the -

5a:470 **TY: Exactly that.**

5a:471 MG: What is it the lady in the black coat?

5a:472 **TY: No.**

5a:473 MG: Because I think the [unclear] go -

5a:474 **TY: No. Mrs - [Pause]**

5a:475 PP: Sirik? [Unclear - but a surname]

5a:476 **TY: No.**

5a:477 AC: Mrs [unclear - another surname - this is a joke and AC laughs with others]

5a:478 **TY: No. Mrs GREN?**

5a:479 AC: Oh yes! We did that in science. [AC is speaking with MG]
MG: Are you talking to me. I don't remember.
AC: In Miss [a teachers' name] - I can't remember if it was with TY or with Miss [same name].

5a:480 **TY: It definitely wasn't with me.**

5a:481 AC: We actually wrote, Dr GREN or something. MRS GREN or something.

5a:482 Several students: Yes.

5a:483 **TY: Yes? Well what was that all about then?**

5a:484 AC: I don't know. [SP and PP laugh]

5a:485 **TY: Oh. [TY laughs]**

5a:486 AC: MRS G for something.

5a:487 **TY: MRS NERG or MRS GREN?**
AC: MRS NERG
TY: And you didn't meet it in Year 6 at all? With Mrs [surname of a teacher]?

5a:488 MG: We wrote it on the side and there were words [MG mimes this with her hand] to stand for - [TY nods] Yes. But I've forgotten.

5a:489 **TY: Well what was 'M' then? ... You've used it today.**

5a:490 DS: Movement.

5a:491 **TY: Movement. 'R' [TY counts these off on his fingers]**

5a:492 Everyone: Respiration.

5a:493 **TY: 'S' [Pause]**

5a:494 AC: [Name of a pupil who is not present] would have known all of them! [all the pupils laugh - TY smiles]

5a:495 **TY: [Pause] No? Ends in 'ensitivity'**

5a:496 Everyone: Sensitivity!

5a:497 **TY: Give me an example of sensitivity.**

5a:498 MG: Touch.

5a:499 AC: Oh yes, like touch.

5a:500 **TY: Yes. So we've done MRS [TY is still counting off on his fingers] G for GREN.**

5a:501 DF: Gravity.

5a:502 **TY: No. [TY lingers on the N] Not quite. [Nervous laughs from the pupils]**
AC: Girl.

5a:503 **TY: Something that you lot are doing and I've probably stopped.**

5a:504 AC: Grinning. [TY does an exaggerated grin and AC laughs]

5a:505 **TY: [Continuing to grin] Something that you lot are doing and I've stopped doing. ... Because I'm old - er.**

5a:506 Several pupils simultaneously: Growing!

5a:507 **TY: Growth. So we've got movement, respiration, sensitivity, growth, - MRS GR - another 'R'. [Pause] Oo. It is to do with the one that AC claimed not to know anything about.**

5a:508 DF: Embryo.

5a:509 **TY: Embryo.**
AC: Oh, embryo.
TY: Is it because you've never seen it written before?

5a:510 MG: We have. There is a poster on it in our science room.

5a:511 Several pupils simultaneously: [Unclear]

5a:512 **TY: Anyway, what is the word that begins with 'R' that might be something to do with embryos, and you wouldn't be here without it. [Pause]**

5a:513 AC: Reproductive.

5a:514 **TY: Reproduction. And what is that one? [TY to AC]**

5a:515 AC: Um - [all pupils smile. PP starts to laugh and AC joins in] Reproducing. [TY signs with his hands indicating he wants more] Breeding. Making babies.

5a:516 **TY: OK. Yes, making babies. MRS GRE - 'E'. Kids love this one.**

5a:517 MG: Embryo.
TY: No.
MG: Environment.

5a:518 **TY: It is something that - No [to MG's suggestion of environment] -**
AC: [Unclear]
TY: You wouldn't do it in public.
AC: Excitement.
TY: Very close, but no.

5a:519 MG: What?

5a:520 **TY: You wouldn't do it in public. [Pause]**

5a:521 MG: Wait. [MG points at TY] Expose. [Everyone including TY laughs]

- 5a:522 **TY: I bet you wouldn't do that [everyone is still laughing], but that is not quite what I was thinking of. I was thinking about excrete.**
- 5a:523 AC: Excreting.
- 5a:524 **TY: Excreting. What is it that you wouldn't do in public that isn't exposing?**
- 5a:525 MG: Exercise.
- 5a:526 **TY: No, excrete. Excrete is when your body gets rid of the stuff it doesn't need - so it is when you're having a pee and you're having a poo and you're sweating and a little bit when you're - no?**
- 5a:527 AC: Yes.
- 5a:528 **TY: MRS G R E N [TY says each letter separately] - the last one. And someone used this as one of the things. One of the reasons today.**
- 5a:529 AC: Nourishment?
- 5a:530 **TY: Nutrition. Yes.**
- 5a:531 AC: Nourishment. [AC says this laughing]
- 5a:532 **TY: That is quite interesting to me because I've never met a bunch of Year 7s that didn't remember that from Year 6 before.**
- 5a:533 AC: I'd never heard of it.
- 5a:534 **TY: Well, thank you very much. So - then next one. And this is the last one.**
AC: Yes!
TY: And you need a pencil and some paper. Do you [JR] want the bags back?
- 5a:535 *JR: Could I suggest you just put them all in a pile, you know, one mat on top of the other and I'll sort them out afterwards. Is that OK? [JR moves round the table collecting the mats] Do you want to pass me the two mats just like that [one on top of the other] - That was me! Sorry. [Some of the cards have slipped off a mat].*
- 5a:536 **TY: Can someone pass SP a piece of paper please. [Pause - TY is reading the questioning route] OK. Has everyone got a piece of paper and a pencil? Lovely. So here we go. ... Oops [the teddy bear falls over on the table and TY straightens it]. I'll just put him the right way up. Sorry.**
AC: That's terrible.
TY: And I'm going to read the question again. So here we go. Where is it? Please imagine you walk into a completely dark room with that torch on and you see teddy. Please make a quick sketch showing the torch, teddy and your eye which explains how you see - how you can see teddy. Stick people are fine. And when you've done the pictures we'll talk about it.
- 5a:537 AC: [Unclear - a joke about the eye I think] I freak out. [AC and PP laugh]
- 5a:538 **TY: So again, don't look at anyone else's, this is about your ideas please. And again, if you get it wrong, who cares?**
- 5a:539 PP: I don't get this.
MG: [Quietly] We did it in Year 6.
- 5a:540 **TY: You don't get it. Shall I read the question again?**
- 5a:541 PP: Yes please. [The other students are drawing]
- 5a:542 **TY: So, imagine you walk into a completely dark room. With the torch on [TY turns on the torch and holds it up]. And you see teddy [TY points at teddy]. Yes? So what you need to do now, is make a quick sketch**
AC: We did this in our science.
TY: Shh shh. Showing the torch, the teddy, and your eye [AC puts his hand up] which explains how you can see the bear. [Pause] Does that make sense now? [PP has started to draw - TY turns to AC]
- 5a:543 AC: Can I just say, do -
TY: [Interrupting AC] Are you going to answer the question?
AC: No.
TY: Good.
AC: Do we have to use straight lines?

5a:544 **TY: If you think that you should be doing straight lines, then you're more than welcome to use the straight edge on there as a ruler [TY passes AC something on the table for AC to use].**

5a:545 AC: Does the torch have to be in his hand? [AC laughs]

5a:546 **TY: Don't worry about the art. What I'm bothered about is the science. If we made it diagrams instead of art that would make me really happy. But don't change what you've done already. [Pause] Jelly baby? [unclear - but clearly a joke shared with SP - both SP and TY laugh]**

SP: [In a whisper to TY - unclear - continuing the joke] [Pause]

TY: I've just realised that we've got three lefties and three righties. How weird is that?

5a:547 AC: Left, left - wow! [Everyone laughs]

5a:548 MG: Is it OK to write on?

5a:549 **TY: If you want to put some labels so it makes more sense that is fine, but the important bit is to see the diagram. Then of course we've got to explain it. [AC shows TY something on his drawing and both AC and TY laugh] And you said those pictures were random. [Pause]**

5a:550 AC: [Unclear] kind of drawing is going to be terrible as well.

5a:551 *JR: Please would you put your initials on the drawings? ... Thanks*

5a:552 **TY: I'm going to come and see you lot in your art lessons. [Everyone smiles - AC is holding up the teddy while he draws it]**

AC: Oh gosh. [Pause]

5a:553 AC: [AC points at the eyes of the teddy and speaks with TY] His eyes are corduroy.

5a:554 **TY: Corduroy. What [unclear] you got?**

AC: [Unclear - something about 'disgusting']

5a:555 MG: [MG is leaning over point to something on DS's drawing - DS starts to shade something on her drawing - TY is looking over at MG and DS]

AC: Salt and pepper. [AC appears to be speaking to himself]

MG: It is the shadow. [MG says this to TY]

5a:556 **TY: Ah? [This word is extended - MG smiles] [Pause] I wouldn't have thought that in a million years.**

5a:557 AC: [Unclear because MG says something at the same time - but it appears to be 'You won't be here in a million years?']

5a:558 **TY: Yes. Would that I lived that long.**

AC: Next step please.

?: [Unclear]

AC: [Unclear - something said very quietly]

TY: OK. I'm going to ask you [AC] to stop being an artist now and speed it up a bit because other people are almost finished.

5a:559 MG: [Unclear as spoken in a whisper] That is meant to be -

TY: Magic.

5a:560 MG: [Unclear - whisper - 'Stand all day?']

AC: [Laughs to himself and sits back in his chair touching his head]

5a:561 **TY: OK. Right, I'm just going to ask once more then that this picture is supposed to explain how you can see teddy.**

MG: [MG says to DS] That is his head. [DS changes something on her drawing]

5a:562 AC: I'm going to label it.

5a:563 MG: Oh, have we started discussing it?

5a:564 **TY: Not yet, but we can do. I think. We all done? Yes? [DF nods] OK. Now again I'd rather you didn't change the pictures once we've started talking please.**

AC: [Unclear]

TY: And don't forget to put your initials on it. DS have you done that? [DS quickly picks up her pencil and puts her initials on]. AC, initials please.

- AC: Oh yes.
- 5a:565 **TY: OK. Right, here we go** [TY says this is a voice a little louder than usual]. So let's have a look. Can you hold them up so I can see please? [Everyone holds their pictures up - AC is still drawing] The light is reflecting on the teddy and reflecting on the wall [This last sentence is read by TY from DS's drawing]. The light reflects off the teddy and into your eyes so you can see the teddy. [Reading from DF's drawing] The light is helping us see through the dark. Light source, torch, eyes, person, teddy bear. [Reading from SP's drawing] Light is showing because it is dark. You can see the light as it is dark [Reading from AC's drawing] Light from torch bounces off toddy. [TY looks at AC as he says this last word and smiles]
- AC: Teddy.
- 5a:566 **TY: Eye bats**
AC: [Smiling] Looks
TY: at light that has bounced off teddy. [End of TY reading - tone changes from here] That person has managed to get his eye out of his head.
AC: [Laughing] Yes.
- 5a:567 **TY: [TY is reading again] Eye, teddy, shadow.** [TY stops reading] **OK. Can someone please tell me in words, and you can point to your diagram if you want. But again please don't change them. How that all works. DS?** [DS has her hand up]
- 5a:568 DS: The person is holding the light.
TY: Listen [AC has been playing with the pencil - TY takes the pencil from him whilst continuing to look at DS]
DS: The person is holding the torch and it reflects on [DS is indicating this on her drawing with her finger] the teddy - on the teddy. Then the shadow comes on the wall - will be the same. [Unclear - two sentences]
- 5a:569 **TY: OK. And how do we see teddy?** [Pause]
- 5a:570 DS: The torch is bright and if you look around you can actually see the teddy bear where it is sitting. And the shadow.
- 5a:571 **TY: OK. And what part does your eye play in that?** [Pause] **How does your eye see teddy?** [Pause]
- 5a:572 DS: The shadow of the light.
- 5a:573 **TY: So you don't see teddy, you see the shadow?** [TY raises his eyebrows, turns his head slightly and there is a larger than normal inflection in his voice to emphasise the question]
- 5a:574 DS: Yes.
- 5a:575 **TY: OK. Thank you very much. PP?**
- 5a:576 PP: The torch is shining on the teddy. And you can see the teddy because the light from the torch is bright enough so you can see it. And the light - the teddy bear - the teddy is blocking the light which makes the shadow on the wall.
- 5a:577 **TY: OK. So you see teddy because it is bright. And again. How does your eye [TY points with his finger towards his own eye and moves his finger in a circle] take its role? What is your eye doing in that process?**
- 5a:578 PP: The eye - the eye can see the teddy because the light shines on -
- 5a:579 **TY: [Pause] On -**
- 5a:580 PP: Teddy.
- 5a:581 **TY: Lovely. Thank you. SP?**
- 5a:582 SP: You can see the teddy because like the torch is pointing right at it. You can see the light. And it can make you see the teddy as well. [SP hold one hand flat on the table with the palm upwards - the other hand is obscured from this angle, but may be visible from the other camera] ... Because it is in darkness so -
- 5a:583 **TY: Say that again. So it is in darkness, you shine light at -**
- 5a:584 SP: The - where ever you want to point it at.
- 5a:585 **TY: Yes.**

5a:586 SP: And if there is something - an object there - you can see the light - you see the light and you can see it reflected onto the object.

5a:587 **TY: Where does the light reflect from? So that it reflects to the object?**

5a:588 SP: It reflects from the torch to the teddy.

5a:589 **TY: So the light reflects from the torch to the teddy [TY mimes this with his hand] and - [TY raises his eyebrows]**

5a:590 SP: And you can see it.
TY: And you can see it. Thank you. [TY indicates with his hand that AC should speak next. MG has her hand up] Hang on. Who is first? DF or AC?

5a:591 AC: Let's go for a vote. Who votes it should be DF? [MG and AC are the only ones to put up their hands] [Everyone laughs including TY]

5a:592 **TY: Democracy in action. Go for it.**

5a:593 DF: Um. Um the tor - there is this thing we did in a science test. Where there was a person, a light, and there was an object. We had to draw arrows on which way it is going to go [DF mimes this with her hand]. So like the person - I think so - is - I think it is from the light to the object - which we can see - and then it goes into a triangle kind of thing.

5a:594 **TY: OK. So are you remembering what it looked like to help you to answer it now? [DF nods] What might be a better way than trying to remember the picture that you almost remember?**

5a:595 DF: Um. [Pause] To do it on this? [DF points at her drawing]

5a:596 **TY: OK. What I'm thinking, in my head - I'm not very good at remembering pictures. I like to remember things step by step by step - do you remember when PP was telling us about his ideas for the steam and the ice and I could hear that he was thinking in steps. And that helps me when I think in steps. So can you think about that again, and then maybe you can tell me something about the diagram. So keep the diagram if it is useful, but I want you to try and build an explain onto it as well.**

5a:597 DF: OK. The torch which reflects onto the teddy which I think bounces off him - goes to your eyes and means you can see the object.

5a:598 **TY: So the torch bounces off your eyes. [TY smiles slightly as he says this and the tone might be slightly mischievous]**

5a:599 DF: [Quickly] The torch reflects onto the teddy bear and then light bounces [DF mimes this] into -

5a:600 **TY: OK. Then I want to ask about two words. Bounce and reflect. What is the difference please?**

5a:601 DF: Um. Bounce is like when it's jumping off something. And reflect is like when there is like a light hitting onto something [DF mimes with her hand this light hitting and coming off] and you can literally kind of see it. Ish.

5a:602 **TY: See it ish.**
DF: Yes.
TY: OK. So it bounce is when something [bell sounds] is jumping off something?

5a:603 DF: Yes.

5a:604 **TY: And light can't do that?**

5a:605 DF: [Very quietly] I don't know.

5a:606 **TY: OK. Thank you. AC? [TY claps]**

5a:607 AC: Step one. [TY puts one finger up] The torch is switched on. Step two. [TY continues to count off each stage with his fingers] The light comes out of the torch and bounces off the teddy. Step three. The eye can see the light that has bounced off teddy.

5a:608 **TY: OK.**

5a:609 AC: That is my explanation.

5a:610 **TY: Thank you. Is there a word that we've just used that you could use?**

5a:611 AC: Um. Reflect.

5a:612 **TY: Go on then.**

- 5a:613 AC: Step one. [Unclear - by TY's reaction this is probably the same as before - could be 'The torch is turned on'] Step two. The light reflects off the teddy and bounces off it. Step three -
- 5a:614 **TY: Hang on. Reflects off the teddy and bounces off it?**
- 5a:615 AC: No. Reflects - no, no. ... Reflect - the light reflects off [unclear - could be 'on'] the teddy I think.
- 5a:616 **TY: On the teddy.**
- 5a:617 AC: Off the teddy.
- 5a:618 **TY: Off the teddy. So where does it start?**
- 5a:619 AC: Can I just say that the the torch - the light hits the teddy [AC mimes this with his hand] and then it comes back to the eye somehow. The eye looks at the light that has bounced off the thing.
- 5a:620 **TY: Which one of those two last statements do you want us to keep? The one where light reflects off or where the eye looks at the light?**
- 5a:621 AC: [AC leans in his chair] ... The torch reflects off the teddy and the eye sees the light.
- 5a:622 **TY: OK. Thank you. MG, why did I leave you till last?**
- 5a:623 MG: Because I'm better than everyone else. [Everybody laughs]
- 5a:624 **TY: OK.**
AC: That was what [unclear]
TY: But what would make you good?
- 5a:625 MG: Um. I was joking about that.
- 5a:626 **TY: I'm still interested. Why would you think it -**
- 5a:627 MG: Because we did this in Year 6 and we learnt about -
- 5a:628 **TY: I left you till last because you did it in Year 6? [TY smiles] What makes you good is you did it in Year 6.**
- 5a:629 MG: Um. Because you thought [unclear]
- 5a:630 **TY: Explain that please [the drawing MG is holding].**
- 5a:631 MG: In Year 6 we did learn that we're meant to do these lines to represent the light travelling. And we had to - yes -
- 5a:632 **TY: Can I just check then. So is this in the same way as DF remembers. That you just remember that you have to draw lines?**
- 5a:633 MG: I don't remember it, but it is because that is what you do. You learn it -
DF: That is like the science test.
MG: It is not like you're just remembering it - but - or shouldn't be - but it is not remembering but because we learnt the whole scientific part of it and then it just -
- 5a:634 **TY: OK. So tell us the whole scientific part of it.**
- 5a:635 MG: I think the light is travelling from the torch to the teddy and then the teddy is reflecting light to our eyes and we learnt that - you have ... I was kind of confused - I kind of forgot whether it was light goes to your eye and then to the object or the object then to your eye. But then now I remember in Year 6 I asked that question and the teacher explained that if the light was in your eye it is like you're shining the light in your eye so it makes it worst to see. So obviously it is the other way round, so that is why I drew it like this.
- 5a:636 **TY: Cool. Well remembered. Yes. That is really interesting [TY sits back a little] hearing the difference in remembering the picture - and I know that does work for some people - but I think what MG has done is actually remembered why [tone of why is lower] and what is going on. There is quite a few ideas this afternoon that have done exactly what we asked for - that haven't been completely right. And that is fine. It is something that we're going to have to come back and talk about at another time. I think we also need to talk about how we can remember things. And I'm still thinking the step thing is good. Although I do understand that for some [TY is looking at MG and or DF as he says this] the picture thing is good. OK. So there**

- are some very quick ones now. ... Of all the things that we've discussed what has been the most useful for you? [Unclear - one sentence]**
- 5a:637 MG: This one [MG points at her drawing], because um because we're probably not going to learn it again in this school, we might learn it again in this school, but it reminded me of what we've learnt in primary school and might need to learn it again. So we need to remember that kind of stuff. [TY nods] Because it is useful.
- 5a:638 **TY: I promise you we will learn that again. Probably three times, which shows you how well we expect you to have learnt it.**
- 5a:639 AC: The living and the non-living one, because it shows that not always we're right, and we have to think - we have to think a lot harder to be right. And also we have to think in other people's points of view so what they're arguing could be right [unclear] about what you [TY] just said.
- 5a:640 **TY: That's true, but do you know what, the idea of having that MRS GREN [TY holds up seven fingers] Seven, six, seven - the idea of MRS GREN is so that you don't have to argue. Because once you've gone through those whole - that whole list of processes everything that is living should have them, and everything thing that isn't living might have some of them, but it won't have - [TY pauses]**
 AC: All of-
TY: All of them. And that is why I kept asking people for a test. And you all came up with a test, and they were good tests, but the trick is that you actually need more than one test for that - that separation task. But yes, you're right [TY is now speaking with AC] it was useful to see how people had to change their ideas based on everybody else's'. PP?
- 5a:641 PP: I think - this one [PP points at his drawing]
- 5a:642 **TY: This one.**
- 5a:643 PP: Because I think it is like - it is confusing. Um. [Unclear - PP speaks this very quietly]
- 5a:644 **TY: OK. Cool. SP?**
- 5a:645 SP: This one, because when you like see the torch you don't really think about these things.
TY: Mm.
SP: And like you're just thinking of [unclear] this being a light so I can see it [?]. It is different to seeing how it happens.
- 5a:646 **TY: Cool. DF?**
- 5a:647 DF: This, because when we learnt about it in Year 6 [unclear - DF speaks this very quietly - and there is noise from the corridor outside] didn't have understanding.
- 5a:648 **TY: Cool. DS?**
- 5a:649 DS: I think the ice and the coffee one because - because [unclear - something like 'we were not frightened to discuss it and to be wrong'? Background noise as the classes are moving]
- 5a:650 **TY: Yes, it was nice having people justify. That was good.**
- 5a:651 AC: Sir? [AC puts his hand up] I think this one could have been quite good because we didn't even switch the torch on, but we knew exactly what it would be like. [TY nods] Well not exactly, but we had an idea about what it would be like.
- 5a:652 **TY: So because it is something that you've experienced before -**
 AC: Yes.
TY: that made it easier -
 AC: Can I switch it on then?
TY: Yes. I don't know if it works.
- 5a:653 AC: How do you switch it -
TY: Bang!
 AC: Oh, it works.
- 5a:654 **TY: Right [bell rings], one last question then. What should we have talked about but we didn't? [Pause]**

5a:655 AC: There was the bicycle.
 5a:656 MG: Gravity.
 5a:657 **TY: OK. Why?**
 5a:658 MG: Because it is something we the learning about that [unclear]
 5a:659 PP: How do you turn it on? [AC has passed the torch to PP]
 5a:660 MG: It is something we learn in Year 7 - one of the first few things.
 5a:661 **TY: And so because we learn about it in Year 7 we should have talked about it?**
 5a:662 MG: Because that is what we're focusing on, so that is what we'll be thinking about in science.
 5a:663 **TY: Fair enough. Anything else?**
 5a:664 SP: Energy.
 5a:665 **TY: [Unclear - one sentence] OK. Right, well thank you very much for this afternoon. I think we'll just [unclear - 'finish'? TY looks over at JR] That was really interesting for me. Really interesting - again thank you. I'm sorry that you had to miss maths [tone and TY's expression indicates this is said 'tongue in cheek'].**
 5a:666 AC: You don't have to apologise [TY laughs - everyone smiles] Like we thank you. [Everyone laughs].
 5a:667 **TY: I don't want to keep you from your interesting lessons -**
 AC: You do.
TY: No. MG? I thought you were going to say something?
 5a:668 MG: I said I'm joking. Because I said yes -
TY: Oh right. Cool. OK. [TY turns to SP] We're going to continue with ideas about energy after half t - after Easter.
 5a:669 END
 JR: [Kit Kats out] Anything else you'd like to say?
 AC: When is the next time you're coming? [Everyone laughs]
[End 5a]

Interview 5b

5b:1 *JR: Excellent. Thank you very very much for doing this. I really appreciate that.*
 5b:2 **TY: OK.**
 5b:3 *JR: [Reading] Please would you watch each video clip and then 'think aloud', by that I mean talk freely about anything that comes to mind about the video. I'm interested in how you might solve these problems. What you'd actually do to help children when they think like this. Please just report your thinking as accurately as you can in your own words. You don't have to edit, explain or justify your thoughts. We'll leave how you understand - well, we'll add to how you understand raised in the second part of the interview. Everything you say will be anonymous - just like the first interviews. There are 17 clips I think [JR checks this on the laptop] Yes, 17 clips, but we don't have to use them all. Please try to do some from each of the three topics. So [pointing at the symbols on the laptop screen] there's the cup of tea, that one is the living - so there are lots and lots from the living one, so we might - please feel free to cut that down if you feel that is necessary.*
TY: Yes.
JR: We'll spend a maximum of 30 minutes on this and I'll keep an eye on the time. [JR looks at his watch] So we're starting at ten to two. I'd like to ask you a few questions which will last another thirty minutes. Please feel free to just say when you've had enough, or when you need a break [TY smiles]. I'll try not to interrupt you while you're watching and responding to the videos. Please don't worry if you can't make sense of what the children say in some of these clips [TY and JR laugh]. Some of the ideas which came are very very challenging, even for trained scientists like ourselves. Since I started exploring children's naive concepts I've discovered several of my own. Please just say if you'd like to unpack an idea together. I'm aware that you're being asked to do something

which is difficult, namely to respond immediately to some very challenging naive concepts [TY nods]. In the classroom we often have to respond quickly, and it is this thinking that I'd like us to explore together. Is there anything you'd like to - [TY shakes his head] check before we start?

5b:4 **TY: No.**

5b:5 *JR: Lovely. Many thanks for doing this. So to play them you click on the link. It should play automatically after 3 seconds. To pause you can click on the video once. If you click once again it should start the video again. And there is a 'home' button in the corner which takes you back to this screen. So you can just go through at your own pace. This tells you how long the clips are. You might not want to watch a clip to the end, and that is absolutely fine.*

5b:6 **TY: Right.**

5b:7 *JR: Thank you.*

5b:8 **TY: Oops. [Clip 1 starts to play then stops]**

5b:9 *JR: Yes. So, if that happens you just go back and play it again. [Pause - video doesn't start - JR clicks it] Sorry about this.*

5b:10 *CLIP 1: air into water [ID 5a:51-74] 5a:51 MG: The ice is melting into the water and the coffee there's - there probably was steam coming off but now it has cooled down so there is less. ...*

5a:52 **TY: OK.**

5a:53 *AC: Because the coffee is hot and the glass [AC touches the ceramic mug] is kind of cold - it was cold probably - there is like condensation going on the edges [MG puts her hand up - TY leans over to look into the mug].*

5a:54 **TY: Of the -**

5a:55 *AC: Cup.*

5a:56 **TY: OK. Yes. I can see that. And how do you explain that?**

5a:57 *AC: ... The hot air rises and it hits the cold surface and turns into water.*

5a:58 **TY: So the air turns into water.**

5a:59 *AC: Yes. No, the surface.*

5a:60 **TY: The surface.**

5a:61 *AC: The hot air. [AC nods]*

5a:62 **TY: Does what?**

5a:63 *AC: Turns into water. [AC is leaning his head on his hand covering his mouth a little - he laughs a little as he says this]*

5a:64 **TY: So air turns into water.**

5a:65 *AC: Yes.*

5a:66 **TY: When it hits a cup.**

5a:67 *AC: Yes. If it is cold.*

5a:68 **TY: If the cup is cold then the air hits it -**

5a:69 *AC: Hot air.*

5a:70 **TY: If hot air hits a cold cup then the air will turn into water.**

5a:71 *AC: [Pause - AC looks round at the other students as if for help - MG has her hand up - TY smiles at AC]*

5a:72 **TY: I'm only checking. Is that what you mean?**

5a:73 *AC: Yes.*

5a:74 **TY: OK. Thank you. [TY turns to MG]**

5b:11 **TY: I... That's really interesting because I think again, he was - we talked before about maybe they thought I was trying to catch them out. And that - I've never seen myself do that before. But what I was trying to do was highlight - without telling him where I thought he was going wrong - what I thought he needed to think about. So the emphasis on the air hitting the cup [TY says these last five words deliberately]. And he'd got a long way past there by correcting me. Because it was the hot air and**

the cold cup [TY smiles slightly as he says this], but he didn't pick up what I was I think at the time probably aiming at, which is that it was the air that was doing it rather than anything else. [Pause] And actually he's - he's one of the best at sticking at it. And everyone is waiting for him to correct me [TY laughs] in the way that he did. So he is doing exactly what I expected him to do in terms of process, erm but failing to get the big hint which was air - and I think probably I would then extend it and ask about - I don't know what I did do. Probably try and set up something that would stand in the way of it being air - ask something about the structure of water - which isn't going to work with Year 7 because they probably don't know that yet. ... [TY turns to JR] And I've now forgotten what I'm supposed to do next. [TY and JR laugh] Is that alright?

5b:12 *JR: That's great. And sometimes with this verbal protocol thing it takes two or three just to sort of get into the swing of it. So please - that's fantastic.*

5b:13 **TY: OK.**

5b:14 *JR: I realise it is weird just seeing a little clip out of things. And a lot of the ideas that are here, obviously you did deal with in all sorts of interesting ways. And I suppose I'm comparing the ways that you actually dealt with it there, to your thoughts now.*

5b:15 **TY: Um ... I think I'd do much the same. But then extend it, as I've suggested. Um. ... And probably spend some time questioning that he was very - he was making an emphasis on the hot and the cold. So spend some time exploring why it was that hot and cold made a difference. Um. And probably try and do something to reverse that idea. So what would happen if we had cold steam hitting a hot cup. But knowing AC he would tell me that you couldn't have cold steam. So. [TY and JR laugh] That would probably fail in its tracks. Maybe that is a step too far. ... It was interesting watching everyone else just sit back - because they are ... I don't think that they had any better idea of what was going on so they were interested to see how he would cope with the the the fencing [TY laughs] of the questions rather than actually - I think they're enjoying it as a spectator sport rather than actually taking part in the model building or the model deconstructing. And I don't - I think normally in a classroom I would probably have been using my eyes to include more people which I didn't do that afternoon. I was much more interested picking out individual pupils' ideas.**

5b:16 *JR: Using your eyes to - ?*

5b:17 **TY: So I might - I'm looking now [TY points at the screen] I think probably at DS or MG who is about to speak maybe. But I would be just checking [TY mimes looking at different people with his eyes] that people - just catching their eye. And it may not be what I think is happening, but I think when I do that they'll either go [TY mimes a student shaking their head], "Ugh, didn't get it." or [TY nods] "Yes, that's where I'm going." Or just try to pull them in [TY mimes pulling something with both hands] whereas SP [TY points at SP on the laptop] is spending most of his time just laughing. I think probably because PP is looking a bit confused. And PP, I think, was - I don't think he got this one at all from memory. So I might then have jumped off and asked PP to compare - I think there was a bit later on about the comparison of those ideas. And probably to see what he could do with AC's idea to turn it into something that he thought was better. And then to justify that. [Pause] [TY nods] **Right. [TY looks at JR]****

5b:18 *JR: Thank you. So the house is in the corner if that is OK. [Pause - the video does not start] Sorry about this. [JR clicks the video again] They should just play.*

5b:19 *CLIP 2: conducting [ID 5a:150-175] 5a:150* **TY: OK. So when I asked what is - I can't remember how I asked it now, we were talking about the heat from the - the steam from the tea melting the ice. And I said, 'what is conducting'? And I think people said the plastic and the steam and maybe some people said the water. Do the answers to that question go with the definition of conducting that you've just told us? ... So if**

- conducting is where heat can go through things, and insulating is the opposite of that, where heat doesn't go through things, is it possible that in the set up that you've described it like this [TY lifts the bowl of ice and places it on top of the cup of tea] is it possible that the steam was 'conducting' or 'going through' the plastic pot? [pause]*
- 5a:151 AC: *I'm not sure. What I think is happening is the steam is going up to the bottom and then it made the bowl underneath warm and because it made the whole bottom bit warm it melted the ice.*
- 5a:152 TY: **OK. And can you do any of that using either the word insulate or conduct?**
- 5a:153 AC: *Probably one of them. Yes.*
- 5a:154 TY: **[Laughing] Do you want to give that a go?**
- 5a:155 AC: *[Laughing] No.
[TY and JR laugh]*
- 5b:5a:156 TY: **Is there a good reason why not? [Still smiling]**
- 5a:157 AC: *Yes, because I'm not sure.*
- 5a:158 TY: **Are we bothered?**
- 5a:159 AC: *Yes.*
- 5a:160 TY: **Are we? [Eyebrows raised and a surprised tone]**
- 5a:161 AC: *Yes, we should be.*
- 5a:162 TY: **We should be but we're not.**
- 5a:163 AC: *No.*
- 5a:164 TY: **But if we all agreed that it was OK to get it wrong. We really don't care. We'd like to just have a good laugh anyway.**
- 5a:165 AC: *OK. I would say conducting. ... Conducting heat ... [TY turns his hand at the wrist]*
- 5a:166 PP: *The heat conducts the bowl which makes the bowl warm and the ice melts - the water makes the - the bowl makes the water warm which melts the ice.*
- 5a:167 MG: *I think maybe -*
- 5a:168 TY: **Hang on just a minute. That was really good. I liked the way that you broke it down into steps. That really worked for me. I still think we need to sort out this word conducting.**
- 5a:169 MG: *I don't think it is conducting because -*
- 5a:170 TY: **What is?**
- 5a:171 MG: *I don't think that the steam is conducting the bowl because we don't know if it is warm, we just know that the ice is melting, but the ice could be -*
- 5a:172 TY: **Hang on. We don't know that what is warm?**
- 5a:173 MG: *If the underside of the bowl - the inside of the bowl - we don't know that it is warm, so we don't know if - because we can't check [MG mimes touching the underside of the bowl?] either because the water is cold, so that is obviously not - So it might just be that the ice is melting as ice melts. And it is not because of the -*
- 5a:174 TY: **Oh, I see what you're saying. So what - I think what you're saying then is you're not sure if AC and PP's idea, that there is heat coming from the tea which is conducting - I'm going to use it how I would describe it - the heat is [TY pauses the video here] conducting through the bowl - you're not sure if that is happening.**
- 5a:175 MG: *Yes.*
- 5b:20 TY: **I just want to stop it now because there are ideas that I'm going to forget. So what I've spotted that I was doing was trying as much as I can to use the words that they used when I mirror it back to them. [TY counts these points off on his hand] Making it clear that I may have got it wrong. So I'm giving them an 'out', rather than, "This is what you said! I'm going to hold you to it." Um. Giving praise for having done the right process - gone through the right thinking process, even though it may not have actually helped us answer the question. Asking them to use the terms specifically because those were the terms that they still haven't got a grasp of**

because they're still incorrectly using this concept that they've built about conducting. Um. And then asking them to unpack those ideas. At least that was the aim. I think. Oo. [TY tries to replay the video, but it jumps onto the next video].

5b:21 JR: Sorry about that, I think it might be starting from the start again. I think you were near the end on that one - would you like to watch it through again or should we -?

5b:22 TY: Yes. We'll watch it. [CLIP 2 plays again from the start]

5b:23 JR: Sorry. There may be a way that we can... I think we were at least a couple of minutes in. If I try and play that? [JR moves the video to near the end - it restarts at line 5a:173] Is that OK?

5b:24 TY: Yes. [TY listens to the end of the clip]

5b:25 TY: Very [unclear]. I also like that PP picked up when it was clear that AC wasn't actually going to go ahead and play with those ideas. That PP had been sitting there quietly and thought, "Do you know, I'm going to give it a go anyway." And right back in September, PP wasn't a logical thinker at all. It was scatter gun just blu blu blu - and then he'd sit there embarrassed because he'd worked out from the questioning process that it had been all over the place. And actually for him to do that, on that day, in front of a camera and [TY turns to JR smiling] and out of his comfort zone. I was really proud of him for that. ... And I'm actually worried now - looking at DS with her hand up there. Because there was a couple of times where she shook her head and I didn't catch - I'm hoping that there is more of a conversation that I might have had with her. But I can't remember one. And I have a funny feeling that I was focusing too much on these three [TY indicates three students on the screen] for this question. And I suspect that he [SP] probably got too much of a fair share SP - on the living things question. ... [TY nods to himself]. OK.

5b:26 JR: You might need to - [JR clicks on the laptop screen]

5b:27 TY: [Reading] Steam wore out. Oh yes! [TY and JR laugh]

5b:28 CLIP 3: steam wore out [ID 5a:182-207] 5a:182 AC: Just out of interest, how long has it been there for?

5a:183 TY: Probably [TY looks at his watch] about twenty bleuh - half an hour.

5a:184 AC: And it was just ice in the beginning?

5a:185 TY: I don't honestly know the answer to that question.

5a:186 PP: When did you make the tea?

5a:187 TY: I didn't make the tea. [TY smiles]
[TY and JR smile]

5b:5a:188 PP: When did you put it there?

5a:189 TY: About half an hour ago.

5a:190 MG: [Unclear - 'was it made before?'] and it is still hot.
PP: The steam might have wore out?
AC: It is still hot.

5a:191 TY: OK, well that is a really interesting idea [TY is looking at PP and sits back in his chair]. The steam might have worn out.

5a:192 MG: And I think -

5a:193 TY: Hold on - I want to hear more about this idea. How can steam wear out?
AC: [Appears to laugh? Sits back in his chair]

5a:194 PP: Because it - the coffee might get cold [TY nods] and the steam can just like go.

5a:195 TY: So are those two things related? Does one cause the other to happen? Or is it just that they happen to happen at the same time.

5a:196 PP: The steam has slowly - like wears out. ...

5a:197 TY: And how does that relate to the tea getting -

5a:198 PP: It is just like - there is hardly any heat going to the - conducting the bowl. To the bowl. And that is how like the water gets warm, but it is not being warm because there is no steam. [TY looks at the ceiling] ... There is no heat.

- 5a:199 **TY:** *OK, right. So at the beginning of the experiment I think what you're suggesting is that there is a lot of steam, and that the steam melted, or helped to melt the ice, and at the end of the experiment there wasn't a lot of steam and so the melting stopped. ... Is that right?*
- 5a:200 **PP:** *Yes.*
- 5a:201 **TY:** *OK, so tell me about - now forget about the ice melting, [TY removes the bowl from the top of the cup] tell me about the steam and the temperature of the tea.*
- 5a:202 **PP:** *The temperature would have gone down and it would have gone cooler and it would take longer for the ice to -*
- 5a:203 **TY:** *No ice. Just tell me about the steam and the tea. So at the beginning you said there was a lot of steam, and what was, what can you tell me about the tea when there was a lot of steam?*
- 5a:204 **PP:** *The tea was very hot. Then as it got cooler the steam slowly wore out.*
- 5a:205 **TY:** *OK. And what do you mean by 'wear out'?*
- 5a:206 **PP:** *Like it goes.*
- 5a:207 **TY:** *So there is less of it. [AC puts his hand up]*
- 5a:208 **PP:** *Yes.*
-
- 5b:29 **TY:** [Pause] Um. ... So what I was doing - I let him say his piece, and then reworded it. [TY looks at JR] And then checked - which he didn't get - I don't think he worked out why I was waiting at the end [TY laughs]. Checked that he was going to agree that that is what he meant by way he'd said. Changing a little bit along the way. And what I didn't do, right until the end, which surprises me now, is ask, "What do you mean by, 'the steam wore out?'". Because that is what I was going after. Um. And I think I got side tracked because he was coming up with a really good model for what might have happened. But the bit I'm int- proud about is that I let go of the bit about the incorrect usage of conduct. Because - these are chronological aren't they? [TY is asking JR] That we'd done that. We weren't going to fix it. And I'm actually surprised because that is one of the things that I've been most irritated about myself this year [TY smiles] - that I get stuck in a rut - I hone in on one little thing that they didn't get right, that at the time feels really important that we fix it - at the expense, I think, of further exploration of other probably more easy - easily fixable misconceptions. And it is one of the big conversations that I've been having this year. Do I, should I, learn to let some things go? Because we're never going to fix them. Or we're not going to fix them to an extent that - that it is worthy. And instead pick up lots of other little bits that are more easily fixed in the period of time that we have available. And I did it! [TY and JR laugh] I don't think I was aware at the time - or at least maybe I was - maybe - It is a very different thing when you're doing it for a different purpose. I think I would have behaved differently in my classroom - I suspect that I would probably have stopped everything else and we would have built a proper model for conducting. Um. I - I half wondered at the beginning if they were - they'd got the concept right, and it was just a grammatical error in using both terms. And I don't think it was actually. I think - I think the conduct - and it would appear that it was all of them get it. And I don't think that that was one person driving how we will understand that term [last six words said with emphasis] I think they all share the same - and shared at the beginning the same type of misconception about using the word 'conduct'. I think PP's 'wearing out of the steam' - that is probably his own. And it is not really wrong how he describes it. Just an interesting way of describing it. Not a very scientific way of describing it. But in the process he is actually probably understood more about the science of what is actually going on. And had some really nice ideas that have come out. And AC is doing the right thing and hasn't interrupted him, and has put his hand up [TY and JR laugh]. Mmm. I like that one. [TY goes to play the next clip] Oh dear! Yes. [TY and JR laugh]

5b:30 CLIP 4: embryo [ID 5a:258-263] 5a:258 AC: Sir, what's an embryo, I'm not sure.
 5a:259 MG: You do [to AC]. You do know what that is. You talked about it in science.
 AC: You do.
 MG: You talk about it in science.
 AC: Me?

5a:260 TY: **You've definitely done about that with [name of a teacher].**
 5a:261 AC: I talk about it? I talk about it? [With a very incredulous tone]
 5a:262 MG: You saw a poster on the wall and then you started laughing, so you do know what it is. [AC stares at the card for a moment].
 5a:263 AC: Oh! [MG and TY smile discretely] Yes, I do know what it is. I didn't realise [Pause] [MG moves one of her cards from one mat to the other - unclear which] [DF moves one of her cards - unclear which]

5b:31 TY: [TY and JR laugh] **I thought it was really nice how MG was trying to - she is sort of doing a me. She hasn't told him what it is. And isn't going to. But is giving him all the clues that he needs to work it out on his own. And he did in the end. And interesting that he hadn't recognised it for what it was divorced from the ideas that go with it. And it is quite a recognisable - I can't actually remember the image itself because there was more than one embryo image wasn't there?**

5b:32 JR: *I think just one of the embryo [JR gets a set of the cards out from the card sort and finds the embryo image]*

5b:33 TY: **Was there? [Pause while JR finds the card - JR passes the embryo card to TY] Oh, and it had the word on it didn't it. Yes. And the funny thing is - on top of that is that that stayed with me for the whole of Easter. Because I went away to [an African country] and saw cashew nuts growing on a tree, and [TY laughs] saw these cashew nuts growing on a tree and went back to this conversation with AC. And what MG didn't do, which I would have done, was to try and work out what that diagram [TY is looking at the image of the embryo on the card] might be by trying to identify features of it. Interesting that he hadn't got even the word. You know, he had nothing linked to that word at all. Easily accessible. But then none of them had for the whole topic. And I've checked and they have don't it. This year. [TY looks sideways at JR]. They've done it - they've done it lots! [TY laughs] Which is really quite a worry. ... [TY nods] And I hadn't spotted MG - I knew that it was interesting. But I hadn't spotted MG doing that at the time. And she has picked up that [TY laughs] irritating style of questioning! [TY and JR laugh] Good for her. [TY plays the next clip].**

5b:34 CLIP 5: gun and bicycle [ID 5a:270-291] 5a:270 AC: *Maybe they was just random. Like a gun firing and a gun silent.*

5a:271 TY: **So when you say random -**
 5a:272 AC: *It was just out of the blue. I just don't think it was appropriate.*
 5a:273 TY: **Why?**
 5a:274 AC: *[Laughing as he speaks] Because it doesn't make sense.*
 5a:275 TY: **Why doesn't it make sense?**
 5a:276 AC: *Because a gun firing and gun silent, there is no way they can be living, in either way.*
 5a:277 MG: *There is no difference between them -*
 5a:278 AC: *There is a difference, something come out of the gun this time -*
 5a:279 MG: *But not living like.*
 5a:280 TY: **Well, it depends how you understand living and non-living doesn't it.**
 5a:281 AC: *Because if you - OK, maybe if you think of living as a moving thing, then yes. Then a gun firing probably would be OK. But to me living means that you have a life.*
 [TY laughs]
 5a:282 TY: **But how do you judge whether you have a life or not.**
 5a:283 AC: *... Um. ... You do.*

5a:284 **TY: OK.**

5a:285 **AC: You need feeding. You eat.**

5a:286 **TY: So the bicycle eats?**

5a:287 **AC: Oh no, I was thinking of the human on it.**

5a:288 **TY: OK, even though it says bicycle on it.**

5a:289 **AC: Yes, because - I mean. Oh!**

5a:290 **TY: No, no, it's fine. There is no right or wrong. I'm just asking.**

AC: That is a mistake. [Said whilst TY is still speaking]

TY: Why is it a mistake?

5a:291 **AC: Because with bicycles I think maybe it is like the silly thing as in that bicycle is still, that bicycle is moving. That gun is still. That gun is firing.**

5b:35 **TY: [TY and JR laugh] Yes, I think again they were expecting - a trap [TY laughs]. Or at least AC was. Um. And his initial response was that it was inappropriate, which is a really interesting choice of word I thought. I thought it was going to be, it is inappropriate because it is a gun. And it wasn't. It was just - to his mind - that was a silly question. But he'd missed the point that the question was, some of these things will be not living, and some of them will be living. And then he started to apply the success criteria for living and non-living, which I don't remember - I can't remember where that was in the discussion of that, but it hadn't been - I left that afternoon feeling a bit downhearted that they hadn't grasped at all that you needed these - all of the seven life processes and hadn't been able to recall them as the life processes. And didn't really - it wasn't an idea that they were interested in either. They felt quite interested in the conduct and the melting, and this - they didn't seem really bothered that they didn't appear to understand. They didn't feel as if they felt ... motivated to explore that idea a bit more either. They weren't not going to do it. But they didn't feel like a [TY mimes something coming together with both hands] ... critical mass of, "Yes, let's go and find out why we don't understand this." And then the bicycle thing. A big thing that I find with our kids, and I don't know if that's a wider problem, is that they misinterpret so much of the written word and so many diagrams that you really do have to unpack it. Because he - you know - he [AC] wasn't suggesting that a bicycle was alive. But in his eyes it was completely acceptable to misinterpret bike with the word and a picture as 'the person riding the bicycle'. Um. And that is where many, many of our issues come from. In that one you couldn't even say it is a cultural thing, because we all know - he knew what a bike was. It wasn't - there was an old SATs [Standard Assessment Task] paper with - and all of our kids got the same question wrong in the same way, because none of them had heard the term 'hedgerow' before. They all knew the term 'hedge', but not 'hedgerow'. And so because it said 'hedgerow', they assumed that it was a new name for a hedgehog [TY and JR smile]. And so it all went pear shaped. And they all went off on one about - and because of that, that one little bit of misunderstanding, piled up against the whole logic of the question [TY mimes this pile with his hands]. It was one about - hhh - ... I think it was something like the number of different species that you'd find in a particular length of hedgerow. And so they'd constructed - well, I interpret that from their answer they'd constructed that for a different length of hedgehog [TY smiles] you'd have different things living in it [TY and JR laugh]. And that made complete sense, instead of just, adjusting your understanding of hedgerow. Um. And that was another, slightly different, but similar example that he's just - His idea, when he sees the bicycle is "I ride a bike, I'm a living thing, therefore the bike is a living thing." And I don't think actually that he'd - well he did get that in the end didn't he, but then he'd put - put both bikes in probably non-living [TY looks at the screen] just because they were bikes. Nothing because of they do or don't move, they do or don't need feeding. And the concept of having a life.**

Yes. It is not what you've been taught about - you need to have the seven life processes [TY mimes these with his fingers quickly], it's that you have a life. What is a life? And that did start sort of a step in the right direction. But again with no great feeling of any of the others - no nodding - no body language that said, "Oh yes, we might be on to something here." Again, "we're going to let AC get on with it. This is fun." [TY and JR laugh]

5b:36 JR: [JR checks his watch]

TY: Do you want to do some of the bottom ones?

JR: *We're almost - we're 25 minutes in.*

TY: OK.

JR: *Now I'm very happy to be flexible on the time. So if you'd like to spend a bit longer on those that is absolutely fine, and I can cut down the second bit in order to fit in if that is OK. If you're happy carrying on then -*

TY: Well let's have a look at these - [this is said simultaneously with JR above]. Well, I'm easy. Well let's have a look at these bottom ones because then we'll miss -

JR: *We can always come back.*

5b:37 CLIP 14: reflection [ID 5a:567-590] 5a:567 **TY: [TY is reading again] Eye, teddy, shadow. [TY stops reading]OK. Can someone please tell me in words, and you can point to your diagram if you want. But again please don't change them. How that all works. DS? [DS has her hand up]**

5a:568 DS: *The person is holding the light.*

TY: Listen [AC has been playing with the pencil - TY takes the pencil from him whilst continuing to look at DS]

DS: *The person is holding the torch and it reflects on [DS is indicating this on her drawing with her finger] the teddy - on the teddy. Then the shadow comes on the wall - will be the same. [Unclear - two sentences]*

5a:569 **TY: OK. And how do we see teddy? [Pause]**

5a:570 DS: *The torch is bright and if you look around you can actually see the teddy bear where it is sitting. And the shadow.*

5a:571 **TY: OK. And what part does your eye play in that? [Pause] How does your eye see teddy? [Pause]**

5a:572 DS: *The shadow of the light.*

5a:573 **TY: So you don't see teddy, you see the shadow? [TY raises his eyebrows, turns his head slightly and there is a larger than normal inflection in his voice to emphasise the question]**

5a:574 DS: *Yes.*

5a:575 **TY: OK. Thank you very much. PP?**

5a:576 PP: *The torch is shining on the teddy. And you can see the teddy because the light from the torch is bright enough so you can see it.*

[TY shakes his head]

And the light - the teddy bear - the teddy is blocking the light which makes the shadow on the wall.

5a:577 **TY: OK. So you see teddy because it is bright. And again. How does your eye [TY points with his finger towards his own eye and moves his finger in a circle] take its role? What is your eye doing in that process?**

5a:578 PP: *The eye - the eye can see the teddy because the light shines on -*

5a:579 **TY: [Pause] On -**

5a:580 PP: *Teddy.*

5a:581 **TY: Lovely. Thank you. SP?**

5a:582 SP: *You can see the teddy because like the torch is pointing right at it. You can see the light. And it can make you see the teddy as well. [SP hold one hand flat on the table with the palm upwards - the other hand is obscured from this angle, but may be visible from the other camera] ... Because it is in darkness so -*

- 5a:583 **TY:** *Say that again. So it is in darkness, you shine light at -*
- 5a:584 **SP:** *The - where ever you want to point it at.*
- 5a:585 **TY:** *Yes.*
- 5a:586 **SP:** *And if there is something - an object there - you can see the light - you see the light and you can see it reflected onto the object.*
- 5a:587 **TY:** *Where does the light reflect from? So that it reflects to the object?*
- 5a:588 **SP:** *It reflects from the torch to the teddy.*
- 5a:589 **TY:** *So the light reflects from the torch to the teddy [TY mimes this with his hand] and - [TY raises his eyebrows]*
- 5a:590 **SP:** *And you can see it.*
TY: *And you can see it. Thank you.*
- 5b:38 **TY:** *They're being incredibly polite, [TY laughs] "Sir, we've told you this three times and you still haven't got it." [TY and JR laugh] Um. So at the beginning with DS I let her go. She told me everything she wanted to say, without answering the question. And then I posed the question again. And I can't remember now if I changed it slightly to try and jump her back [TY mimes this with his body] to where I wanted her to be. I accepted what she told me, didn't say whether it was right or wrong, but tried to refocus her on what I actually wanted to know. I've just rea [I think TY is about to say 'realised' but can't be sure] - I made a mistake during this one because I I I should have kept my gob shut while they were still drawing. And I think that I sent them off on the wrong track because I think it was DS who was the first one to draw a shadow, and I was just impressed that anyone had done it. So I said something, and suddenly although I'd asked them not to, everyone had a shadow. And so because I had acknowledged that shadow I think they all went off on one thinking, "Oh, shadow is the right answer. What shall we say about shadows." But again, they haven't got 'reflect'. They're using 'reflect' for transmit really [TY mimes this with his hand]. The light transmits from the torch, hits teddy. And they haven't got at all - I keep trying to suggest that the eye might have something to do with this in an active sense rather than just - it is there. And there's - well, there would appear to be nothing there at all in terms of that. There didn't - there wasn't even a sort of a nudge from anyone else around the table that they knew where this was going. Whereas MG, had for some of the other bits I think she was sitting there thinking, "I know this, but I'm not going to get involved." I don't think this was - I think we're on to a loser with this one! [TY and JR laugh]. And they were, you know, PP even - he pretty much just restated - when I asked him again about - I think using your eye. And he just pretty much said, word for word what he'd said before ... without the sarcasm which I would have added in! [TY laughs and goes to play the next clip].*
- 5b:39 *CLIP 15: remembering [ID 5a:593-601] 5a:593 DF: Um. Um the tor - there is this thing we did in a science test. Where there was a person, a light, and there was an object. We had to draw arrows on which way it is going to go [DF mimes this with her hand]. So like the person - I think so - is - I think it is from the light to the object - which we can see - and then it goes into a triangle kind of thing.*
- 5a:594 **TY:** *OK. So are you remembering what it looked like to help you to answer it now? [DF nods] What might be a better way than trying to remember the picture that you almost remember?*
- 5a:595 **DF:** *Um. [Pause] To do it on this? [DF points at her drawing]*
- 5a:596 **TY:** *OK. What I'm thinking, in my head - I'm not very good at remembering pictures. I like to remember things step by step by step - do you remember when PP was telling us about his ideas for the steam and the ice and I could hear that he was thinking in steps. And that helps me when I think in steps. So can you think about that again, and then*

maybe you can tell me something about the diagram. So keep the diagram in your head if it is useful, but I want you to try and build an explain onto it as well.

5a:597 *DF: OK. The torch which reflects onto the teddy which I think bounces off him - goes to your eyes and means you can see the object.*

5a:598 *TY: So the torch bounces off your eyes. [TY smiles slightly as he says this and the tone might be slightly mischievous]*

5a:599 *DF: [Quickly] The torch reflects onto the teddy bear and then light bounces [DF mimes this] into -*

5a:600 *TY: OK. Then I want to ask about two words. Bounce and reflect. What is the difference please?*

5a:601 *DF: Um. Bounce is like when it's jumping off something. And reflect is like when there is like a light hitting onto something [DF mimes with her hand this light hitting and coming off] and you can literally kind of see it. Ish.*

5a:602 *TY: See it ish.*

DF: Yes.

5b:40 *TY: [TY laughs] I think that there is - is in a short video clip why I teach the way I teach. And it is not just because that is the way that I learn, it just irritates me so much when kids turn up and they say, "Well it is like this 'cause I remember it from the test." ... [TY shrugs and shakes his head slightly] Because she doesn't, she doesn't understand it, she doesn't know why it is, she will never be able to explain why it is using the faulty model that she has. Because her model is faulty. I did try and hint that her model is faulty [TY smiles and laughs slightly] which she wasn't going to accept - easily, then. ... And that's probably one of my biggest struggles as a teacher, is trying to, in my view, repair the damage that others have made because they have convinced kids that if they remember the diagram it will all be OK [TY turns his face to JR and smiles]. Or if they remember [TY raises his eyebrows] the order of the words, it will all be OK. And yes, diagrams are important and words are important, but actually knowing stepwise why cause and effect - or having the skills to - to question yourself and your own understanding so that you can build that model, is far more important. And she doesn't have it. And she doesn't have the confidence to do that either. And so she is - I have a colleague who calls it 'pretty handwriting syndrome' - because she'll work her socks off, and learn (as she sees it) everything that is written in her book. And it will be pretty and beautiful. And yet, when it comes down to it she won't, doesn't, [a student knocks on the door to the room where this interview is taking place - TY turns to look and continues speaking] and unless she changes her model, will never understand it. [TY mimes 10 minutes with his hand and then gives the thumbs up - the student leaves] Um, will never understand it. And that is really sad [TY laughs]. Really sad. [Bell goes] Um. ... And, yes. ... So, I very almost gave the game away and told them how annoyed I was [TY and JR laugh] that - I remember this now [TY puts his hand on his head]. I was really disappointed. Um. ... And then I think I got control again and started off on one about bounce and reflect. Um. And what the words mean. And again you have to have a model for the word. There is no point just using the word because you've been told that this word is - "This is reflect! ... There you go. Have it. [TY mimes sending students away with his hands] Go and play with it." Well there was no play [TY looks briefly at the laptop screen where the video had been playing]. It was just, "That's the word, take it away, use it in this - in this question. That you will remember." Badly. Instead of, "This word reflect it means bounce." And you could see she was trying - I thought she was doing a model, but I don't think she actually was. Whereas AC was at the corner being - trying to be helpful - and giving her a clue [TY mimes something bouncing with his hands - imitating what AC had done in the video clip] that this is how you can remember bounce. That is a boy approach. Because he is an inquisitive [TY smiles] kid who wants to know how things work.*

And DF's girl approach I think, in this instance, has been proved to be a bit of a fail. That is a really really interesting clip. [TY smiles and sits back in his chair with his hands on his head].

5b:41 JR: *Fascinating isn't it.*

5b:42 TY: ... Maybe I need to - I might set something like that up again just to show people. I don't think people get it. I really don't think that they get it. They think that they're doing the right thing ... and it - [TY sighs deeply and smiles]. This is why my lessons take so long. ... Um. And why I'd like to cut out half the curriculum. Because you haven't a chance - unless you regress to, "There's a diagram, learn the diagram." Then ... you're never going to be able to do it. [Pause] Right. [TY moves to play the next clip with a smile] Move on. [TY and JR laugh]

5b:43 CLIP 16: *step one [ID 607-621] 5a:607 AC: Step one. [TY puts one finger up]*

[TY and JR laugh]

The torch is switched on. Step two. [TY continues to count off each stage with his fingers] The light comes out of the torch and bounces off the teddy. Step three. The eye can see the light that has bounced off teddy.

[TY smiles and shakes his head]

5b:5a:608 TY: **OK.**

5a:609 AC: *That is my explanation.*

5a:610 TY: **Thank you. Is there a word that we've just used that you could use?**

5a:611 AC: *Um. Reflect.*

5a:612 TY: **Go on then.**

5a:613 AC: *Step one. [Unclear - by TY's reaction this is probably the same as before - could be 'The torch is turned on'] Step two. The light reflects off the teddy and bounces off it. Step three -*

5a:614 TY: **Hang on. Reflects off the teddy and bounces off it?**

5a:615 AC: *No. Reflects - no, no. ... Reflect - the light reflects off [unclear - could be 'on'] the teddy I think.*

5a:616 TY: **On the teddy.**

5a:617 AC: *Off the teddy.*

5a:618 TY: **Off the teddy. So where does it start?**

5a:619 AC: *Can I just say that the the torch - the light hits the teddy [AC mimes this with his hand] and then it comes back to the eye somehow. The eye looks at the light that has bounced off the thing.*

5a:620 TY: **Which one of those two last statements do you want us to keep?**

[TY smiles and says "Mmm"]

The one where light reflects off or where the eye looks at the light?

5a:621 AC: *[AC leans in his chair] ... The torch reflects off the teddy and the eye sees the light.*

[TY shakes his head slightly]

5b:44 TY: ... So this could be an argument about semantics, but I keep suggesting 'light' as the word and AC keeps going back to the torch. Um. In the same sense that earlier on they were going for tea - coffee when it was tea. I found that really interesting that they'd just assumed it was a cup, therefore it is a coffee cup, therefore it was coffee. Even in the light of me suggesting - It was black wasn't it. [TY looks at JR who shrugs] I think that really threw them and so they were probably too polite and I wasn't going to go for the big argument because it was just interesting. They were quite convinced it was coffee. He [AC] is quite convinced this is all about the torch and that the light is coincident. ... And he is not actually listening to the question either. Because I asked him to choose one of his last two statements and in response I think he just changed to a different statement again. A third statement. And he came very close to the right answer. And then [TY mimes with his hand veering off] chose the opposite direction. Went somewhere else with it. [Pause] I can't remember what

went in in in before. But I'm back to [TY mimes counting off the steps on his hand as he had done in the clip] one two three, where is the process? I want a process. And in fact that's - I think that's something that I've drifted away from because of the key stage four curriculum - or the way it is examined I should say. It used to be 'write and explanation', 'describe and explain how this phenomena happens' - and it disappeared and I think that was a big mistake for the curriculum, and thankfully it is back now - and I can feel it changing my teaching again. Because there was no point teaching people who would never go on to use science that actually you probably need to write sentences in a logical order, because they were going to get assessed by tick box. And even - all you need then is a little bit of understanding. You don't have to have the linguistic skills to do this. And now we're back to proper teaching - proper linguistic skills needed, because you're going to be assessed in that fashion. And suddenly there is more value to doing that properly in the lesson. ... [TY sighs] Which I'm not proud to admit, but, [TY shrugs slightly] if I don't spend - if I didn't spend the time arguing about how to structure a sentence it meant that I could spend the time insisting that they at least understood some of the key terms [TY laughs]. Apples and pears, swings and roundabouts. ... I can't remember now what they [TY points at the laptop screen] found funny. Probably because he was pulling a face while I was going [TY mimes counting off the steps on his hand as he had done in the video clip] like this. But I know I was doing this [TY mimes counting the steps again] on purpose so that they would - there is a physical link to it. And maybe a visual link to it. I do try to do something stupid in each lesson that is going to secure the main - the main point. It looks like I'd decided [TY laughs] that we'd got where we were going and that we were going to finish. "Remember this. Now recreate it as a diagram." [JR and TY laugh] Badly.

- 5b:45 *CLIP 17: light in eye [ID 5a:635] 5a:635* MG: *I think the light is travelling from the torch to the teddy and then the teddy is reflecting light to our eyes and we learnt that - you have ... I was kind of confused - I kind of forgot whether it was light goes to your eye and then to the object or the object then to your eye. But then now I remember in Year 6 I asked that question and the teacher explained that if the light was in your eye it is like you're shining the light in your eye so it makes it worst to see. So obviously it is the other way round, so that is why I drew it like this.*
[TY nods several times as he watches this clip]
- 5b:46 **TY: OK. So MG has got a better method ... and has remembered an explanation. I think - and it works for her and she has remembered it, but I'm not sure it is a useful - it is not not true, but it is not the one that I would choose to use. Um. But really interesting that she's - in fact I may go back and see where - I'm pretty sure they went to two very different schools. Um. That she has remembered it in a completely different way. And she is much more able, and much more willing to give thinking things through a go in the lesson as well. I don't remember that bit of it at all. I can't remember what the question was and whether - is she referring to - I don't know if you [JR] remember? - learning that then or is she referring to a distant learning.**
- 5b:47 *JR: So do you mean the overall question for this bit or -*
- 5b:48 **TY: She [MG] starts by saying that "we learnt" - and I can't remember if she meant that - had I just taught them ... or is she referring to [unclear]**
- 5b:49 *JR: No. I think she is referring to what she learnt in primary school.*
- 5b:50 **TY: OK. ... Mmm. [Pause] [TY shrugs] Right. [TY and JR smile] Is there any [TY is clicking on the laptop] that you want particularly?**
JR: *Um.*
TY: Oh let's have a look at MRS GREN [TY smiles]. Because that was interesting. [Unclear] that intrigues me.

5b:51 *CLIP 12: step ladder [ID 5a:447-458] 5a:447 AC: You know how they said, because the bicycle is moving it is a living thing. But for the bicycle [AC hits the card on his mat with his finger] to be - for the bicycle to be moving a human needs to be on it.*

5a:448 **TY: [Pause] Oo. I don't think that is true.**

5a:449 *AC: Unless the wind is blowing it.*
PP: [Unclear]

5a:450 **TY: What if I took a bicycle up to the top of a step ladder and then let go.**

5a:451 *AC: Yes, you need a human to take it up to the top.*

5a:452 **TY: Ah, but that is not what you said. You said you had to be on it. Didn't he? [TY looks at SP at this point and the tone indicates that TY is not questioning whether he is right, but is asking SP if he agrees that that is what AC said].**

5a:453 *AC: OK. A human has to move it.*

5a:454 **TY: Just a human? What if I had -**

5a:455 *AC: Gravity, human [AC says this quite loudly with a tone that indicates some exasperation and smiles - TY smiles too]*
[TY and JR laugh]

5a:456 *PP: Animals.*
AC: OK.

5a:457 **TY: Yes, we could have a monkey do it.**

5a:458 *AC: [Everyone laughs] A very smart one. Yes.*

5b:52 *JR: That is just wonderful!*

5b:53 **TY: Gravity, human, whatever! [TY and JR continue to laugh] Yes, so I think his concept was something else has to move the bike [these last seven words are said with a deliberate tone]. ... And again, he - his understanding of 'human' - you know - he didn't mean 'human', he meant some other entity had to move the bike which is where gravity, human comes from, I think. And yes, so again I'm trying to give him a way out - or a barrier to the model that he's using. ... So that he has - hoping to just jog him a bit into a different way of thinking about it.**

5b:54 *JR: A barrier to the model that he was using.*

5b:55 **TY: Something that will dist- [TY pulls a face] destroy [TY laughs] - Yes. [TY looks at JR and nods] Something that will properly shatter that model. Gently, maybe [TY pulls a face]. Maybe shatter is the wrong word. But ... dent. Make him realise that the model that he is using isn't going to work in every instance, so that he has to restructure his thinking to come up with a model - which I don't state, but a model that will work for every instance that we can possibly think of. Um. And I don't think we got there in the whole thing. Maybe that will come - turn up in that last MRS GREN clip. But I remember feeling that we really hadn't got it. That what we needed was a test that would work in all instances. And definitely at the beginning they were all coming up with some - some wacky ideas ... Um. I think we - he referred to the wind and we'd been talking about the wind earlier on. I remember that - just some very peculiar ideas. But none of them - I mean there was no evidence of a scientific method. That we'll test it even if it is just a thinking experiment. That we'll test it for this one, and then we might test the same thing in the same way, but change one thing. Um. But then I guess the way that we teach them, that kind of an investigation with the element of fair testing, which they all know by rote really well, probably never gets taught in the sense of testing living and non-living. That is not an investigation in the curriculum sense of the word. Although it is a really good investigation, it is a proper investigation. Nice open ended one. [TY moves to play the next video]**

5b:56 *CLIP 13: MRS GREN [ID 5a:478-484] 5a:474 TY: No. Mrs - [Pause]*

5a:475 *PP: Sirik? [Unclear - but a surname]*

5a:476 **TY: No.**

5a:477 AC: Mrs [unclear - another surname - this is a joke and AC laughs with others]
5a:478 **TY: No. Mrs GREN?**
5a:479 AC: Oh yes! We did that in science. [AC is speaking with MG]
[TY and JR laugh]
MG: Are you talking to me. I don't remember.
AC: In Miss [a teachers' name] - I can't remember if it was with TY or with Miss [same name].
5a:480 **TY: It definitely wasn't with me.**
5a:481 AC: We actually wrote, Dr GREN or something. MRS GREN or something.
5a:482 Several students: Yes.
5a:483 **TY: Yes? Well what was that all about then?**
5a:484 AC: I don't know. [SP and PP laugh]
[TY is shaking his head]

5b:57 **TY: [TY and JR laugh] "Oh yes, we do know it, but don't understand what it is for."**
5b:58 JR: And the chronology of it - this was right at the end. [JR laughs and TY nods]
5b:59 **TY: But also the fact - so badly have they not got it that it could possibly be DR GREN [TY smiles]. [TY and JR laugh] And not only that he has remembered it being written on the board, but he can't remember if it was [the name of a teacher] or me who did it. Oh my dented ego! [TY and JR laugh] And I think there were some bull shit agreement at the end there - I think SP, it sounded like PP as well, was doing an "Oh yeah." when they actually meant, "What?" [TY smiles]. [Pause] [TY and JR laugh] Alright, I want to see some more now. This is fun. Yes [unclear]. I really did enjoy this afternoon. It was, it was -**
5b:60 JR: Good. Me too. Me too.
5b:61 **TY: It was - [TY is clicking on the next clip]. Oh yes. Is this the one about the small plant and the big plant? [JR and TY start laughing]**
5b:62 JR: [While laughing] This is just brilliant. It is one of my favourites this. [TY and JR laugh]
5b:63 CLIP 9: plant breathing [ID 5a:378-408] 5a:378 **TY: OK. Show me breathing? [The students laugh - AC starts to breathe loudly]**
5a:379 AC: No, no, no.
5a:380 **TY: No! That was good breathing.**
5a:381 AC: OK, it was breathing, but breathing can be done like this. [AC breathes more normally]
5a:382 SP: He doesn't want [unclear].
5a:383 **TY: I can't tell if you're breathing or not. Tell me how the plant over there is breathing? [Pause]**
5a:384 AC: It is breathing, but I don't know how!
5a:385 **TY: OK. Does anyone agree? Is the plant breathing?**
5a:386 MG: The leaves might be moving a tiny bit. [MG indicates a very small amount of movement with her hand] We can't see.
[TY smiles]
5a:387 AC: But that is probably because of the wind.
5a:388 **TY: So to breathe things have to move?**
5a:389 Several students: [Unclear - but clearly 'no']
TY: Hang on, DF is going to tell us.
DF: No. Um. With the air around the object
[TY nods]
it somehow - maybe the soil or something - takes it in - goes through the stem of the plant [unclear].
5a:390 **TY: So the soil takes the -**
5a:391 DF: Air.

- 5a:392 **TY:** *Air. Through the -*
 5a:393 **DF:** *To the roots.*
 [TY shakes his head]
 Then through the stem.
- 5a:394 **TY:** *OK.*
 5a:395 **DF:** *And then spreads it around the plant.*
 5a:396 **TY:** *OK. Where is there more air going to be? Up around the leaves, or down by the roots?*
 5a:397 **DF:** *Up by the leaves. [DF laughs]*
 5a:398 **TY:** *Up around the leaves, so might you want to change your idea at all?*
 5a:399 **DF:** *[DF starts as if she has just thought of something] The air goes from the top of the plant [DF mimes this] to the bottom.*
 5a:400 **TY:** *OK, how?*
 5a:401 **DF:** *Um*
 5a:402 **TY:** *AC, breathe again. [AC does this]*
 [**TY smiles and laughs**]
 Have you ever seen a plant do that? When a plant has been doing some really hard work out there in the garden have you ever seen a plant do that?
 [**TY and JR laugh**]
 No?
- 5a:403 **MG:** *Maybe with humans you have to move, or animals you have to move,*
TY: *Nice one.*
 and plants they just - they can do it secretly.
- 5a:404 **TY:** *[Unclear] So it is like magic? And you said humans and animals.*
 5a:405 **MG:** *No, just animals. I changed it to animals.*
 5a:406 **TY:** *Because -*
 5a:407 **MG:** *Because like a dog would move when it was breathing and so on. All things with like a face.*
 [**TY and JR smile**]
- 5a:408 **TY:** *So animals are things with faces. [TY gives thumbs up and smiles] Love it. I love it an awful lot.*
- 5b:64 **TY:** [**TY and JR laugh**] *Brilliant. Um. I just. I was much kinder with DF than I remember being. Um. Offering her the advice, "Maybe you want to change your model?" Whereas I think most of the time I just drop the bomb and run. And hope that someone is going to realise that that is what I mean. And I don't know what I think about that. Um. [TY sighs] [Pause] I'd love to know how many times I do that. Offer the advice, "Maybe you want to change your model?" I think most of the time I'm expecting people to just grasp that that is what I want them to do, um, and maybe that is something I need to do more of. [Pause] I think probably 'the look', is just the short hand for, "Do you want to change your mind?" [this last phrase is accompanied by TY miming an incredulous expression]. And again, really interesting, I think that is another learnt diagram. She has remembered, maybe, that things go through the leave [TY shakes his head] - through the roots [TY mimes something flowing into the roots of a plant]*
- 5b:65 **JR:** *Something goes through the roots -*
 5b:66 **TY:** *Something goes through the roots, therefore it must be air, because that is what we're talking about. Although there isn't a lot of air near the roots [TY laughs]. And yes, MG's 'things with faces' - I'd forgotten that one as well. I actually thought - and again I thought as I watched it again that she had worked out that humans are animals. But that is not, I think, what she had worked out. ... But that - that one goes all the way up until the sixth form. We have arguments that humans aren't animals. And the logic one for that one is, so we must therefore be plants. [TY and JR laugh] And you see the penny drop quite easily with that one. Brilliant. ... Yes. This one [TY*

points at the laptop] was on the very edge of my understanding [the last five words are said emphatically], so I was thinking, "If we go much further I'm not sure if I can accurately describe at the moment how plants [TY does an inverted comma mime] 'breath' ". And I didn't really want them to get into the difference between 'respire' and 'breathe'. Although we probably must have talked about it at some point, because it would have popped up with MRS GREN. Ah no, we didn't, because that came on much later didn't it. Um. [Pause] Mm. [TY laughs slightly] And at the back of my mind as we were doing this, at the time was the - [TY puts his head down and puts his hand on his forehead] there were those famous interviews with MIT or Harvard graduates asking them what is in a plant. [TY and JR smile] And I was laughing on the inside [TY and JR laugh] because I thought, this is brilliant. And I'd forgotten the dog thing. That is brilliant. [TY and JR laugh] Nice one.

5b:67 JR: *I'm conscious of the time. So we're - with the hour, we'd have another five minutes left. Obviously I've got plenty of time, so it is really -*

5b:68 TY: **I'm fine.**

5b:69 JR: *Are you OK if we go for another - a little -*

5b:70 TY: **Yes, yes. What time is it? [TY looks at JR's watch] Is it quarter to three? Yes, we're fine.**

5b:71 JR: *And I need to get back for quarter past five, so I definitely need to be on my way by quarter past three.*

TY: **OK.**

JR: *Could I perhaps ask you a few of the -*

TY: **Mm. Yes.**

JR: *Thank you ever so much. I'm - I'm - that's*

TY: **It's a pleasure. [TY laughs]**

JR: *It has been such a pleasure, you know, going through those. I mean, you can see, there is gold in there.*

TY: **Yes.**

JR: *But also this opportunity to hear your thoughts about it. And, I mean I've been desperately keeping my mouth shut, hopefully allowing you to express your thoughts, but there is an awful lot in there I'd like to unpack. [JR reaches for the questioning route] I'll just grab my ... [Pause] [TY thinks of something and laughs]*

TY: **[TY reaches for a piece of paper] I think I'm going to write that one down.**

Animals with faces.

JR: *Sorry about this. I've mislaid a bit of paper. Ah. [JR finds the paper] Sorry about that. I put it out in order that it was at reach. [Pause]*

[End 5b]

Interview 5c

5c:1 JR: *From all of those [JR indicates the video clips from the EMT interview 5a that have been playing on the laptop] is there anything that comes to mind that has been sort of - been in your head that you haven't said - about that - that you'd like - thoughts that have - just before we go onto something else.*

5c:2 TY: **... No.**

5c:3 JR: *No. Thank you. Could you tell me what that experience is like. Being asked to think aloud as you're -*

5c:4 TY: **To watch it back?**

JR: *Yes.*

TY: **Um. ... I I it was the - what I was trying to avoid was speaking over the video. Actually it was it was quite comfortable. It is one of the things that I've been trying to practice doing anyway, as part of teaching kids how to write stuff [TY mimes writing on a board] practice writing a paragraph on the board. But the first time I**

tried it when I was writing it was really difficult. I think the ... I think I'm relieved that I don't think I got anything wrong [TY laughs]. It may be that someone else watching it would suggest that I got it all wrong. But I at least feel that, looking back at it, I don't think I'd have done much differently for this. Like we've said, if it was from - in a lesson - I'd have changed quite a lot and taken some time -

JR: *Yes.*

TY: - to really hammer it home. To explore it.

5c:5 JR: *That would have been the difference in a lesson, taking -*

5c:6 **TY:** Yes. And it - I would have picked up far more of the grammatical errors and the misuse of key terms or the non-use of key terms. Probably tried to run into the prep room and collect a load of crap, dump it on the table and build a - an experiment there and then to either prove or disprove some of their concepts. Um. Or resorted to a bad diagram on the board. Um. ... And in fact what I didn't do was give them some time to talk about it, without me being the the leader of the conversation. Um. So I probably would have sent them away, "Go to your room and think about it!" [TY mimes a grumpy parent and then laughs]. And maybe with one of my questions to take with them, and then just tour the room and drop some little things in. And then lead a bit more of an intelligent discussion because I'd have picked the people that were going to give me the good bits. And pick the people that were going to give me the useful bits. So get it wrong, but get it wrong in the right way. ... But you know - and that wasn't the model. At the time actually - I didn't think that at the time. Just watching it now know that that is what I would normally do, but it was too much fun to explore on the afternoon [TY and JR laugh]. And it was it was - it was so nice because to - I think I said on the day - to actually do that with six kids - and you get so much more ... um ... contact with their proper thinking. Which in a classroom of thirty-one, as they are, that is impossible [TY shakes his head]. Um. And yet all the research suggests - well mind you, I think the research also suggests that when you get it down to that number it does make a difference. But making a difference between thirty and twenty maybe wouldn't make such a difference. I still think I disagree with that. And I think - you know, I didn't realise, until that afternoon, how badly SP didn't understand certain things. And I hadn't grasped that DF doesn't do, what I would call logic. She wants to learn a picture. But the other issue with that is that she is far from vocal, so it was nice for her to have the opportunity to be vocal. And it was also really good to see AC butting out. I have a funny feeling that if you wrote down the number of minutes that he spent talking he'd probably win. Followed by MG probably. ... And then my recall would be SP and then PP. But watching him, and he was quite a lot of the time paying attention to other peoples' ideas, there were definitely a couple of times where he drifted off and he did need refocusing. Um. And again, for him, in that situation that was better, because normally you can't refocus everyone every step of the way. And for rebuilding models like that, they really need to hear and be actively hearing, all of the conversation. And this lot now have got it as a group. But other groups don't recognise - or individuals in other groups don't recognise that just because I'm talking to one person doesn't mean that it is not a conversation of us all. Which is why often I'll bounce the conversation around so that everyone does get involved. ... What they weren't doing very much in the clips that we've just now seen was build on each other's ideas. It was very much, "Oh, now it is my turn to say what I thought all along." Which isn't what I would normally do. I hadn't recognised that on the afternoon. I wonder if it is different for the whole interview.

5c:7 JR: *Yes. It could be just the particular selection. And we did get a little bit didn't we with MG -*

TY: The reflection?

JR: *Yes. Building on what what AC was coming up with.*

- 5c:8 **TY:** Yes, there was wasn't there. Yes. Definitely that is what I would normally aim at doing. And quite often I'll make it really explicit that, "I want you to take what he just said and change it. So if you want to add, subtract, do whatever - but it has to be based on what you've just heard. And then we're going to ask kid A to see the difference." And was it better or worse. And I thought that that was to help understanding, but now that I've just said that. After I said it, maybe I do that to make people listen more [TY has closed his eyes and has his hand on his forehead]. This is why this conversation is interesting. I don't know. I don't know why I do that anymore. Maybe it is twice - two things. [Pause] Mmm. Don't know.
- 5c:9 *JR: I'm just fascinated at how complicated this [JR looks for a moment at the laptop screen] dynamic is here. You know we get - you know we lived it with both being present for that first interview [TY smiles and nods] seeing it sort of play out at normal speed. And now to be able to just take a few elements of that. I suppose I'm wondering, are there principles that guide you in - in the way that you teach? Are there particular strategies that you're consciously employing?*
- 5c:10 **TY:** ... Um. [Shaking his head] Probably no.
- 5c:11 *JR: Or is it intuitive?*
- 5c:12 **TY:** [Pause] I think probably if I wound it back to different times the answer would be yes. ... But I'm really conscious now that when I try to model stuff for BTs [TY goes on to explain this in a moment] and for NQTs -
JR: I'm sorry?
TY: Student teachers and Newly Qualified Teachers - that I can't put into words, or I can't any longer [TY smiles] do what I was making them [TY looks at the laptop indicating probably that he is referring to the students on the video clip] do, which was put into a logical sequence why I do things. I just know why I do them - [TY shakes his head and pulls a face] that I do them. And I do them because it works. Um. Principles [TY looks up then puts his hand on his chin]. ... Mmm. ... I guess the big one I aim at doing is making sure that everyone has a go. And making sure that everyone goes out feeling more confident than they did on the way in, even if they are not necessarily any better at doing what we hoped they would be able to do. At least they went out feeling that, "Next time I might be a step closer to being better." Rather than - you know, often at the beginning of the year, you'll see some kids get to the door of the science lab and the body language changes. And the face changes and you can just see them go, [TY mimes with his eyes by looking up to the ceiling] "Science, [TY blows a raspberry, clicks his finger and then signs a 'no' with his hand]. Done." So quite a lot of it is just making sure that - or trying to make sure that they don't do that [TY smiles and emphasises the last three words]. That they come in and lighten up [these last three words are said more quickly and TY mimes a pupil's face lighting up] when they come through the door. Or at least don't slump [TY smiles and the laughs with JR]. And I think that is probably the biggest guiding principle rather than anything else. And the rest of it is probably not even subconscious anymore. It just happens. Earlier on in the year I was videoed with this lot quite a lot trying to do this 'how to write a lab report' thing. And caught myself ... I know that I'm quite expressive [TY moves his hands] with my hands and with my eyebrows and there are certain phrases that come up again and again and again. Um. And I had to bite my tongue - because I know there is also times when I'm probably not as polite as I could or should be, but I would argue that I do that for a similar reason, that if you just sat in a boring polite lesson all the time [TY laughs] what would you - ? So partly I would hope that it is motivating to see, 'what TY is going to do this week - daft'. [TY raises his eyebrows and JR laughs]. And most of the time it doesn't back-fire, so maybe that's correct. Um. But yes, making it enjoyable, I guess is what I'm aiming at.

5c:13 JR: *I loved that sort of exaggerated [JR mimes TY counting off the steps for AC in 5a:607 - TY and JR laugh] - and they did as well. It was clearly [JR exaggerates the counting even more] - It doesn't need to wobble [JR mimes the thumb wobbling] but it can. [JR and TY laugh]*

TY: Yes.

JR: *[Pause - JR is checking the questioning route] Could you tell me about experien- [JR changes his mind about the question and says to himself] I was going to go with that one ... Yes, actually maybe go back to that. Are there questions or ideas from the pupils that you anticipated coming up, and others that didn't anticipate coming up. Could you say a little bit about that.*

5c:14 **TY: Ahh. ... The tea cup one, I had - I've never asked it before [TY shakes his head and looks at JR with his eyebrows raised]. It was a really interesting exploration because I had to think on my feet. And I never expected them to have a bad model for conduction. I've never experienced that before. And probably the reason is that because I know it isn't expressly taught anywhere else, I thought naively that it was my concept to define. So I've never bothered asking before - about the word, the term - I've asked how it happens, but I've never expected, and I've never heard in fact the word incorrectly used like that. That was novel. Um. And so I did have to think quite carefully about what I was going to do with that. And so the process I was trying to go through was to ascertain what they were using it to mean. Because I didn't know whether it was just a nonsensical grammatical construction, or whether they really didn't understand the science behind it. And I'm still not sure [TY points at the laptop and looks at JR]. I still - I think - and again from watching those clips, that they think that something other than heat energy was passing through the material of the cup, and that is what I was trying to get out from that questioning. Um. And I don't even think - I don't think there is enough evidence that we have from that to know whether that is what they really felt, but I think implied it. And they didn't contradict it when suggested that that is where they were going with it. So no, that one was completely new. I pretty much knew what to expect with the light question. Um. And do use that one regularly up to Key Stage 5 [pupil age 16 to 18] and they still get it wrong [TY and JR nod]. ... And I hadn't ever thought before that at Key Stage 5 they might be remembering a Year 6 question. But now that DF suggests it, that may well be what they're doing. And I just thought that it was a lack of ability to think logically. I'd never recognised that as them going back to a cherished model that they had already learnt. In the sense that I'd know never to try and build on somebody else's model for current, because they're never going to work. I need everyone to deconstruct it all and we'll start again from scratch. Which is probably a little arrogant, [TY pulls a face] but I need it to work [TY smiles and then laughs]. And I do always say, "You know, this is my model." Quite a lot - I heard myself say lots of - "For me, this is what I need to do." And the im- what I implied is that, "You might not want to do this." But I didn't say it, which is interesting. I might consider doing that ... in the future. Um. And also I always own up when I don't get it [TY points at the laptop]. I think it is really important that they recognise that there were times, and will still be times, and will be times in the future, when I don't understand it. Or when I don't know how to fix it. But that's fine, because that's life, and this is how we will get round it. Not by remembering a diagram [TY laughs and then mimes with his hand the steps as he had done in the video clip] but by working out the logical steps. Um. And the MRS GREN one was just a shocker. I've never experienced kids incapable of recalling MRS GREN from Year 6. [TY has a puzzled expression] I wonder if it has disappeared from the [name of a county] - I haven't actually checked the Year 6 curriculum. Maybe that's - mmm. ... [TY shakes his head] I've never known them not be able to parrot MRS GREN. I was really surprised. And I've - we've done sort tasks before [TY mimes**

- this with his hands] and I guess normally I'm not very ... attentive when they're doing them. I suspect that that is probably a task where I trust the science will happen, and so I'm using it for behaviour management instead, and I go round and make sure that people are actively engaged. ... So I don't think I can accurately judge whether they did that as I would have expected it. But definitely the conversation afterwards was a shocker. ... Um. Some some - you know - yes, [TY closes his eyes] you expect that a moving car for instance, they would sometimes misclassify as living. And that takes quite some undressing. Um. The bicycle thing [TY smiles] was interesting. It would have been interesting to see that answered with a person sitting on it. But then again, that was - I hadn't thought, although I've spent some time this afternoon talking about how people misinterpret diagrams, I hadn't before thought that people might misinterpret the diagram and therefore not understand whether it was living or non-living. I've always imagined, again naively for those, that "doh, it's there!" [TY smiles]. They didn't go for the leaf, or did they? I don't remember them going for leaf verses plant. Which are traditionally -
- 5c:15 *JR: I don't think they did. No. We had plant verses tree I think at one point. [JR and TY smile]*
- 5c:16 **TY: We did didn't we [TY and JR laugh]. Can it not just grow? [TY and JR laugh]. Yes, I remember that bit. But no, traditionally I think kids normally would pick up leaf and tree, and then have an argument about - instead of 'living' verses 'non-living', it would be about 'was living' verses 'not living now'. Um. I seem to remember quite some discussion about the sun and the wind - um.**
- 5c:17 *JR: Wind was living on a lot of peoples' mats.*
- 5c:18 **TY: Yes. And ... yes, I don't think I've experienced that with wind before, definitely we've argued about the sun before. Um. And then interestingly other stars, and stars often come up as dead, whereas the sun often comes up as alive. Um. Which is probably far too big a concept for Year 7 [TY laughs]. But it might be something I now bring up at Year 10 [14 or 15 year old pupils]. That will be an interesting thing. My 11s [Year 11 pupils are 15 or 16 years old] are convinced that stars and the sun are separate things. Um. And I got told I was a fool today for thinking that stars don't move. And then we had to redefine it, because of course they were right [TY and JR laugh]. It was just I was talking relative to us [JR mimes frustration] they were talking relative to everything else. And it took ten minutes of unpacking to work out where that one came from. But it was [unclear 'worthy' or 'worth it?']. [TY and JR laugh] Mmm. ... So yes, for some of them, from my experience and things I may have read a whole load of ideas I know I'm going to have to counter. And the others [TY shakes his head and smiles], no, that was quite a lot -**
- 5c:19 *JR: And who could predict that? [JR smiles and laughs]*
- 5c:20 **TY: No. [TY and JR laugh] ... But that is why they're fun.**
- 5c:21 *JR: It is such a pleasure talking with you about this, I'm very conscious of the time [JR looks at his watch] ... Just to sort of round up, with this whole experience of the first interview with the children (we've been watching bits) and this, is there anything else you'd like to say or any thoughts you'd like to share just to finish.*
- 5c:22 **TY: [Long Pause] I - It's been really interesting thinking with a [TY points back and forward between himself and JR] - someone to bounce it from, what I do, why I do it. And I think that process has probably been, well it has been really useful [TY looks and JR and shrugs]. And it is lovely to show off my kids [TY laughs].**
- 5c:23 *JR: Mmm. They're just wonderful aren't they.*
- 5c:24 **TY: Because they are really cool. Even when they don't get anything [TY and JR laugh]. And eventually I - I sort of feel that I need to go back and do some fixing up. And not just for them. It was a a a real eye opener about how you can think that a kid has learnt something - and you could probably prove it on paper that at the time**

they had learnt it, and yet I don't think they were hiding understanding, I don't think that understanding was there. Which is, yes, it is quite a shocker.

5c:25 *JR: And radically different understandings.*

5c:26 **TY: Yes. Yes. Or just nothing there. I don't - they'd got some very interesting models for 'alive' and 'not alive', but none of them had got a scientific method for proving it. [TY laughs] Ouch! [TY and JR laugh]. Or to remember who it was who didn't teach it to them! [TY and JR laugh] Yes. No, it's been really interesting. ... I was thinking - I know I was thinking before the first one about actually can I modulate my normal teaching style to not go off and get side tracked and just spend the half hour teaching about one particular misconception that we first hit, em, and that was the only bit actually that I was nervous about. I'd screw it up for you in terms of the usefulness of what you were going to see. And actually watching it back, [TY sighs] catching myself leaving go of one bad misconception and moving on, I'm actually quite proud of that - I'm surprised I did it. I don't remember - that wasn't one of the ideas I walked away with that I'd done that. So that was - it is interesting to see yourself. But also I think, had I watched that through again, I wouldn't have noticed that I'd done it, but having someone highlight it as something interesting was really useful for me. And I - with these kids there's lots of video of me doing literacy stuff, and I've watched the whole lot two or three times, and I'm expecting now - I'm not going to go and do it again. But if someone else was doing the editing, I think they'd probably find some completely different stuff that I've overlooked. ... Mmm. No, really interesting, thank you [TY smiles].**

5c:27 *JR: Thank you so much. It has been a real pleasure talking with you. Thank you. [TY and JR smile]*

TY: Thank you.

[End 5c]

Interview 6a

6a:1 **TZ: Thanks for doing this. This afternoon we're going to be talking about science ideas. Um. And the main thing, like we do in class, it is not about having the right answer, it is about your ideas and how you change your ideas during the course of the discussion. OK? [Unclear] All clear? OK? [JP and ?? nod their heads]. OK. So first question [unclear] that we'd like to ask you. I'm going to ask this to each student [TZ indicates the whole group using her finger]. Please tell us who you are and how you feel about science. [TZ indicates that JP should start using both hands]**

6a:2 JP: [JP smiles] I'm JP and I like science because um we do practicals and we get to um - we get to learn about like the atoms and how things formed together and like we learn how we would - we learn about acids and alkalis [TZ nods] and how if you put - use certain alkalis it can solve certain things or - and stuff like that. So.

6a:3 **TZ: Like a range of things [TZ mimes this range with her hands]. OK. [TZ nods towards VG]**

6a:4 VG: I'm VG and I like science because I like doing the practicals and also it just like shows you what you use in everyday life like with metals and carbon and stuff like that [VG sits back in his chair].

6a:5 **TZ: So we talk about lots of real life applications.**

6a:6 VG: Yes. That you use every day.

6a:7 **TZ: Excellent. [TZ looks expectantly at TV]**

6a:8 JW: I'm JW and I like science because of the practicals and it is just fun to find out about [unclear] and stuff to do with science.

6a:9 **TZ: In particular [TZ emphasizes this last word] for practicals what have you actually [unclear - 'done']?**

6a:10 JW: Bunsen burners.

6a:11 **TZ: Why do you like the Bunsen burners?** [TZ smiles as she says this and all the students laugh]

6a:12 AS: Fire!

6a:13 **TZ: [TZ looks at AS] Fire. [TZ laughs]**

6a:14 JW: Fire [unclear - said very quietly]

6a:15 **TZ: Just that fascination with Bunsen burners?**

6a:16 JW: Yes.

6a:17 JP: You can burn stuff. [JP, VG and TV all laugh]

6a:18 **TZ: [Quietly] You can burn stuff. [TZ smiles - TZ indicates that AS should speak next using both her hands]**

6a:19 AS: I'm AS and I like science because it is like interesting to learn [TZ nods] about how things are like made and stuff - like when we're doing the metals how many atoms are inside the thing.

6a:20 **TZ: OK. So - excellent. Getting a bit deeper. Not just looking at the big picture but going in a little bit more detail. [TZ smiles towards FL]**

6a:21 FL: Hi, my name is FL. I never used to like science and found it quite boring. Because we didn't really like do much. We didn't really do that all the time [this sentence is said very quickly and is a little unclear]. But since this school it is like we do a lot more practicals and stuff and - ... burning. [Everyone laughs]

6a:22 **TZ: Gosh. [TZ looks at KG indicating that it is her turn]**

6a:23 KG: I'm KG and I like science because you like know something about the world and how it is made. I quite like looking at the animals and things like that.

6a:24 **TZ: ... Animals really interest you.**

6a:25 KG: Kind of.

6a:26 **TZ: Kind of. [TZ looks at the questioning route]**

6a:27 FL: [FL says something unclear to KG quietly - it appears to be a joke - TZ hears it and smiles but continues what she was doing]

6a:28 **TZ: OK. Excellent. Um. [In an undertone] It says optional, but we'll cut it down. [Back to a normal voice] What is the first thing that comes to mind when you hear the word 'science'? Think about - [TZ raises her finger to FL who has just said 6a:29 as if to stop her, but quickly TZ lowers the finger and leans forward to listen to FL]**

6a:29 FL: Blowing up stuff [said quietly as TZ is saying 'about' in 6a:28].

6a:30 **TZ: [TZ leans forward] Blowing up stuff. [FL laughs]**

6a:31 FL: That is just what I think about.

6a:32 **TZ: OK. Blowing up stuff. [TZ looks at TV]**

6a:33 AS: I think about experiments.

6a:34 **TZ: Experiments. Excellent. Blowing up stuff, experiments. [TZ nods at each person who has said these last two and turns to TV who is the next person around the table].**

6a:35 JW: I think of physics, [TV is counting these off on his hand] biology and - what is the other one?

6a:36 JP: Chemistry.

6a:37 JW: Chemistry.

6a:38 **TZ: So do you see them as three separate ... disciplines [TZ mimes separating something on the table with her hand] - or three separate subjects?**

6a:39 JW: I think they're not exactly separate, but they're sort of joined, but mostly separate.

6a:40 **TZ: Mostly separate. OK. [TZ turns to VG]**

6a:41 VG: I think of some like mad scientist who is always doing experiments and blowing up and stuff like that. [Pause - TZ then turns to JP]

6a:42 JP: Um. [Pupils laugh after VG's comment] I think of like atoms and of the like the atom bomb - stuff like that. And how like - when - how small atoms are and they're in like everything. And there's atoms in like everything around us. And I didn't know that before. It is like and now I learnt that here - so.

6a:43 **TZ: Doesn't that amaze you that everything is made of something so small?**

- 6a:44 JP: Yes. Everything is made up of something so small [JP mimes holding an atom].
- 6a:45 **TZ: OK. [TZ looks at KG and smiles] Finally KG.**
- 6a:46 KG: Err. Well I don't know because sometimes it makes me think of things like chemistry and things like that. [Unclear] I also think of the geography side of it.
- 6a:47 **TZ: OK. What does that - what do you mean?**
- 6a:48 KG: Like. Well like how it affects the world.
- 6a:49 **TZ: OK.**
- 6a:50 KG: Like all the chemicals like in pollution and things like that.
- 6a:51 **TZ: So you think about climate change.**
- 6a:52 KG: Quite a lot. [With a tone that indicates 'not that much']
- 6a:53 **TZ: OK. Excellent. [TZ looks at the questioning route] So. Drawing on that [TZ mimes this with her hands] please tell us about any experiences you've had where you, or someone else has changed their minds about science ideas. [Pause] I'll give you an example. Maybe. Like today. When we were talking about elements and we came across this idea that elements are made up of one type of atom. Some of you didn't have that idea, and we tried - I tried to take you on a journey - [TZ uses her hand on the table to mime this journey] help you come to that idea - change your idea to actually appreciate why that state we have is true. OK? So that is an example of me trying to change your science ideas by doing certain activities. So are there any - has there been any time where you're had - held an idea and you've had to - you've changed it because of something that you've experienced or you've done or you've heard [TZ mimes this with her hands] or you've learnt.**
- 6a:54 AS: My one was with energy.
- TZ: OK.**
- AS: When we were burning all the stuff I thought that with energy I thought that you had to calculate all the ingredients and do it like that. But when you - can just burn it and use the heat energy to [unclear] try and do that.
- 6a:55 **TZ: OK. So you clarified - you said that realised that - Are you trying to say that your ideas was changed - that you didn't realise that there was energy locked up in food -**
- 6a:56 AS: [Nodding] Yes.
- 6a:57 **TZ: And that gave off when you burn it?**
- 6a:58 AS: Yes, yes.
- 6a:59 **TZ: OK. Excellent. That's a good example. TV.**
- 6a:60 JW: Um like when we were looking at metals recently um it was that - on the origin of names isn't the same as when the element is shortened down. Like gold is Au which is Latin. I can't remember what it was for.
- 6a:61 **TZ: OK. Excellent. And there was that - ... Why was that surprising to you?**
- 6a:62 JW: Because normally you assume that gold you think either Go or G1 or Gd.
- 6a:63 **TZ: Why would you assume that? [TZ sits back with a puzzled expression on her face and crosses her arms]**
- 6a:64 FL: It is just like in the name. [FL says something as TZ is saying 6a:65 - unclear as said simultaneously]
- 6a:65 **TZ: It just is in the name [TZ smiles at FL - uncrosses her arms - nods and puts her palm upwards towards FL - TZ's tone changes as she says this]. OK. So your ideas had to change [TZ is speaking with TV again and mimes this change with her hands] because you didn't - to accommodate the fact that some of those elements names [TZ mimes the elements stacked up with her hands] are based on a different language. Whether it is Latin, or German, or something else.**
- 6a:66 FL: It is all connected.
- 6a:67 **TZ: It is all connected. Excellent. VG?**
- 6a:68 VG: Mine was a bit like JW's really, with the elements and everything. I didn't realise that they all - I thought that they were just like initials of the first two letters - like was their

- actual sort of like meaning. But then like as we started to learn more about it I realised that it was sort of like for different languages and stuff like that.
- 6a:69 **TZ: OK. And what was the main one that everybody thought - that was the main example?**
- 6a:70 JP: Potassium.
VG: Yes. It was K.
JP: Everyone. K because - Yes.
- 6a:71 **NS: K. And the other one? Iron?**
- 6a:72 JP: Urm. Iron. No. [JP appears to be thinking]
- 6a:73 AS: It was ... F.
- 6a:74 **TZ: Yes. [TZ nods] So Iron. Everyone said 'I' -**
VG: Like the complete opposite.
TZ: - and we had - [TZ pauses to wait for the answer]
- 6a:75 FL: Fe
- 6a:76 **TZ: Fe. So again we had 'Ir' and we had to change your ideas. Excellent. ... Haven't said one? [TZ indicates FL then turns to JP indicating with her hand that he can speak if he wishes] Have I said?**
JP: Oh no, sorry.
TZ: [TZ mimes embarrassment and confusion - pupils laugh - she touches her head as if she has made a mistake]
- 6a:77 JP: Um. Right. When we did the - when we did energy with the screaming jelly baby [this is a demonstration where the energy stored in a sweet is released quickly through a chemical reaction - it makes a loud noise and looks like a flare going off] -
- 6a:78 **TZ: OK.**
- 6a:79 JP: I didn't realise that one small thing could have as much energy as what it did. Like I didn't know that there was like energy inside food. I thought it was just sugar and stuff like that.
- 6a:80 **TZ: So you just thought it was sugar.**
- 6a:81 JP: Yes.
- 6a:82 **TZ: OK. So you didn't realise - appreciate that food is an energy store.**
- 6a:83 JP: Yes.
- 6a:84 **TZ: Which reactants give off - [Unclear as pupils next door are making noise moving their stools] that type of - lots of energy.**
- 6a:85 JP: Yes. ... Yes.
- 6a:86 **TZ: Do you remember how, in terms of [TZ mimes one hand flat out and the other circling around it] changing your ideas - did it - did you actually appreciate that something so small could give off - or transform [this word is said more slowly] the energy stored in it [TZ mimes the jelly baby] into so many different forms? [Unclear - JP has started to speak]**
- 6a:87 JP: Yes. Yes they changed because - I didn't expect it to be as much as what there was. I expected it to be a little bit less. Whereas it was - ...
- 6a:88 **TZ: Can you describe that reaction?**
- 6a:89 JP: It was like a flare. Sort of. And it was really really bright red and pink. Yes.
- 6a:90 **TZ: Pink. And can you remember - so - in terms of changing ideas - did it did it show you that energy can be transf - a clear example that energy can be transformed from one form to another?**
- 6a:91 JP: Yes.
- 6a:92 **TZ: Yes? Can you remember what it is transferred - the types of energy it was transformed into?**
- 6a:93 JP: It was trans - um [JP looks at TZ] it was - when we heated it up it had - where it burned it turned into smoke. Well there was smoke everywhere around, and light energy I think. Because from where it was really really bright.
- 6a:94 **TZ: So light energy -**

- JP: Yes.
 TZ: - is definitely one. Smoke is not an energy [TZ is counting on her hand].
 JP: No, but. Heat.
 TZ: But that was given off [TZ nods several times as she says this]. Light and, could you hear it? [TZ holds her ear lobe] -
 JP: Yes we heard it.
 TZ: - because it is called the screaming - OK. Excellent. Right. KG? [TZ sits back in her chair]
- 6a:95 KG: I didn't really know that everything is made up of something from the periodic table.
 TZ: Right. [TZ nods at KG, TZ is sitting back in the chair with her arms folded]
 KG: I thought there was more things than just that.
 TZ: Right.
 KG: Because like everything is made of something from it. I didn't know the - it is like all made from something.
- 6a:96 TZ: So what made you change that idea?
 6a:97 KG: Probably the [unclear]. Because it is like everything is made up of something from it now.
 TZ: Uhu, uhu. So that was interesting for you [TZ nods as she looks at KG] OK. Good.
 KG: Kind of.
 TZ: Good. [TZ indicates with her hand that FL should go next]
- 6a:98 FL: The particles -
 TZ: OK.
 FL: - because we did particles - I didn't really - I thought that they were just like all the same because now thinking about it it is a bit stupid because a gas isn't going to be the same as a solid - like, they are quite different.
- 6a:99 TZ: So when you say particles, how did your ideas of - of - or your understanding of gas, and liquid, and solid [TZ mimes laying these out on the table with her hand] change?
- 6a:100 FL: I knew they were different, it is just that I didn't know that they were that different. Whereas with a solid they would be flowing everywhere.
- 6a:101 TZ: OK, so your ideas of - so did you appreciate that within a solid there were particles and it is just the fact that those particles are arranged in a different way that allows us to have solid, liquid and gas?
- 6a:102 FL: Yes. [Said perhaps a little uncertainly]
 6a:103 TZ: ... You tell me. How did your ideas change? [TZ smiles]
 6a:104 FL: Well after we did the experiment and after we did the homework - bit of research, it shows it is quite obvious really.
- 6a:105 TZ: OK. OK, so we've all had experiences of how our ideas have changed. Excellent. So, we're going to do our first little thinking activity. [TZ gets the cup and bowl - pupils look at them]
- 6a:106 AS: A cup of tea and some ice cubes.
 6a:107 TZ: Really simple. OK. So we have, a cup of tea and some ice. Um. [TZ is reading from the questioning route] And I'm just going to ask a simple question. And first of all I'm just going to sit back and let you discuss and then I'm going to intervene and then probe you to change your id - try to help you develop your ideas - develop your thinking. So the question is: Please tell me what is happening to the hot tea (which is here) [TZ lifts it up] and the cold ice [TZ points to the ice] in as much detail as you can.
- 6a:108 FL: So the ice is melting. [JW puts up his hand]
 6a:109 TZ: So I'm just going to sit back for a minute [TZ puts both hands up palms facing the pupils and sits back in her chair] -
 6a:110 JP: [Unclear]

- VG: Yes, I was going to say they're both like -
 KG: And the ice turns -
 VG: Yes, its - the ice is sort of like melting just turning into room temperature - sort of like getting colder.
- 6a:111 AS: And that's turning from a solid to a liquid.
- 6a:112 JP: I think what will happened [sic] is when the ice is melted it's still would have to take a while to get to -
 VG: Room temperature [simultaneous with JP below]
 JP: - room temperature because where it is ice is will still be cold, so you're going to have to wait.
 VG: [Simultaneously with JP but talking towards TZ whereas JP is speaking towards FL] we still have the temperature of the ice - actual ice [unclear]
- 6a:113 FL: [Simultaneously with both JP and TZ at the end of 6a:112 above] The tea takes less time than ice to get to room temperature because that [the ice] is like freezing whereas, even though it is hot like, it is not as hot as like -
 KG: It is not boiling.
 FL: - the tea pot. It is not going to be at a hundred degrees [unclear - could be 'exactly'].
- 6a:114 **TZ: So we've established, I just sat there and listened, there is something that is - a change in temperature is going to happen. This hot tea is eventually going to become - [TZ pauses]**
- 6a:115 JP: Room temperature.
- 6a:116 **TZ: - room temperature. And our ice is eventually, if we leave it for long enough, it will melt, yes? And then it might become - it will get to room temperature. So if we think of what is happening, what is being - what's - Let's look at the ice first of all, [unclear], let's think of the ice first of all. Someone said it's melting. So in terms of its state, what's happening?**
- 6a:117 JW: It's changing from a solid, which is ice, which is below zero degrees to a solid - I mean a liquid that is -
 JP: Above
 JW: - higher than the freezing point. So it is changing its state to a liquid.
- 6a:118 **TZ: Say that what you just said - say that again [unclear] and just listen very carefully.**
- 6a:119 JW: It is changing its state from a solid to a liquid.
- 6a:120 **TZ: OK, so it is changing its state from a solid to a liquid. OK.**
- 6a:121 JW: And it is going above the freezing point, so it is melting, and it would - the hot tea is helping it also because it is near it. And like the heat coming off of it is also melting the ice.
- 6a:122 **TZ: So you're saying the heat from this is also melting the ice.**
- 6a:123 FL: At the moment that's hotter than room temperature so - as they're next to each other [unclear - but appears to be from how FL moves her hand 'it goes from the tea to the ice'].
- 6a:124 **TZ: [unclear]**
- 6a:125 JP: No, the warmth.
- 6a:126 KG: If you move that closer -
 VG: The warmth from -
 JP: Yes, the warmth where it's near -
- 6a:127 **TZ: The heat that has been given off - or the energy that has been given off from our cup of tea, you're saying, is having an impact on that [TZ points to the ice].**
- 6a:128 JP: Yes. [AS also nods]
- 6a:129 **TZ: OK. So we've got loads - a few ideas together which I need to try and unpack and try and delve my way through [TZ mimes weaving through these ideas with her hand]. So you talked JW just a minute ago about it getting above - is that above room temperature? Um. Above freezing?**
- 6a:130 JW: Yes.

- 6a:131 **TZ: What is above freezing. Is it in here [TZ points to the water around the ice cubes] above freezing? So if we had to put a thermometer in here, what reading might we get?**
- 6a:132 FL: Minus.
 JW: If you were trying to measure the ice it would be in the minuses. Below zero. If you were measuring the water it would just be above zero, because it is three different temperatures almost.
- 6a:133 JP: [TZ is about to speak but JP comes in and is addressing JW] Can I just say that, you know when you put ice in water it cools it down. So isn't the ice in there cooling down the water?
- 6a:134 JW: Yes.
- 6a:135 **TZ: Ice in here [the bowl] is cooling down - what does that mean [TZ is speaking to JP]?**
- 6a:136 JP: Um. ...
 AS: Yes, they're about the same temperature.
 JP: Yes.
- 6a:137 **TZ: So they're about the same temperature, JW is saying that the water - as we said there is no right or wrong answer - I'm just trying to have - understand it. The water is - [TZ pauses]**
- 6a:138 JP: Warmer.
- 6a:139 JW: Warmer.
- 6a:140 **TZ: Warmer.**
- 6a:141 JW: Slightly, and the ice is colder.
- 6a:142 **TZ: Colder. OK.**
JP: Oo, [unclear]
TZ: OK, so ... [TZ nods a few times] at what temperature might our ice be? What temperature does ice need to be at -
- 6a:143 JP: Minus - zero. Minus five.
 JW: Minuses. [Simultaneously with JP above] As in - ?
 AS: [Unclear]
- 6a:144 **TZ: What temperature does ice freeze at? What temperature does water freeze at?**
- 6a:145 FL: Is it minus - ?
 JW: Zero point one.
- 6a:146 **TZ: Zero point one.**
- 6a:147 JP: Minus -
- 6a:148 **TZ: Let's just go round. [TZ points at JP] What temperature does water freeze at?**
- 6a:149 JP: Is it minus - It might be about minus five.
- 6a:150 **TZ: Minus five. [TZ points at VG]**
- 6a:151 VG: I was going to say between like minus five and minus ten. Something like that.
- 6a:152 **TZ: Between minus five and minus ten. [TZ points with a flat hand to JW]**
- 6a:153 JW: Um - zero. Zero point one. [TZ indicates AS]
- 6a:154 AS: I thought it was like minus a hundred.
- 6a:155 **TZ: Minus a hundred. [TZ appears to have a very slight change in facial expression - like a very slight smile]**
- 6a:156 AS: I thought it was really low.
- 6a:157 **TZ: Really low.**
- 6a:158 JP: [Unclear]
 FL: I thought it was really cold because like freezers and radia - not radiators - [AS laughs] and fridges they are usually about minus a hundred and twenty or something like that.
- 6a:159 JP: No they're not. [JP shakes his head]
- 6a:160 **TZ: So -**
- 6a:161 KG: Round about minus twenty seven.

- 6a:162 JW: [Smiling] Fridges -
JP: [Unclear]
- 6a:163 **TZ: [Quite loudly over the top of several students who are all speaking at once] OK. So you're [AS] saying - What point do you say ice - water turns - What is the freezing point of water?**
- 6a:164 FL: Maybe ... minus a hundred?
- 6a:165 **TZ: Minus a hundred. [TZ points to KG with her thumb]**
- 6a:166 KG: Zero. Because in the snow when it is all iced up [at the moment KG turns to FL] it is not exactly going to be at minus a hundred outside is it?
- 6a:167 JP: Yes! [JP points at KG with his finger] You've got a point there because -
- 6a:168 KG: You're not going to be out there in the like snow stuff playing if it is like minus a hundred.
AS: [Unclear - said simultaneously with KG]
- 6a:169 **TZ: OK. So we've got different perceptions, understandings, concepts or ideas about when water - the temperature at which water freezes. Before I unpack that, let's just go and check - What is the temperature that water boils at?**
- 6a:170 JP: About a hundred.
- 6a:171 AS: That's probably where I got the hundred from.
- 6a:172 **TZ: So is there a kind of agreement? [TZ sweeps her hand around the group and everyone nods]**
AS: Yes.
TZ: Right, so why do you say water freezes at below - below zero?
- 6a:173 JP: Because - um - Because -
FL: It melts the bottom. [Unclear]
JP: - you've got the melting point and freezing point. And we were told that the freezing point was, I think minus one - or zero. And the boiling point for water was a hundred. And like each um like each certain thing would have a certain boiling point and freezing point and - that's what I thought.
- 6a:174 **TZ: So you're correct to say each pure substance has a set boiling point and freezing point.**
- 6a:175 FL: Because sometimes like outside in the puddles when it gets really cold in the winter -
KG: It freezes.
FL: - it freezes over.
- 6a:176 **TZ: OK.**
- 6a:177 FL: So obviously if you're not going to be minus -
- 6a:178 JP: Yes, but it is not minus a hundred is it.
- 6a:179 FL: It is not going to be minus a hundred.
AS: Yes, I got the hundred from [unclear - the boiling point?]
- 6a:180 **TZ: So it is not going to be minus a hundred.**
- 6a:181 FL: It is going to be close to zero, maybe -
- 6a:182 **TZ: OK. Under what what what conditions you know - do we ever get minus a hundred on Earth?**
- 6a:183 KL: No.
AS: Maybe in Greenland. Is Greenland warmer than us[unclear - 'one of us' or perhaps 'warmer than us' - said very quietly and other students speaking simultaneously].
- 6a:184 JP: No. Greenland is the biggest island in the world [TZ nods].
- 6a:185 AS: Yes, but it's got ice.
JP: Mmm. [Agreeing]
- 6a:186 **TZ: So in our poles [TZ mimes the poles of Earth with her hands] - in the poles it is very cold. It is very cold. You might get minus - [TZ pauses slightly]**
JW: Twenty seven.
TZ: - minus thirty or - I'm not sure it goes down to minus a hundred.
JP: I think it goes down to minus sixty.

- TZ: But it goes very - it becomes very very cold, but, this idea ice, water freezes at minus. [TZ changes her expression here] ... I would say comes from those experiences. Yes? If we had to do an experiment to change that thinking, what do you think we could do? To try and prove or disprove that idea?**
- 6a:187 KG: Isn't there that chemical that can freeze stuff really quickly? ... What is that one called?
AS: Could we put it in the freezer?
- 6a:188 **TZ: So if we think about just ice. What could we do to decide that the freezing point**
-
- 6a:189 JP: We could measure.
6a:190 KG: Melt it.
6a:191 **TZ: We could - [TZ pauses]**
6a:192 KG: We could try a different temperature, then one degree less [KG mimes this with her hands] every time.
- 6a:193 **TZ: OK. So - so we could - So think about the practical we could do. I think you've got some ideas there. So if we had a block of ice - not water, but a block of ice, OK, - Because we're trying to work out freezing point - is that different from the melting point?**
- 6a:194 FL: Yes. [Fairly confidently]
AS: Yes. [Less confidently than FL]
- 6a:195 **TZ: Is freezing point different from the melting point?**
6a:196 JP: Yes. [Very confidently]
6a:197 VG: Yes, because -
JP: One's cold, one's hot.
VG: I was going to say, because your like freezing point has got to be colder for the liquid to actually freeze -
KG: And the melting point - [Said simultaneously with VG above]
VG: - and the melting point -
KG: - goes down.
VG: - is where it goes from like ... from basically being frozen to actually melting and turning back into a liquid so it needs to be hotter and colder. [JP starts speaking in 6a:198 while VG says this]
- 6a:198 JP: So ... so ... so ... so in like water's case, if it was boiling point it would turn into a gas, and freezing point it turns into a liqui - um a solid sorry.
VG: Solid.
- 6a:199 **TZ: OK. So if we had to explore that. I mean I know we've focussed a lot on this ice at the moment. So if we had to explore that, and change our perceptions, what practical could we do to try and change that thinking? Or trying to get an answer.**
- 6a:200 JW: Would you basically get the block of ice, and then ... maybe leave it out in the sun but keep an thermometer on it and go back to it every 5 10 minutes and record the time. And then see when it has completely melted.
- 6a:201 **TZ: So what would we - what would we -**
JW: And record the temperature.
TZ: So I think you've got on the right track. We couldn't just leave it [TZ looks at JP who nods], OK. We've got a watch [unclear - 'to watch'?), yes? If we had to - we've used a temperature probe haven't we? [JP and others nod] That logs things digitally. So if we had - we've got an idea - so we've got the block of ice - [TZ lifts an ice cube out of the bowl and puts it on the table] temperature probe, stop watch [TZ mimes holding the stop watch in her hand]. OK. That's from JW. What could we do?
- 6a:202 KG: ... Record each time more water comes. Because that's -

- 6a:203 **TZ: So, if we've got a block of ice, frozen, completely frozen, and we want to - we want to try and work out what's happening to - to the temperature of the anything. What could we do [TZ looks towards VG and JP]?**
- 6a:204 JP: We could -
 KG: You could probably like get a big beaker of water and like put the - like how - measure it to the right temperature, so you could do like, I don't know, like zero degrees first, and then try it with the ice and see if it melts or not. Keep adding hot water for five minutes and make it a higher temperature.
- 6a:205 **TZ: And the results that we get probably would change our perceptions [VG nods] about when is the freezing point, when is the melting point. At what point. OK. And, has anyone seen those graphs that go [TZ mimes drawing the graph with her finger] up like that and flat, up again and flat.**
- 6a:206 JW?: Yes.
 VG: Um.
 JP: Line graph.
- 6a:207 VG: Is it lines or - ?
- 6a:208 **TZ: Yes. It is like a cooling curve or heating curve. So. It is really what those flat parts mean [TZ is miming the flat parts of the graph] - of those graphs.**
- 6a:209 KG: It just stays at one temperature.
- 6a:210 **TZ: It stays at one temperature, but why does it stay at one temperature? What is happening to something at that one temperature? Is something that we could explore to really change our perceptions about freezing point and boiling point. Any ideas [TZ starts to tidy the bowl and cup away - her voice changes tone slightly], any discussions, any final points about our - our tea? [Pause] Who is brave enough to pop their finger in [JP and VG both put their hands up quickly].**
- 6a:211 JW: I will! [In a sing song voice]
- 6a:212 [Pause while students put their finger in the tea - TZ smiles slightly]
 AS: It is not that hot. [Tone implies some surprise]
- 6a:213 **TZ: It is not that hot. OK.**
- 6a:214 FL: It has already gone like - started to reach room temperature.
 JW: [Unclear as said simultaneously with FL - appears to be repeating 'started to reach room temperature']
- 6a:215 **TZ: OK. ... [Unclear - one sentence]. [Students and TZ are putting their fingers in both the bowl of ice and the tea]. So, why - why has the tea - what has happened to the - to the tea. Tell me - you know - why has the temperature of the tea gone down? [TZ mimes something going down with her hand]**
- 6a:216 VG: [Unclear section as everyone talking at the same time] 'Cos it's ... going to room temperature.
 KG: [Unclear]
 FL: [Unclear]
- 6a:217 **TZ: OK, but why?**
- 6a:218 KG: [Unclear as KG and VG are talking simultaneously]
 VG: It is kind of like - yes -
- 6a:219 JW: There is more coldness in this room than there is in the hotness of the tea, so that is kind of -
 FL?: Transferring [FL appears to be agreeing with JW]
- 6a:220 JP: Because where like we've got wind, and stuff like that, that is flowing against -
- 6a:221 **TZ: But where is the wind in this classroom? [TZ holds her hands up and smiles as she says this]**
- 6a:222 FL: But it is all the air, because if you put something over the cup of tea like that, then it would hold the heat in more than -
 JP: [Simultaneously with FL] You've got oxygen in the air. [JP looks at TZ, TZ is listening to FL]

- 6a:223 KG: [Simultaneously with FL in 6a:222] Oh the heat would go like -
 VG: Conduct - oh er [VG corrects himself] - no err - insulator.
- 6a:224 KG: The heat comes like out [KG points upwards] -
TZ: So is -
 KG?: - if you put your hand over the top like you can feel the heat coming off.
- 6a:225 KL: Whereas now -
- 6a:226 **TZ: So what's being transferred from the tea to the surroundings?**
- 6a:227 JP: It is gas.
 ??: It's a -
- 6a:228 JW: Water vapour.
- 6a:229 JP: Steam?
- 6a:230 KG: Tea vapour!
- 6a:231 **TZ: Tea vapour. [TZ smiles]**
- 6a:232 JW: Evap - there is - it's evaporating into the air.
- 6a:233 **TZ: So it has evaporated into the air. What's evaporated into the air?**
- 6a:234 AS?: Steam
 JW: So because it is hot and, when it is hot it um ... when it has got to a certain point, I don't know, it starts to steam. And steam is - and water, is evaporating up into the air and going into our atmosphere.
- 6a:235 **TZ: And at what point would we have a change of state, not necessarily now, but at what point would we have a change of state?**
- 6a:236 AS?: [Unclear as simultaneous with TZ in 6a:235]
 FL: If it was boiling then -
 KG: Or you could do hotter.
 FL: - around the same temperature as that [FL indicates the bowl of ice cubes].
- 6a:237 JP: What? With room temp - You could boil it.
- 6a:238 JW: Or for it to go to a gas you need to go to its boiling point and stay at a higher point around there. And then you would have to wait for it to evaporate or you could turn the temperature up higher to make it go -
- 6a:239 **TZ: [Picking up the tea] In the cup of tea? [TZ smiles]**
- 6a:240 KG: Not in the cup of tea.
 JW: But if you had like a jug of water or like a kettle then you can like hold it down.
- 6a:241 **TZ: But the cup of tea has just been sitting here -**
- 6a:242 FL: Because like the jelly we made like was solid, it did evaporate after a while and it did almost spurt everywhere.
- 6a:243 **TZ: OK. With the jelly that we did we were heating it. It boiled and then some of the - some of the jelly liquid evaporated. But, what was being transferred - if we're talking about - what's being given off from [TZ indicates the cup with her hand] -**
- 6a:244 AS: Steam. Heat.
- 6a:245 **TZ: The steam. Heat. OK.**
- 6a:246 FL?: Heat energy.
- 6a:247 **TZ: Heat energy is being transferred from our -**
KG: Tea.
TZ: - tea. So what is it doing to the - what is it doing to the air? [TZ mimes something with her hand]
- 6a:248 AS: Is it heating the room up?
- 6a:249 **TZ: It is heating the room up. OK. So it is heating the room - not the whole room, but maybe -**
- 6a:250 JP, VG, KG, AS: The area. [Unclear as several students speak at once - but students are agreeing with TZ]
- 6a:251 FL: That's [the ice] probably melted [unclear] the first one.
- 6a:252 **TZ: Could have done.**
VG: It [the tea] is probably affecting that [the ice].

TZ: Affected that.

6a:253 KG: Around the [unclear] like that it is probably more [unclear].

6a:254 **TZ: Yes. Like a camper van. [Unclear] So if the cup of tea is transferring its heat energy to heating up the surroundings, ... who might might be able to explain why doesn't the overall temperature [unclear - TZ says the last two words very quietly]**

6a:255 AS: [Unclear - the noise from the classroom next door means that it is very hard to hear at this point]

6a:256 **TZ: [Unclear]**

6a:257 AS: Yes.

6a:258 KG: Because it is colder in the air, isn't it. It is colder in the air so -
AS: It is letting more heat out.

6a:259 VG: I was going to say -

6a:260 **TZ: It is transferring its heat -**

6a:261 VG: It is sort of - it is sort of like it is exposed, because - because of like it is not at room temperature yet, it is sort of like being overpowered - like it is all going down -

6a:262 KG: If you want to heat something up quickly you [unclear] use a pan with like a lid on top so to try and keep the heat in.

6a:263 VG: You insulate it.

6a:264 KG: Yes, that is what I'm trying to say.

6a:265 JP: That's not really insulating is it.

6a:266 **TZ: Well yes. You just try and not -**

6a:267 JP: You just kind of seal [unclear - 'conceal' 'couldn't see all?'] the heat what's coming out. [JP mimes this with his hands]

6a:268 VG: You're sealing all the heat and sealing it in it. [Unclear as said simultaneously with JP in 6a:267]

6a:269 AS: If you put cling film over hot food [unclear] that keeps in.

6a:270 JP: [Unclear]

6a:271 **TZ: Right. [TZ lifts the cup of tea and ice off the table] So I think we've talked about the tea and ice quite a lot. Right. Our next target [TZ turns to JR who is preparing to pass the card sort activity]**
?: [Unclear - quiet talking between the girls]
TZ: Right, so in our next [unclear] everyone gets a bag [TZ passes these out] ... and a board [TZ passes these]. Two each.

6a:272 JP: We used to play this sort of thing in primary school.

6a:273 JW: Oh yes, I remember that.

6a:274 FL: Don't we get two each?

6a:275 ??: [Unclear]
JW: Oh, this is going to be easy.

6a:276 FL: Do we only need one each, or two?

6a:277 VG: Two each, because it is living and non-living.

6a:278 **TZ: OK. So in our next activity -**
AS: Oh, we're putting them into living and non-living.
TZ: Um. [TZ is reading from the questioning route - pupils are getting their cards ready] ... What I would - um ... What you need to do, it is saying - Please sort the cards into [JR removes the bags from the table] - onto the spaces on the mats, quickly. One - one for living things and one for non-living things. Try not to look at what your neighbour is doing - don't look at anyone else - um - Try not to look at what your neighbour is doing as the idea is to explore the different ways in which we might understand the word 'living'. It is OK to have your own ideas on this and you can change your mind later if you want. So just do it really quickly. [Pause]

6a:279 KG: Is this leaf dead or alive?

6a:280 AS: It says dead leaf.

6a:281 JP: Does it say 'dead leaf' on it? [With a little irony perhaps] ...

6a:282 FL: TZ, when you talk about milk, are you talking about the actual milk, or the organisms living inside the milk?

6a:283 KG: Or the organisms living inside the soil [KG is holding the 'soil' card]. Because like to you get worms and -

6a:284 FL: [Unclear] talk about living. But milk could be living.

6a:285 KG: And how does it stop living? [Unclear - one sentence]

6a:286 **TZ: Right, you just do your thing -**
JP: Yes, do your own.
TZ: Do yours, and once everybody's finished we'll have a discussion. [TZ sorts her own pack of cards next to the mats so she can see all the images] OK.

6a:287 JP: Would you see wind as alive? [JP appears to be speaking to himself] ... You've got two bicycles. But one's got a person on it.

6a:288 AS: Is that the person on the bicycle or the - ?

6a:289 **TZ: Suit yourself. [TZ says this very quickly after AS speaks in 6a:288]**

6a:290 FL: No, because you've got the person haven't you and the bike moving.
 JP: We can always change it.

AS and FL: [Unclear - quiet discussion]

6a:291 **TZ: OK. Try not to have no discussions with anyone -**

6a:292 JW: [Unclear - but JW appears to be asking TZ what an embryo is and showing TZ the card]

6a:293 **TZ: An embryo.**
JW: Yes.

6a:294 AS: But I know what it is. [Unclear - AS appears to be mocking JW a little - this could be 'But you don't know what it is.']

6a:295 JW: That's hard, because - Oh no.

6a:296 AS: Actually - !

6a:297 **TZ: Right, don't change yours [AS] yet, put yours back until we've had a look at what you've done.**

6a:298 KG: Is the egg hard boiled or is it still like - you know -

6a:299 **TZ: Well it is in a cup, so I would imagine [KG laughs] that it's a hard-boiled egg. [TZ looks at JR who shrugs - then TZ shrugs towards KG] I don't know. Egg. It is in a cup. So I would imagine.**

6a:300 JW: It used to be alive.

6a:301 KG: [Unclear - something about 'a little soggy bit']

6a:302 **TZ: Well. It's an egg, in a cup, so I would imagine that it is an egg that you can eat. [Pause]**
AS: [Unclear - quietly talking with FL]
 FL: Hurry up boys!

6a:303 AS: The seeds I wasn't sure about.

6a:304 **TZ: OK. ... Excellent. So we've all organised - well you've all organised this into - in different ways. So, let's just go round the group and let's have a look at your thoughts and ideas of why you've put some things onto living or non-living. So start with KG.**

6a:305 KG: Well I didn't know about the soil. Because things like soil, river and water - they have things in them. So water has like plankton, or something like that, in it. And soil could have like worms, and thing like that, in it. I don't know if it is classed as soil, on its own, or just like - you know -

6a:306 **TZ: So having some clarification of soil - but soil is soil, OK, with things in it. OK? With things in it. ... So if you pick up a handful of soil it will be soil, plus whatever is in it. So -**
FL: Something else.
TZ: That - OK? Right, OK? So is that what you're going to say about [TZ mimes KG's mats with her hand] - have you said everything?

6a:307 KG: Yes.

6a:308 **TZ: OK. [TZ indicates that FL should speak - TZ uses her hand to do this]**

6a:309 FL: I picked the most obvious ones - the ones that were living because - the spider obviously has to be living, a dog is living, a lion's living, and an embryo is living. And a person is living. [Unclear] You can see because like a lion moves so.

6a:310 **TZ: OK. Excellent. So, OK. AS [TZ uses her hand to indicate that AS should go next].**

6a:311 AS: I put fire in the living because like ... do you know we had the - the seven thingies of life -
TZ: Uhu.
AS: - it kind of has all of them - nearly all of them.

6a:312 **TZ: We're going to hold on to that and come back to what those seven thingies of life - in a minute.**
KG: Oh yes. [Unclear - but KG seems to be acknowledging that she is changing her mind about something]
TZ: That's fine [to KG]. Don't change anything just yet KG.

6a:313 JW: MRS NERG.
JP: MRS NERG.

6a:314 AS: Yes, that's the one.

6a:315 **TZ: OK. Don't change anything just yet. [TZ uses her hand to indicate JW] JW.**

6a:316 JW: Um. I put - [JW moves his chair loudly and some other pupils laugh] The one I wasn't sure about though is seeds, because - um - you put them in the soil then you water them and then they become living. But I'm not sure if they're living before. And the other one that confused me was the person on the bicycle because you're not sure if they just mean the bicycle again.

6a:317 **TZ: But what does the card say?**

6a:318 JP: [With others simultaneously] It just says bicycle.

6a:319 VG: Same as the other one.

6a:320 **TZ: OK. So the fact that - if it's a bicycle [AS is holding up the two cards and TZ points at them] this is still a bicycle. But with a person on it -**
JW: It is moving.
TZ: - it is moving, but it is still a bicycle. It is still a bicycle. Regardless of whether -

6a:321 JW: A moving bicycle.

6a:322 **TZ: A moving bicycle.**

6a:323 JW: And then egg also confused me a bit, because, if you think about it, it was living - there was a [unclear - 'chick' or perhaps 'chicken?'] that like - And then you cook it an eat it.

6a:324 **TZ: OK. VG?**

6a:325 VG: Um, well, I did like the tree and the plant, because they're all living like. With the tree like, because it like intakes gases and breathes out gases and stuff like that. But like what FL said, everything that is living was moving, but trees and plants don't really move. Like sometimes I -

6a:326 AS: Yes they do. They can sway in the wind.

6a:327 VG: Yes, but that's like the actual [VG looks out the window at the trees] -

6a:328 FL: Plant moves towards the sun [FL says this to VG and then looks at TZ]

6a:329 JP: Yes.

6a:330 VG: Yes I know, but the trees don't. It is just like the wind - apart from that.
AS: Well they grow.
VG: - apart from that. [VG sits back in his chair, smiles and taps the table]

6a:331 JW: They grow towards the light.

6a:332 VG: Yes.

6a:333 JW: They grow towards the light.

6a:334 JP: A tree is just a bigger version of a plant really.

6a:335 VG: Yes.

6a:336 **TZ: Right. JP.**

6a:337 JP: I put - in my one - my living, I put the sun. Because it is like um the living - because the sun and water they create the plants and the trees. And like I put water in there because um - I don't - I thought that most um - what's it called - life forces start with water.

6a:338 **TZ: So water therefore must be living? [JP nods]**

6a:339 JP: Yes.

6a:340 **TZ: OK. Excellent.**

6a:341 KG: Miss I've just go a thing to say -

6a:342 **TZ: [TZ holds her palm downwards towards KG] Now don't change anything just yet. OK. [KG clearly still wants to come in here] Go on then.**

6a:343 KG: Everything on it has to be living, because it has like germs and all that [VG seems to be agreeing] so -

6a:344 **TZ: But the fact that it has something on it living -**
KG: No, I'm just saying -
TZ: - does it mean that itself is -

6a:345 JP: [JP is speaking directly to KG] A dead person could have - something -

6a:346 **TZ: [Unclear - but TZ appears to be confirming - 'it is dead, on it is something living'] So let's come back to AS's - she made this really - really good statement that says that thing - that seven things - what did you [AS] call them again?**

6a:347 AS: I just called them the seven things.

6a:348 FL: We call them MRS NERG.

6a:349 JW: The seven things of life. Move, reproduce, -

6a:350 **TZ: [Several students are speaking at once - TZ says with a loud voice] So, all things must - [TZ pauses and counts off on her fingers]**

6a:351 Several students: Move.

6a:352 **TZ: Move. [TZ continues to count off each characteristic on her hand]**

6a:353 Several students: Reproduce.

6a:354 AS: [Pause] S - S - S - S - S -

6a:355 FL: Sensitive! [FL points at TZ]

6a:356 **TZ: Sensitive to its environment.**

6a:357 VG: NERG. N.

6a:358 KG: Nutrition. They need nutrition.

6a:359 **TZ: Yes. [TZ nods]**

6a:360 JW: What is that one where it goes to the toilet? Respiration.

6a:361 **TZ: To the toilet. ...**

6a:362 Several students: Yes.

6a:363 **TZ: So far we've got - I remember it as MRS GREN. [TZ counts off each one on her fingers] Moving, Respiration, - what is respiration? [TZ has a puzzled expression on her face]**

6a:364 Several students: Going to the toilet.

6a:365 **TZ: [TZ pauses and has an unhappy expression on her face]**

6a:366 AS: Or getting rid of waste.

6a:367 **TZ: Respiration is a chemical process that takes place in each one of your cells, which releases energy. ... OK. So a process that releases energy -**
 AS: We don't really see energy.
 VG: So it is like - it is a bit like -
TZ: - So it is a process that releases energy in your food. That uses - the process uses oxygen and glucose - OK? So we've got Movement, Respiration, Sensitivity, Grrr - [TZ lengthens the word and waits for the pupils to complete it]

6a:368 Several students: Growth.

6a:369 **TZ: Growth, Reproduce or Reproduction -**

6a:370 JP and VG: Reproduction.

6a:371 **TZ: Excretion is where you get rid of waste [TZ is still counting off on her fingers].**

6a:372 AS: Ahhh!

6a:373 **TZ: OK?**

6a:374 JW: And then you've got N for Nutrition.

6a:375 **TZ: And then you've got N for Nutrition. So all - so something that's living shows all those seven life processes.**

6a:376 FL: Because technically fire does sort of reproduce. It gets bigger and bigger.

6a:377 AS: Yes.

6a:378 **TZ: OK. So, with that in mind [these last four words are said more loudly and TZ mimes with her hands a circle] - with that in mind, would that change [AS and KG are trying to speak over TZ] anything that you would - anything - or how you've arranged -**
AS: No.
TZ: - your cards on your table?
AS: [Sharp intake of breath] Yes.

6a:379 **TZ: OK. So think about that. Your question is, think about each one of these. Does each one of those follow the seven life processes? If it doesn't, then can it be living?**

6a:380 FL: Yes. [With a sing-song tone!]

6a:381 AS: No.

6a:382 **TZ: No.**

6a:383 FL: Soil doesn't -

6a:384 **TZ: Can - If it doesn't - For instance, there is this argument that a car - just look at the car as an example.**
AS: Beep beep.
TZ: Is that living or non-living?

6a:385 Several students: Non-living.

6a:386 **TZ: OK.**
FL: Because it doesn't reproduce -
TZ: Right, let's think about - let's think about the life processes then. Does it do any life processes [question seems to be directed at JW]?

6a:387 JW: It moves.

6a:388 **TZ: It moves.**

6a:389 FL: That is the only thing it does.

6a:390 AS: It doesn't get rid of -

6a:391 KG?: It gets rid of gas.
 JP: It gets rid of waste.

6a:392 **TZ: So it gets rid of waste.**

6a:393 FL: It gets nutrition from petrol.

6a:394 **TZ: So it could be fed I suppose. [TZ is counting off on her fingers again] [JW laughs] But does it reproduce?**

6a:395 Several students: No.

6a:396 **TZ: It's -**

6a:397 AS: It doesn't grow.

6a:398 **TZ: Does it grow?**

6a:399 AS: No. No, because a car doesn't all of a sudden go [AS mimes the car growing with her hand]

6a:400 **TZ: It is not a transformer! Those are just - [TZ smiles as she says this - several students laugh]**

6a:401 AS: No.
 JP: No.

- 6a:402 **TZ: OK. So, in terms of res - like chemical reactions - where might be - or how could we argue that in a car there are some chemical reactions? What do we put in, [TZ mimes putting something into a car] -**
- 6a:403 JW: Petrol.
- 6a:404 **TZ: Petrol. And there's -**
- 6a:405 JW: Oil.
- 6a:406 JP: Diesel.
- 6a:407 **TZ: So - not necessarily the oil, but with the petrol there is chemical reactions going on with the petrol that makes our car go forward. But, does it follow all seven life processes?**
- 6a:408 AS: No.
- 6a:409 **TZ: So if it doesn't, is it alive?**
- 6a:410 Several students: No.
- 6a:411 **TZ: So bearing that in mind, with that kind of thinking look back at your boards and begin to re-change [TZ mimes this with her hands] your ideas of what's living and what's not living.**
- 6a:412 Several students: [Unclear as all speaking at once]
- 6a:413 KG: One thing that doesn't follow MRS NERG - isn't it like bacteria and stuff like that? It can't reproduce by itself it has to like go on other people? [TZ sits back]
JP: [Simultaneously with KG and others] Well what I put in my living. [Unclear] Person, mushroom, fire. -
VG: [Sits up] All living?
JP: - sea, dog, leaf, plant, sun, bicycle, water, river, wind, and [unclear].
- 6a:414 VG: [To JP whilst TZ continues to talk with KG] How is fire living? How is wind?
[Unclear - but could be 'How is river?']
TZ: [To KG whilst JP talks with VG] So that is thinking about viruses. Yes? They need to go in. [TZ changes the volume of her voice] But, but just thinking - thinking about what is in front of you [TZ looks over at JP and VG who are still talking] look at the cards that you've got -
- 6a:415 JP: River. I put river on living because you know if you were to dig a tunnel to the side [JP mimes this with his hand] of a river. Then it would go that way which -
- 6a:416 **TZ: But - but - If we think about a river [TZ holds her hand up and counts off on her fingers] does it reproduce? You're saying you've got that [TZ mimes with her hand several 'tunnels' to the side of a river] - Does it have got chemical reactions? Does it respire?**
- 6a:417 JP: Respire. What does that mean. I've forgot.
- 6a:418 **TZ: Where there's a chemical reaction between glucose -**
JP: Oh. Probably not.
TZ: - and oxygen.
JP: No.
- 6a:419 **TZ: Right. So. So, on that basis, on that thinking, -**
AS: [Holding up the seed card] So a seed doesn't live.
TZ: - so on that thinking [TZ says this again with emphasis and is looking at AS], does it - does it - are those, are some of those things - Now a seed is quite interesting isn't it. Because with a seed - with a seed - ... under what circumstances do we kick start it -
- 6a:420 FL: It needs to be boosted.
- 6a:421 JW: So basically the water and the soil fertilize it to grow, is it -
KG and FL: [Unclear - KG and FL say something together quietly]
- 6a:422 **TZ: So - Who's ever grown cress seeds? [TZ changes the pace with which she says this and smiles slightly]**
- 6a:423 KG: Me. [In a bored tone]
JP: No.

6a:424 JW: Me. Because -

6a:425 **TZ: My daughter got some from -**
KG: [To JP - unclear]

6a:426 **TZ: Do you need to - do you need to put cress into soil for it to grow?**

6a:427 Several students: No. No you don't.

6a:428 JW: We put it in -

6a:429 **TZ: What did you just put it in?**

6a:430 **KG:** Cotton wool, tissue, -
 JW: Yes, that is what we did. Water.
KG: - just water, soil, [unclear].

6a:431 **TZ: OK. So something is - the fact that a seed is lying dormant until something comes and -**
JP: Chain reaction.
TZ: - kick starts the reaction -
AS: [Unclear] water.
TZ: - for ex [TZ puts her hand palm up towards AS] - for it - to be water. So in seed's respect it is water. So actually it's dormant, but once it's starts to gr - starts to sprout and starts to grow, does it -
FL: So it is living.
TZ: So you've got - you [FL] make that decision. OK. So relook at your things and then - your cards - and then think about all the things - Does it fill up all those seven [TZ counts them off quickly on her hand] life processes.
 ??: [Unclear]
TZ: [Loudly] If it does, then it must be living. If it doesn't it can't be. So who's made a change?

6a:432 **AS:** Well with the seeds, you're saying they're living, but they don't like get rid of waste.

6a:433 **TZ: [Pause] By itself? [Pause] Oo. A seed, if we cause it to grow, if it starts to grow -**
KG: It makes little shoots [KG mimes this with her hand]
TZ: - if it starts to grow - like a plant. If we get like a seedling, is it living?

6a:434 **AS:** Yes.

6a:435 **TZ: OK. [Pause] Right, so, who's made changes? [VG yawns]**

6a:436 **JP:** I have.

6a:437 **TZ: Who's still got something in their living that is a bit controversial?**

6a:438 **AS:** Does that mean 'not sure'?

6a:439 **TZ: Yes.**

6a:440 **JP:** Err. ... Leaf? I put leaf living, but I'm not sure.
VG: I put - I put - [Unclear]
JW: The wind.

6a:441 **TZ: OK. So, -**

6a:442 **KG:** I'm not sure about water. I don't think water is because - the organisms in water might be living -
JP: Yes [JP is disagreeing with KG]. Because every life form begins with water.

6a:443 **KG:** But that -

6a:444 **TZ: The fact that [TZ holds up the card for water] - the fact that every life form gets - or has some connection with water. Does that make water living?**

6a:445 **KG:** No.
JP: No.

6a:446 **TZ: Does water follow - does it grow?**

6a:447 Several students: No.

6a:448 **AS:** Yes.

6a:449 **TZ: Does it reproduce?**

6a:450 **AS:** Yes.
JP: Nya [Unsure] No. No.

- 6a:451 **TZ: [To AS] How does it reproduce? [TZ has a puzzled expression]**
- 6a:452 Several students: [Unclear]
- 6a:453 **TZ: But how does it reproduce? [With even more emphasis]**
- 6a:454 FL: It doesn't, but it helps to.
- 6a:455 VG: Yes.
AS: [Unclear - said simultaneously with JP in 6a:457]
- 6a:456 JP: Oh yes! When it rains, when it rains miss!
VG: Yes.
AS: [Unclear - said simultaneously with JP]
JP: Because where the sun heats up the ocean, -
FL: It is exactly the same [unclear]
JP: - it goes up and forms clouds and falls as rain. The same cycle over and over and over again.
- 6a:457 **TZ: But that's not reproducing, that's recycling. It is not actually creating a new life form [TZ smiles].**
- 6a:458 KG: We have the same water we had three - five million years ago. [KG shrugs] So it is not -
- 6a:459 **TZ: It is not recycle - it is not reproducing. It is not making a complete new [JP tilts his head in what may be a sign of accepting the point] water. OK. So it doesn't reproduce. Is it sensitive to its environment?**
- 6a:460 VG: Not really.
JP: Yes, because if it was in a hot place then that would - um
- 6a:461 **TZ: OK. I can [unclear] [TZ nods as if accepting the point]**
- 6a:462 VG: Not really because -
JP: Yes!
VG: - no, because it is not sensitive because you see water anywhere. You see it in a puddle, you see it in mud in the field, -
JP: No. Because if you see -
VG: You can see it in the sea, or something like that.
JP: - Because if you see water in like Antarctica, then it would be frozen. If you saw it in, say, South America, or somewhere like that, it would soon heat up and turn into a gas.
- 6a:463 **TZ: [Unclear - 'From your?'] point of view. We can argue slightly, that ... it might [TZ has adopted a very sceptical tone of voice] - on the boundaries, follow some [TZ looks at JP] of the life processes. I wouldn't necessarily agree, but generally does water follow,**
JP: No.
TZ: - in a concrete way, MRS GREN?
- 6a:464 VG: No. Not because -
- 6a:465 **TZ: So actually water must be [TZ puts JP's water card on his non-living mat] non-living.**
- 6a:466 AS: I think the wind -
JP: I thought the leaf -
- 6a:467 **TZ: The wind [TZ puts her hand palm upwards towards AS]. OK. Why do you think the wind is -**
- 6a:468 JP: That is what I thought.
- 6a:469 AS: Because it does kind of reproduce - it gets stronger and stronger. So it like makes more wind.
- 6a:470 KG: Does it reproduce? [Unclear - this could be 'It doesn't reproduce' - KG speaks at the same time as TZ above]
- 6a:471 JP: That is what I was talking to you about with the river. [JP addresses TZ, but TZ is looking at AS]
- 6a:472 **TZ: But - but, so. When we reproducing, are we making more of us [TZ indicates herself with her hands]. Am I making more of us because my offspring [TZ mimes a**

- child next to her] looks identical - some of you just saw my children [unclear] - Did they look identical to me?**
- 6a:473 VG: No.
JP: Yes. [JP, JW and VG smile]
- 6a:474 **TZ: So am I producing more of me? I would have to be reproducing how?**
JW: Um.
TZ: Sexually, or asexually?
- 6a:475 JP: Sexually.
- 6a:476 **TZ: Sexually means that two things come together -**
JP: Yes.
TZ: Asexually means me just reproducing - [TZ pauses]
- 6a:477 AS: Loads of you. [AS points at TZ]
- 6a:478 **TZ: Loads of me. [TZ laughs slightly]**
VG: So it is like twins or cloning.
TZ: That would provide - not twins, but cloning. OK? So wind is -
- 6a:479 *JR: I'm really sorry to interrupt, can I just check with the time - are you OK until five to? Or a little bit longer? If five to we probably need to move on soon. [TZ nods]*
- 6a:480 **TZ: So we've got, we've got - [TZ draws in breath] we've got a few more discussions.**
- 6a:481 *JR: Would you mind if I took a quick photo of the table?*
TZ: Yes, that's fine.
JR: Would that be alright just so I can see sort of where cards are at at the moment. I know they're changing round all the time. Is that OK with everybody?
Several students: Yes.
- 6a:482 **TZ: So the wind, let's just quickly end on this one because we've got one more thing to do. The wind. Does it do all of MRS GREN?**
- 6a:483 FL: No, no, no.
JP: No!
AS: It does!
- 6a:484 **TZ: Please put your hand up if you think it does do all of MRS GREN. [AS puts her hand up. No other student does]**
JP: In some cases yes, in some cases no.
VG: But [unclear]
- 6a:485 **TZ: Hands up who thinks it doesn't go with MRS GREN [KG and JP put their hands up straight away - JW and VG do eventually]**
- 6a:486 VG: It does some of them, but not all of them.
- 6a:487 FL: It is just like water.
- 6a:488 **TZ: It is a bit like water.**
- 6a:489 FL: Because we're just like reusing it, we wouldn't be producing more.
- 6a:490 JP: That's what rivers are - that's what I was arguing with rivers.
- 6a:491 AS: We are!
- 6a:492 FL: We're not!
- 6a:493 JP: It's [the river] is like that because wind it will go everywhere. And like the river it is going to go everywhere as well.
- 6a:494 KG: How does wind excrete? How does it go to the toilet?
- 6a:495 AS: It does, it gets rid of the carbon - no it doesn't. [Several students including AS laugh]
- 6a:496 **TZ: No. Right. So have you changed your idea?**
- 6a:497 AS: Yes.
- 6a:498 **TZ: OK. So on that note, I think we're going to have to put these away. It was a really good discussion. Let's put those away -**
- 6a:499 FL: TZ, [unclear - but from the tone it is a question]
- 6a:500 *JR: Can I suggest just putting them just as they are on the side so we can go straight to the next one? Please don't worry about sorting them out.*
- 6a:501 **TZ: Say again? [To FL] Is soil living?**

- 6a:502 FL: Is soil living or not?
- 6a:503 **TZ: Well soil is just bits of rocks and [unclear] - it doesn't go with MRS GREN [unclear - this passage is difficult to hear as everyone is tidying their cards and TZ is talking quite quietly with FL - possibly 'the key is, does it go with MRS GREN yes or no?']**
- 6a:504 FL: Does that stuff [unclear - possibly 'that grows on building']? Do you know the little green stuff? [Unclear]
- 6a:505 KG: Little green stuff!
- 6a:506 KG: I've forgotten what it is called.
- 6a:507 **TZ: Plants?**
- 6a:508 VG: Moss? [Another student repeats this - unclear who]
- 6a:509 FL: It is not moss. I've forgotten the name. But -
- 6a:510 **TZ: But - things that grow on it do [unclear - could be 'live']**
- 6a:511 JP: Moss is living, isn't it? [TZ is turning to get the teddy bear activity ready while JP says this]
- 6a:512 VG: It is like a slimy [unclear]
TZ: Right. Our last thing that we need to discuss this afternoon [JR passes the teddy to TZ who smiles] -
 FL and AS: Teddy teddy bear!
TZ: Mr teddy bear. Right. So [TZ is reading from the questioning route]. Now you've got to imagine that this - this teddy bear [TZ places it in the middle of the table] - um - Oh. I'll say it again. ... OK. Right teddy bear [unclear - 'on the table']. So. Um. Imagine you walk into a completely dark room. So it is completely dark. And you have the torch and the bear. Yes? And it is on [TZ tries to turn the torch on]. So if I push [TZ is turning the torch in her hand - JR moves to help turn on the torch].
- 6a:513 FL: If you can find the switch! [FL says this in a slightly ironic tone]
- 6a:514 AS: Whoa! [TZ has found the switch, turned on the torch and shone it accidentally in AS's eyes]
- 6a:515 **TZ: Sorry! [AS and TZ laugh slightly] It's on. OK? But it is in a dark room. Um. And you see the teddy.**
 AS: Can I hold the teddy?
TZ: Oh, we need some paper [said to JR]. So we'll get some paper [said to the students] and you're going to make a quick sketch showing the torch, the teddy [TZ holds both torch and teddy up for the students] and your eye. The torch, the teddy and your eye.
- 6a:516 FL: Don't our pupils expand when we go into the dark? [JR is passing out the paper and pencils]
 JP: Cheers.
- 6a:517 **TZ: Which explains how you see the teddy. And you can just draw stick people if you want. So basically you're making a drawing to show how you see the teddy, in a dark room, when you've only switched on the torch.**
- 6a:518 FL: Don't we see like blurry -
- 6a:519 **TZ: OK [TZ holds her palms downwards and towards FL]. Right you -**
- 6a:520 JW: Are you just pointing the torch down?
- 6a:521 **TZ: ... You decide. You can see - you've got the swit - you've got a teddy [TZ holds the teddy up] -**
 JW: A torch and your eye.
TZ: - you've got the torch. You go into a dark room. You switch on the torch, you see the teddy. Why?
- AS?: You see [unclear - said very quietly]
- 6a:522 AS: ... You see half of it.
- 6a:523 **TZ: [Very quietly] OK. You [AS] just draw. Stick men are fine.**

6a:524 VG: Do we have to draw the actual pupil or just the eye.

6a:525 **TZ: No, you have to draw - the torch, teddy and your eye.**

6a:526 KG: Can we do like not pointing? Can we do like so it reflects off of the wall -

6a:527 **TZ: You do it however you want. ... If you want to draw a torch, teddy and your eye.**

6a:528 AS: My eye is a bit weird.

6a:529 FL: A bit big isn't it girl? [a joke - AS laughs slightly]

6a:530 AS: I've got [unclear] look. [AS shows her drawing to FL and TZ. JW looks over]

6a:531 VG: [Unclear]
KG: And then you see how blurry it is.

6a:532 FL: Isn't it when you're born and you don't see as well as after six months.

6a:533 AS: You see 18 centimetres. Because my cousin -

6a:534 **TZ: As you - as you - when you're born you can only see things really close to you.**

6a:535 JP: So you're short sighted.

6a:536 AS: I've got an eight week old cousin and when he - we were like standing quite far away like talking to him, if you know what I mean, and then my auntie said, "He can't see you." And I went, "Oh!"

6a:537 **TZ: Don't forget, these are just quick sketches, not works of art.**

6a:538 KG: It don't make any sense! [KG appears to be talking about her own drawing]

6a:539 **TZ: Not works of art. OK. [JP puts his pencil down with a clatter - TZ looks at JP] And then have a look.**

6a:540 AS: Shall we put our name on?

6a:541 *JR: Oh, yes please. Would you put your initials on each of your drawings please.*

6a:542 FL: Oh no! [TZ laughs]

6a:543 *JR: Sorry! Just quick sketches is fine.*

6a:544 **TZ: Yes, really quick sketches.**

6a:545 KG: [Unclear]

6a:546 **TZ: OK. Now.**

6a:547 AS: [Looking at FL's drawing] He looks like a Bradz doll! [Several students laugh]

6a:548 **TZ: It is just a quick sketch. It doesn't matter how it looks like. ... Right. So let's go around the table. ... We've all got this idea that light, I think - [VG is still drawing]**

6a:549 AS: Can I demonstrate? [FL reaches over and gets the teddy and torch off the table]

6a:550 KG: [Taking the torch] Or, if it bounces off something, [unclear] it will bounce straight off onto that [KG indicates light bouncing off her hand onto the teddy].

6a:551 JP: No, if it was a mirror.

6a:552 **TZ: OK. Before, before, before, before we even go into it, I want you all to hold up your drawings.**

6a:553 FL: If that makes any sense. [Everyone holds up their drawings - TZ and the students look at the drawings]

6a:554 **TZ: [TZ is trying to turn the torch off and fails. She puts it down with a thump and laughs.]**

6a:555 AS: Miss, it might turn off on its own.

6a:556 **TZ: Right, so we've got [TZ is looking at, and pointing to, JP's drawing] the torch giving out some light and it falls onto the teddy. [JW goes to add something to his drawing] Don't change your ideas now.**

6a:557 JW: I'm not.

6a:558 VG: I did the torch travels sort of like towards the eye and you can actually see. ... You know.

6a:559 **TZ: OK. So the torch is travelling - the light falls -**
VG: Sort of like towards you.
TZ: - comes towards you then - [VG pauses]

6a:560 VG: Then you'd be able to actually see it.

6a:561 **TZ: ... You can actually see, the teddy. OK. I can't really see yours [JW] so just describe yours JW.**

- 6a:562 JW: Basically that's the torch light going down there, and you can see part of the teddy. But where the torch isn't shining you can only see it partly.
- 6a:563 **TZ: So you can only see the part that the light falls on. OK. [TZ points towards AS with her palm downwards and smiles]**
- 6a:564 AS: Mine's like - you're shining light and you can only see like a little bit of it.
TZ: OK.
AS: So like if you were shining it at the top of it -
- 6a:565 **TZ: Where's your torch?**
- 6a:566 AS: There [AS points to the lines]. The little lines. [With a slightly incredulous tone]
- 6a:567 **TZ: Oh. Those are the torch. So the the, the light falls onto the teddy [TZ is pointing at AS's drawing] -**
AS: Yes.
TZ: OK. And then you can see.
- 6a:568 FL: On my one you can't see the details of it because when you first turn on like your pupils [FL seems to be miming her pupils getting bigger] and then after a while they get bigger.
TZ: OK.
FL: And ... after - because I didn't draw any features of the teddy because as soon as you hit it [FL mimes a flicking motion with her wrist indicating perhaps moving the light beam downwards such that the light hits the teddy] you would see a faint outline.
- 6a:569 **TZ: So you're saying again this idea that light falls onto the teddy [TZ looks up at FL as she says this] and then you'd be able to see.**
- 6a:570 FL: Eventually.
- 6a:571 **TZ: Eventually. OK. KG.**
- 6a:572 KG: It might be things like [unclear]
- 6a:573 **TZ: OK, so you've got this idea that light, from the torch bounces off of something, hits the teddy and then we can see it.**
- 6a:574 KG: Yes.
- 6a:575 JP: So it is like a triangular motion.
- 6a:576 **TZ: Right. Don't make any changes. So. We've got these ideas. I think there's a consensus of [TZ sweeps her hand round the table] - consensus of ideas - apart from maybe JW's I think - apart from - no, VG's -**
VG: Yes. Then I just realised that -
TZ: - this idea that light - Don't change.
- 6a:577 VG: No. I've just realised that it shouldn't have gone light to the teddy so then you can see.
- 6a:578 **TZ: Alright [Said quietly]. OK, why have you [VG] changed, before I've even talked, why have you made that change?**
- 6a:579 VG: It just that it seemed a bit more, sort of like, logical. In a way, because you can't really shine it into your eye and be able to see - like you could like sort of like shine it in front of you because if you're holding the bear you'd be able to see it. But you couldn't like shine it into your eye and be able to see, because it would sort of like blind you.
- 6a:580 **TZ: OK [TZ says this with a puzzled tone]. OK. So that's a really good - What VG is beginning to explore there is good thinking and he's changing his ideas. I think, lots of are quite correct in saying that light will fall onto the object [TZ has taken up KG's drawing and points to what she means on it], but if light is just falling onto the object, how do we actually see it?**
- 6a:581 AS: With your eye. [AS points at her eye but doesn't appear to be indicating that light enters the eye, her tone indicates that this is obvious]
JW: It is the reflection.
KG: [Turns round and looks at the camera behind her]
- 6a:582 JP: [Unclear] reflects off that [the teddy] into your eye. [JP mimes this]
- 6a:583 FL: If you look [unclear - noise from the next classroom makes this difficult to hear]

6a:584 **TZ: How - so how - so I think we need to come back to VG's idea - we need to come back to VG's idea that if light just travels into your eye, that's no good. Are we saying that because - somehow [FL picks up the torch] we have to get the image into our eye. But for light just to be travelling into our eye that's not going to be doing any good is it.**

6a:585 AS: No. It hits on the teddy and then when it - because you can see it you can like follow the light with your eye -

6a:586 **TZ: So so so so, something then must be travelling from the teddy to your eye?**

6a:587 AS: The picture of it.
 KG: [Unclear - she shakes her head]
 FL: [Unclear - something said in a whisper to KG]

6a:588 **TZ: So, OK. So the picture of it. So actually light must travel - the light from the torch is travelling in all directions -**
JP: Yes.
TZ: - if light hits the teddy -
FL: [Unclear]
TZ: - OK, but the light that hits the teddy then must do something - must do what VG?

6a:589 VG: Sort of like bounce -
 JP: Reflect.
 VG: - reflect and bounce back to -

6a:590 **TZ: Into your - [TZ pauses]**

6a:591 VG: Eyes.

6a:592 **TZ: Eyes [TZ sits back a little as she says this]. OK. So on the opposite side now, based on that ever so small discussion, how might you change what you've drawn?**

6a:593 KG: Can't I just do it on there [add to her original drawing], just do another little line?

6a:594 **TZ: No. Do it a completely new [TZ mimes turning the page over with her hands] - just a sketch. How might you change your ideas? [Pause]**

6a:595 AS: Urr. I can't really draw. ...

6a:596 KG: [Unclear]
 FL: Because light tries to go through, and if it sees something there'll be a shadow.

6a:597 **TZ: Well don't forget that we get shadows because light travels in straight lines. OK?**

6a:598 FL: [Unclear]
 [Another teacher comes into the room at this point who has not realised we're filming and goes to sit in the corner of the room. FL turns round and smiles]

6a:599 *JR: [Quietly to the new teacher] Sorry, do we need to stop? [JR indicates the camera with his hand. The teacher leaves. TZ looks at JR and smiles]*

6a:600 **TZ: So, light travels in straight lines, so shadows are formed because light doesn't bend round corners. OK. But we're not talking about shadows, we're talking about how do we see. [Pause] [FL is making exaggerated strong pencil lines on her drawing and wobbling back and forth a little - JW looks over]**

6a:601 *JR: Would you put a number 2 on that page just so I know which is - which on the drawings? Thanks ever so much.*

6a:602 FL: [FL picks up the teddy] ...

6a:603 KG: It is awkward now because of the - ...

6a:604 **TZ: Would you put the direction would you think the arrow - the light is travelling.**

6a:605 AS: Ahh. I think it goes that way and then back that way.

6a:606 KG: If that makes any sense! [KG shows turns her drawing towards TZ for TZ to see]
 JP: [Unclear - JP whispers something to VG and they both look at JP's drawing]

6a:607 **TZ: OK. So anyone that's slightly different? [TZ takes JP's drawing] So we've still - JP has still got from the eye -**
JP: To the torch.

TZ: - the light is going from the - So this tells me - what this tells me - that light is given out by your eyes and goes to the torch and then -

6a:608 JP: Oh! OK. So they need to be swapped around.

6a:609 **TZ: So, so - OK [AS shows her drawing to TZ].**

6a:610 AS: Miss, I've got that the light travels to the teddy bear and then travels back into your eye.

6a:611 **TZ: OK. So. Does that make sense? [TZ emphasises this with hand movements] [Unclear - could be 'because that is what we're saying']**

6a:612 VG: That is what I did.

6a:613 **TZ: Right. How has that changed from what you'd done?**

6a:614 AS: I've just done the - you shine the torch and it goes onto the teddy bear and you see it. [Unclear]

6a:615 **TZ: OK. But it makes - because then the image is taken from the teddy and taken to your eye [TZ mimes this with her hand]**
AS: To your eye.
TZ: And then, does it stop there? How does the image go -

6a:616 AS: It goes into your brain.

6a:617 **TZ: How does the image fall onto the back of your eye?**

6a:618 KG: Oh, your - [unclear] you have.

6a:619 **TZ: The right way up, or up-side-down? [TZ mimes this with her hand]**

6a:620 AS: Is it up-side-down?
 KG: Up-side-down.

6a:621 **TZ: Up-side-down. Up-side-down, then information gets sent to your - [TZ pauses]**

6a:622 JP: Brain.

6a:623 **TZ: Brain. And it processes it and everything like that.**

6a:624 AS: So everything we're looking at right now is actually up-side-down?

6a:625 **TZ: But our brain processes - it is such a massive computer to help us see the right way up. Right let's see, any great changes?**

6a:626 FL: I thought, mine is a bit like JW's where [there is a quiet exchange between JP, VG and JW in the background at this point - unclear what they are saying] it is just sort of - it is just coming out of the eye I thought at first. So now is that the torch is shining everywhere and we can see the teddy.

6a:627 **TZ: OK. So for us to see, something must be going ... into ... our ... eyes. OK? [VG puts his hand up]**

6a:628 FL: Brains.
 AS: Yes, like this [indicating her drawing].
 VG: But couldn't you also like - you know like as you - like what people something like when you sort of like scan round with the torch, surely wouldn't you be like watching in the direction your hand was going in [VG mimes this with his hand and an imaginary torch]. So you're sort of like that [VG mimes this].
 KG: Or you're like that [KG mimes shining the torch in one direction and looking in another - she laughs slightly]
 VG: So you're like watching the way the torch is actually going. [TZ picks up the torch]

6a:629 **TZ: [Unclear - one word], but then you'll only be seeing the torch - you'd not be seeing teddy.**

6a:630 VG: No, no, I mean - what I mean is you see the light coming down like that [TZ is shining the torch on the table - VG points to the beam of light between the torch and the table]. So you'll be watching where the light is going and then as soon as you went onto the teddy you'd see the teddy.

6a:631 **TZ: Yes, but for the same reason the light goes here and then travels into our eye. [VG sits back and then his attention turns to what AS is doing with the teddy] OK.**
AS: [Simultaneously with TZ] So that [AS is holding the teddy upright] is really like that [AS holds the teddy up-side-down].

- 6a:632 **TZ: Can I just say you've - you've actually um [TZ is turning off the torch] ...**
FL: You have to hold it just - hold it.
TZ: [TZ manages to turn off the torch and turns and smiles at KG as if she is proud of herself - KG laughs] **You've actually done really well this afternoon [TZ nods several times], some really - you've said some really interesting things. Um. What's been the most useful for you? In terms of the discussion.**
- 6a:633 AS: I think it was that bit we just done. Knowing how the picture comes into our brain.
- 6a:634 **TZ: And actually it is a real - the way - how we see things is a real - pupils find it really difficult to understand that our eyes do not give out light [TZ mimes this] ...**
OK? Something must enter into our eyes.
- 6a:635 FL: We're like a receiver.
- 6a:636 **TZ: [Nodding] We must be receiving.**
- 6a:637 AS: Is that why - if the sun explodes or whatever we won't be able to see anything?
- 6a:638 KG: Yes, we'll probably be dead by then! [Said with irony]
- 6a:639 **TZ: We will just be dead! [TZ laughs] Because -**
- 6a:640 FL: But if we were a superhuman.
 KG: Superman.
- 6a:641 **TZ: Um. Think about - yes - um - yes. I think [TZ is addressing AS more seriously] I think we'll be dead by then. So, yes that's really -**
- 6a:642 JP: Yes, if the sun explodes we'll be dead.
- 6a:643 **TZ: But just think about - um -**
JW: [Unclear]
TZ: - have you - have you ever for [KG reacts to something] Sorry - from a really bright room -
FL: Yes.
TZ: - into a dull - into a - into a -
KG: Dark room.
TZ: - dark room. Or from a really dark room into -
VG: Cinema. It is like the cinema.
TZ: OK.
- 6a:644 JW: When you go from a light room and you go into a dark room it is much more like dark.
- 6a:645 JP: Like when you come out of a tunnel [TZ keeps her attention on JW].
- 6a:646 JW: And then once you adjust to the darkness you can see the outline of stuff.
- 6a:647 **TZ: OK. So your eyes have to adjust and um - just adjust for the light level actually within the room. [FL wants to come in at this point and TZ indicates with her hand that FL should speak]**
- 6a:648 FL: Is it the longest day of the year today?
- 6a:649 **TZ: I think they said [TZ nods] -**
- 6a:650 VG: It was yesterday I think.
- 6a:651 **TZ: Was it yesterday or today?**
- 6a:652 JP: No, no, it is today. Today is the twenty-first.
- 6a:653 **TZ: Twenty-first. [TZ nods]**
- 6a:654 AS: It has gone really quick.
- 6a:655 KG: You have to take like five minutes for your eyes to adjust [TZ is looking at the questioning route] so - if you like out at night with a torch or something and you only like shut one eye -
- 6a:656 **TZ: But I don't think it will take like that long, I think [TZ looks over at the clock on the wall of the classroom] - I'm going to finish now because I know it is [unclear - 'late'? TZ says this last line in an undertone] - I know it is going - it is a very quick reaction. So we actually - we are not usually aware of. Right. So, very quickly then. Is there anything that we should have talked about but didn't? Anything we -**
- 6a:657 KG: I think we've covered it.

- JP: Yes.
- 6a:658 **TZ: And I think you've been really ... really ... awesome this afternoon. And I will write some yellow forms [TZ mimes writing] to say thank you.**
- 6a:659 KG: Gold.
- AS: [Unclear - VG laughs loudly at what AS has said]
- 6a:660 **TZ: [TZ smiles] Gold forms. They used to be called yellow. So, [TZ turns towards JR] I don't know if we need to say anything else?**
- 6a:661 *JR: Can I just add, I'm really grateful. I don't know about you, but I found it absolutely fascinating the discussion. Loads of really interesting ideas. I hope you've enjoyed it.*
- AS: Yes.
- VG: Yes.
- JR: That's it. We'll be looking at video clips from this, to really explore about, you know, about how we change our ideas. Both of us are interested in that. Many thanks for that.*
- 6a:662 **TZ: Well done [to the pupils]! Thank you.**
- 6a:663 *JR: I don't know, can I just offer you [JR gets some Kit Kats out of a box] - do you like these things?*
- KG: Ooo, yes!
- JR: If anybody can't eat them for any reason - I could get you something else. Anybody allergic to whatever?*
- JP: No.
- FL: I don't think so. [Said with a little irony perhaps]
- JR: Thank you very very much indeed. Would you like to pass them round?*
- 6a:664 **TZ: Thank you ever so much.**
- [End 6a]**

Interview 6b

- 6b:1 *JR: Excellent. Thank you so much for agreeing to do this. I hope you'll find this really interesting. [JR looks at the questioning route] Just the sort of formal introduction if I may. Um.*

Please watch each video clip and then 'think aloud'. By that I mean talk freely about anything that comes to mind about the video. I'm interested in how you might 'solve' these problems - these issues, these - whatever happens. What you'd actually do to help the children when they think like this. Please just report your thinking as accurately as you can in your own words. You don't have to edit, explain or justify your thoughts. We'll leave how you understand the issues in more depth raised to the second part of the interview. Everything you say will be anonymous.

There are 13 clips, but we don't have to use them all. Please try and do some from each of the three topics. We'll spend a maximum of 30 minutes on this. I'll keep an eye on the time, so you don't need to worry about that. After that I'd like to ask you a few questions which will take about another 30 minutes. Please feel free to say when you've had enough or if you need a break! I'll try not to interrupt you while you're watching and responding to the video clips. [JR addresses TZ] But if there is anything you'd like to ask me about, you know, please feel free.

Please don't worry if you can't make sense of what the children say in some of these clips. I know it is of an interview that we've done together, but - there are still detail that, you know, there is only so much that it is possible to take in I think sometimes on a first viewing. Some of the ideas which came up are very challenging even for trained scientists like us. Since I started exploring children's naïve concepts I've discovered several of my own!

Please just say if you'd like to 'unpack' an idea together. I'm aware that you're being asked to do something which is difficult, namely to respond immediately to some very challenging naïve scientific concepts. In the classroom we often have to respond quickly and it is this thinking that I'd like to explore together.

Is there anything you'd like to check about this before we start?

- 6b:2 **TZ: No.**
- 6b:3 *JR: Many many thanks for doing this.*
- 6b:4 **TZ: That's OK. So I can start.**
- 6b:5 *JR: Yes please.*
- 6b:6 **TZ: Oh, so I choose one. So any one?**
- 6b:7 *JR: Perhaps - In order if you don't mine because that's in chronological order.*
- 6b:8 **TZ: OK. [Pause - TZ waits for the clip to start]**
- 6b:9 *JR: Normally they should start automatically, I'm really sorry, there is something funny going on there. [The auto save was causing a problem with the videos playing. TZ and JR had to wait for this to finish which took a few minutes. During this time TZ and JR spoke, but this was not related to the research so this was not transcribed here]*
- 6b:10 *JR: While we're waiting for that silly thing, this is the software I use.*
TZ: OK.
JR: Your video would play there and I do the transcript there and code here. [TZ and JR continue to talk while waiting]
- 6b:11 *CLIP 1: minus a hundred [ID 6a:148-172] 6a:148* **TZ: Let's just go round. [TZ points at JP] What temperature does water freeze at?**
- 6a:149 *JP: Is it minus - It might be about minus five.*
- 6a:150 **TZ: Minus five. [TZ points at VG]**
- 6a:151 *VG: I was going to say between like minus five and minus ten. Something like that.*
- 6a:152 **TZ: Between minus five and minus ten. [TZ points with a flat hand to JW]**
- 6a:153 *JW: Um - zero. Zero point one. [TZ indicates AS]*
- 6a:154 *AS: I thought it was like minus a hundred.*
TZ: Can I talk as it is playing?
JR: Yes. Or click it to pause it if you prefer. [JR pauses the video] Sorry, I'd better do that again [set the pointer to be always visible]. Otherwise the arrow will disappear. Thank you. [Video is paused - TZ starts 6b:12 now]
- 6b:6a:155 **TZ: Minus a hundred. [TZ appears to have a very slight change in facial expression - like a very slight smile]**
- 6a:156 *AS: I thought it was really low.*
- 6a:157 **TZ: Really low.**
- 6a:158 *JP: [Unclear]*
FL: I thought it was really cold because like freezers and radia - not radiators - [AS laughs] and fridges they are usually about minus a hundred and twenty or something like that.
- 6a:159 *JP: No they're not. [JP shakes his head]*
- 6a:160 **TZ: So -**
- 6a:161 *KG: Round about minus twenty seven.*
- 6a:162 *JW: [Smiling] Fridges -*
JP: [Unclear]
- 6a:163 **TZ: [Quite loudly over the top of several students who are all speaking at once] OK. So you're [AS] saying - What point do you say ice - water turns -**
TZ: [TZ pauses the video again at this point] Oh. Is that right? [See 6b:13]
What is the freezing point of water?
- 6a:164 *FL: Maybe ... minus a hundred?*

- 6a:165 **TZ:** *Minus a hundred. [TZ points to KG with her thumb]*
- 6a:166 **KG:** *Zero. Because in the snow when it is all iced up [at the moment KG turns to FL] it is not exactly going to be at minus a hundred outside is it?*
- 6a:167 **JP:** *Yes! [JP points at KG with his finger] You've got a point there because -*
- 6a:168 **KG:** *You're not going to be out there in the like snow stuff playing if it is like minus a hundred.*
- AS:* [Unclear - said simultaneously with KG]
- 6a:169 **TZ:** *OK. So we've got different*
- TZ:** [TZ pauses the video here - see 6b:14]
perceptions, understandings, concepts or ideas about when water - the temperature at which water freezes. Before I unpack that, let's just go and check - What is the temperature that water boils at?
- 6a:170 **JP:** *About a hundred.*
- 6a:171 **AS:** *That's probably where I got the hundred from.*
- 6a:172 **TZ:** *So is there a kind of agreement? [TZ sweeps her hand around the group and everyone nods]*
- AS:* *Yes.*
- TZ:** *Right,*
- TZ:** [TZ pauses the video here - see 6b:15]
so why do you say water freezes at below - below zero?
- 6b:12 **TZ:** *I think at this point I was just going around the group because just to find out their - you know their kind of knowledge of freezing points, melting points you know. Without going into things like absolute zero and all those types of things [TZ smiles]. You know I wanted to know if they had that concept of melting point, especially of water, and freezing point. Did they know zero zero - do you know what I mean. So that is why I think I started going round trying to check. [Unclear - said very quietly - could be 'Is that what you want?' JR nods] [TZ lets the video continue playing from where it was paused]*
- 6b:13 **TZ:** *So - you know - at that point I was amazed that they were saying minus - for water. Which is a common ... everyday common knowledge type of fact, so to speak, about you know - freezing point, melting point of water. And I was a bit shocked when they started saying minus - minus - whatever they said. And I was just like a bit shocked. So I mean. If I was practically in the classroom doing this probably we would then get out some equipment and try some ice, and try to um kind of - have a play to gather some data to see if we could move their thinking on. Just saying it I don't think is good enough. I think kids need to be able to see it in a way so that they can actually begin to change their understanding of a concept. So making it visible for them. So they can begin to unpack and, "I can understand why" - and, "I can see it now". So maybe getting some ice. Maybe - you know - you know - putting on a Bunsen burner, heating it up and using probably a digital thermometer to help them begin to see what is happening with the temperature. Which is probably what I would do there, just to help them move on and look at that idea. [TZ plays the video from where it was paused]*
- 6b:14 **TZ:** *And actually the technique of going around the class - or going round the group. I find it is useful for me, because it gives me time to process and try to understand what they're saying and what they're thinking. And giving each person an opportunity to talk. And giving them their time, their space to air their ... ideas. I think it is useful because not only are the kids verbalising what they're thinking so they can actually hear what it sounds out loud. Other pupils then are able to interact with them and interact with their idea and - you know - you start having that dialogue going on ... with each other. [TZ restarts the video]*

- 6b:15 **TZ:** So at this point it is quite amazing that they are really quite certain ... about the boiling point of water. So - ... not sure, you know, why then there is a difference with their understanding about freezing. Don't know if you had any ideas on that, or what you found out - but yes. The boiling point seems for them a lot more concrete. I suppose because in everyday life - you know, the kettle boils and all that type of thing. It is a bit more concrete.
- 6b:16 *JR: Yes. I found with AS, I'm sorry I don't know her first name.*
TZ: AS [TZ gives AS's first name].
JR: With AS saying - at first she said ... water freezing at minus a hundred.
TZ: Yes.
JR: And then here, right at the end she seems to be saying, "Ah, maybe that's where I got the hundred from". [JR and TZ smile]
TZ: Yes. Yes.
JR: I suppose that was one of the reasons I was picking that clip.
- 6b:17 **TZ:** Yes. Because - they're very happy with that and I think ... understanding - I think probably um ... to help with their understanding it is this idea of doing a piece of work with the cooling curve, so they're really - you know understanding about that. And I don't know if we moved off the point though [TZ mimes this with her hands] - I think kind of moved off the point [TZ laughs slightly] in terms of what actually we were looking at in terms of what was in front of us - the cup of tea and the ice. Um. But just that was just where - how it evolved really - the conversation really evolved really. I think. [TZ restarts the video - only one word sounds and then the video is at the end]
- 6b:18 *JR: That's the first clip.*
- 6b:19 **TZ:** Oh right. [TZ and JR smile] I'll go back here [TZ clicks on the menu button on the laptop and selects the next clip]
- 6b:20 *JR: Can I just check the camera is recording?*
- 6b:21 **TZ:** Yes. Shall I go on?
JR: Please.
TZ: There was quite a lot on the cooling curve [TZ says this to herself].
- 6b:22 *CLIP 2: cooling curve [ID 6a:186-209] 6a:186* **TZ:** So in our poles [TZ mimes the poles of Earth with her hands] - in the poles it is very cold. It is very cold. You might get minus - [TZ pauses slightly]
JW: Twenty seven.
TZ: - minus thirty or - I'm not sure it goes down to minus a hundred.
JP: I think it goes down to minus sixty.
TZ: But it goes very - it becomes very very cold, but, this idea that ice, water freezes at minus. [TZ changes her expression here] ... I would say comes from those experiences. Yes? If we had to do an experiment to change that thinking, what do you think we could do? To try and prove or disprove that idea?
TZ: [Without pausing the video - please see 6b:23 below]
- 6a:187 *KG: Isn't there that chemical that can freeze stuff really quickly? ... What is that one called?*
AS: Could we put it in the freezer?
- 6a:188 **TZ:** So if we think about just ice. What could we do to decide that the freezing point -
- 6a:189 *JP: We could measure.*
- 6a:190 *KG: Melt it.*
- 6a:191 **TZ:** We could - [TZ pauses]
- 6a:192 *KG: We could try a different temperature, then one degree less [KG mimes this with her hands] every time.*
- 6a:193 **TZ:** OK. So - so we could - So think about the practical we could do. I think you've got some ideas there. So if we had a block of ice - not water, but a block of ice, OK, -

Because we're trying to work out freezing point - is that different from the melting point?

6a:194 FL: Yes. [Fairly confidently]

AS: Yes. [Less confidently than FL]

6a:195 TZ: **Is freezing point different from the melting point?**

6a:196 JP: Yes. [Very confidently]

6a:197 VG: Yes, because -

JP: One's cold, one's hot.

TZ: [TZ pauses the video at this point - please see 6b:24 below]

VG: I was going to say, because your like freezing point has got to be colder for the liquid to actually freeze -

KG: And the melting point - [Said simultaneously with VG above]

VG: - and the melting point -

KG: - goes down.

VG: - is where it goes from like ... from basically being frozen to actually melting and turning back into a liquid so it

TZ: [TZ pauses the video at this point - please see 6b:25 below]

needs to be hotter and colder. [JP starts speaking in 6a:198 while VG says this]

6a:198 JP: So ... so ... so ... so in like water's case, if it was boiling point it would turn into a gas, and freezing point it turns into a liqui - um a solid sorry.

VG: Solid.

6a:199 TZ: **OK. So if we had to explore that. I mean I know we've focussed a lot on this ice at the moment.**

TZ: [TZ pauses the video at this point - please see 6b:26]

So if we had to explore that, and change our perceptions, what practical could we do to try and change that thinking? Or trying to get an answer.

6a:200 JW: Would you basically get the block of ice, and then ... maybe leave it out in the sun but keep an thermometer on it and go back to it every 5 10 minutes and record the time. And then see when it has completely melted.

6a:201 TZ: **So what would we - what would we -**

JW: And record the temperature.

TZ: So I think you've got on the right track. We couldn't just leave it [TZ looks at JP who nods], OK. We've got a watch [unclear - 'to watch?'], yes? If we had to - we've used a temperature probe haven't we? [JP and others nod]

TZ: [TZ pauses the video here - please see 6b:27]

That logs things digitally. So if we had - we've got an idea - so we've got the block of ice - [TZ lifts an ice cube out of the bowl and puts it on the table] temperature probe, stop watch [TZ mimes holding the stop watch in her hand]. OK. That's from JW. What could we do?

6a:202 KG: ... Record each time more water comes. Because that's -

6a:203 TZ: **So, if we've got a block of ice, frozen, completely frozen, and we want to - we want to try and work out what's happening to - to the temperature of the anything. What could we do [TZ looks towards VG and JP]?**

6a:204 JP: We could -

KG: You could probably like get a big beaker of water and like put the - like how - measure it to the right temperature, so you could do like, I don't know, like zero degrees first, and then try it with the ice and see if it melts or not. Keep adding hot water for five minutes and make it a higher temperature.

6a:205 TZ: **And the results that we get probably would change our perceptions [VG nods] about when is the freezing point, when is the melting point. At what point. OK. And, has anyone seen those graphs that go [TZ mimes drawing the graph with her finger] up like that and flat, up again and flat.**

6a:206 JW?: Yes.

VG: Um.

JP: Line graph.

6a:207 VG: Is it lines or - ?

6a:208 TZ: Yes. It is like a cooling curve or heating curve. So. It is really what those flat parts mean [TZ is miming the flat parts of the graph] - of those graphs.

6a:209 KG: It just stays at one temperature.

6b:23 TZ: Again, I was just talking about - you know, getting them to think about - well, they've got an idea, can they go off, can they test it, can they collect some evidence, because that's what science is all about. Collecting evidence and, you know - sorry - [TZ pauses the video] This idea that a theory is only a theory until you collect certain evidence to prove it or disprove it really isn't it. So if they've got this idea, if they've got this understanding of something, well if we can do an experiment to collect some data that is going to actually - er - agree or disagree - If it disagrees with what they're thinking then there is going to be some cognitive conflict there really isn't there. And then it is going - it is the question that "Why is it? Is the theory wrong - Is the theory wrong or is the experiment wrong?" But if we've got some data we can change our thinking and maybe fit the data ... with our changed thinking. And maybe it is our original thinking, our original understanding was wrong. So actually getting them to think about - it is all about getting them to be real scientists [TZ nods as she says this]. And getting them to go off and explore and unpick their understanding, and apply their thinking in different ways. I believe that's where I was going on in this section. Really to pull that - kind of abstract talking about things that they're really - you know, just chucking around these terms. But by doing something a little bit more concrete they'll be able to have some physical association with something that they've seen moving on a thermometer [TZ mimes this] or recording. And then they'll begin to understand, and unpick - Oh, and maybe have an understanding of maybe their ideas are correct or not. ... I don't know if that's what your interpretation is? [JR nods - TZ restarts the video at 6a:193]

6b:24 TZ: One's cold, one's hot! [TZ and JR laugh] I mean - [big sigh] you know I look at this and actually it makes me think um probably ... we have done changes of state. [TZ smiles and JR nods] And probably ... this is highlighting that probably they didn't understand that at the point - that the freezing point, melting point - actually what are we actually - you know - talking about here. ... Yes. Just kind of, "One's hot and one's cold." [TZ laughs] That just - [TZ shrugs] That just ... yes. I think that goes to show you they really don't understand the kind of - what we're looking at there really. Um. And I think actually trying to unpick it maybe not from that point of view, maybe as I was doing there, but from the energy transfer and talking about what the energy - what's going on with the actual particles, probably might be a better way to have a look at it. I don't know. But just, "One's hot, one's cold." It is really - [TZ restarts the video from 6a:197]

6b:25 TZ: [TZ frowns] I don't get - So there again, that idea there - I don't know. They've got it but they're - you know - just lis [listen?] - What this is showing to me is just really listening, listening to the pupils talk um is really important. And as teachers I think we've got to be very - our ears have got to prick up [TZ mimes this] when they make a statement that is half true, nearly true, - but yet still holds some kind of elements of misconception, misunderstanding, mis - like the wrong application of ideas. And I think we've then got to challenge and try to unpick. [TZ restarts the video at this point]

6b:26 TZ: Again like probably again I don't know if I had enough time - I think I was conscious of the time - not actually picking up what maybe what VG had said to actually begin to - just to double check and make sure his ideas were really spot on

- there. Even though I think they were, but ... not as clear as I suppose I would have liked them to be. Instead of just moving on. [TZ smiles and restarts the video]
- 6b:27 **TZ:** Again there - just listening, he had some good ideas, but, you know, leaving it - not a good idea. And record the time - so actually - that shows me actually they're not really appreci - what is it that we want to measure. It is not time lapse there. ... It's measuring the temperature. And that's the key one - looking at the temperature. So I suppose in terms of science teaching and understanding, I think it is twofold. They were looking at - you're developing your concept and your ideas. But if you're using practical work to look at that you've got to make sure that they're quite skilled up. Do they know what they're measuring? Do they know like the dependent variable to measure things. Do they know their independent variable - what they're changing? I know - so in this respect it will be their dependent variable - what are they actually measuring? And making sure that they're not confused. That we're quite clear. What is the data that we want, to be able to help us understand our thinking on that particular issue. [TZ restarts the video]
- 6b:28 **TZ:** [TZ reaches the end of CLIP 2] Mmm. Again I think, probably ... I'm not sure, I know I mentioned it, I'm not sure if they will have had that understanding. I don't think ... our schemes in Year 7 allows goes into that depth at that particular time. So actually we're probably talking about something that they have no experience of. But I think it is worthwhile looking at because that's a - for this idea that we were exploring I'm not sure if it is the right one or the wrong one, but that kind of helps with their understanding of this idea of freezing and melting. What's going on - and it is more I think probably - from a teaching point of view, really getting them to understand about actual particles within your solid, within your liquid, within your gas. What's happening - happening to them when they change state in terms of - you know - how much the movement of those particles - the energy that they have and, you know, um - and therefore the arrangements of - within our solids, liquids and gases as - you know - as they change from one state to another. So actually that begins to explain those flat parts, what is happening there. [TZ goes to restart the video] Oh. That's it.
- 6b:29 **TZ:** [CLIP 2 starts again] Oh no. I've started it again.
JR: *That's OK. So [JR points to the 'home' button on the screen to get back to the menu]*
TZ: That?
JR: Please.
TZ: OK. Um. Do you want me just to continue?
JR: *Please, if that's OK.*
TZ: Yes?
JR: *Are you OK?*
TZ: Yes. Yes [TZ smiles].
- 6b:30 *CLIP 3: brave enough [ID 6a:210-231] 6a:210 TZ: ...[Pause] Who is brave enough to pop their finger in [JP and VG both put their hands up quickly].*
- 6a:211 *JW: I will! [In a sing song voice]*
TZ: [TZ and JR smile and laugh but TZ does not pause the video or say anything]
6a:212 *[Pause while students put their finger in the tea - TZ smiles slightly]*
AS: It is not that hot. [Tone implies some surprise]
- 6a:213 **TZ:** *It is not that hot. OK.*
- 6a:214 *FL: It has already gone like - started to reach room temperature.*
JW: [Unclear as said simultaneously with FL - appears to be repeating 'started to reach room temperature']
- 6a:215 **TZ:** *OK. ... [Unclear - one sentence]. [Students and TZ are putting their fingers in both the bowl of ice and the tea]. So, why - why has the tea - what has happened to the - to the tea. Tell me - you know - why has the temperature of the tea gone down? [TZ mimes something going down with her hand]*

- 6a:216 VG: [Unclear section as everyone talking at the same time] 'Cos it's ... going to room temperature.
 KG: [Unclear]
 FL: [Unclear]
- 6a:217 **TZ: OK, but why?**
- 6a:218 KG: [Unclear as KG and VG are talking simultaneously]
 VG: It is kind of like - yes -
- 6a:219 JW: There is more coldness in this room than there is in the hotness of the tea, so that is kind of -
TZ: [TZ pauses the video - please see 6b:31]
 FL?: Transferring [FL appears to be agreeing with JW]
- 6a:220 JP: Because where like we've got wind, and stuff like that, that is flowing against -
- 6a:221 **TZ: But where is the wind in this classroom? [TZ holds her hands up and smiles as she says this]**
- 6a:222 FL: But it is all the air, because if you put something over the cup of tea like that, then it would hold the heat in more than -
 JP: [Simultaneously with FL] You've got oxygen in the air. [JP looks at TZ, TZ is listening to FL]
TZ: [TZ pauses the video here - please see 6b:34]
- 6a:223 KG: [Simultaneously with FL in 6a:222] Oh the heat would go like -
 VG: Conduct - oh er [VG corrects himself] - no err - insulator.
- 6a:224 KG: The heat comes like out [KG points upwards] -
TZ: So is -
 KG?: - if you put your hand over the top like you can feel the heat coming off.
- 6a:225 KL: Whereas now -
- 6a:226 **TZ: So what's being transferred from the tea to the surroundings?**
- 6a:227 JP: It is gas.
TZ: [TZ pauses the video here - please see 6b:35]
 ???: It's a -
- 6a:228 JW: Water vapour.
- 6a:229 JP: Steam?
- 6a:230 KG: Tea vapour!
- 6a:231 **TZ: Tea vapour. [TZ smiles]**
- 6b:31 **TZ: [Smiling] There is more coldness in this room than there is hotness in the tea! I mean that is just - that language there. There is no way that we teach them to talk in that way. But yet they still hold that kind of that vocabulary - the way that they express themselves. I probably think that it is because they find it very difficult to put their ideas into words. But giving them the experience of actually putting their fingers in to the tea and probably into the ice was - so actually - just to help stimulate their thinking. And again it is making ... looking at a more concrete example there - so they actually put their finger in and they actually realise that it is not very hot, and they could begin then to think about reasons why this might be.**
- 6b:32 JR: And you said, "Who's brave enough..."
- 6b:33 **TZ: [JR and TZ laugh] Yes! Um, again, yes because I think ... probably an element of science teaching - you know, psych them up - get them - to engage them to grasp. And actually if you're brave enough maybe - that sense of danger - so actually they were all willing to participate and then move on. [TZ goes to restart the clip]**
- 6b:34 **TZ: So again, JP, his idea - "We've got wind in the room." I said, "Where's the wind?" "But we've got oxygen." So there's actually - wind is a very difficult concept - I know they're brought up later on, but linking oxygen to wind in such a flippant way -**
 JR: Yes.

- TZ:** - just, "So it's wind then isn't it." [TZ imitates the body language a pupil] It is just wind, that is what they're trying to say. I just - [TZ restarts the video]
- 6b:35 **TZ:** "It's a gas." [TZ looks upwards in an exasperated way and then smiles] What's being transferred? "It's a gas." [TZ wobbles her head from side to side] I mean that's really interesting in terms of - probably thinking there evaporation [TZ looks at JR, JR nods]. What's being transferred in terms of, "It's a gas." Evaporation, but they're not looking at it from an energy point of view. And I think because that idea of energy - Do we all understand energy? I don't know. It is a really difficult - it is a really hard -
- JR: *Fiendish! Fiendish idea.*
- TZ:** - concept to get your head around. So actually that's just shown you - they're not making - they're trying not to make - well actually at that point, that link between energy transfers, and what's being transferred to the surroundings - to heat up the surroundings. But they can associate this idea that some evaporation is taking place. So they think that a gas is being transferred to the surroundings. So I would imagine there - it is just the concept of energy is really difficult anyhow. [TZ restarts the video]
- 6b:36 **TZ:** [TZ listens through to the end of CLIP 3] Tea vapour! [TZ and JR laugh] Ah gosh! [Pause] [TZ starts the next video clip]
- 6b:37 *CLIP 4: overpowered [ID 6a:243-261] 6a:243* **TZ:** *OK. With the jelly that we did we were heating it. It boiled and then some of the - some of the jelly liquid evaporated.*
- TZ:** [TZ pauses the video at this point - please see 6b:38]
- But, what was being transferred - if we're talking about - what's being given off from [TZ indicates the cup with her hand] -*
- 6a:244 *AS: Steam. Heat.*
- 6a:245 **TZ:** *The steam. Heat. OK.*
- 6a:246 *FL?: Heat energy.*
- 6a:247 **TZ:** *Heat energy is being transferred from our -*
KG: *Tea.*
TZ: - *tea. So what is it doing to the - what is it doing*
TZ: [TZ pauses the video here - please see 6b:39]
to the air? [TZ mimes something with her hand]
- 6a:248 *AS: Is it heating the room up?*
- 6a:249 **TZ:** *It is heating the room up. OK. So it is heating the room - not the whole room, but maybe -*
- 6a:250 *JP, VG, KG, AS: The area. [Unclear as several students speak at once - but students are agreeing with TZ]*
- 6a:251 *FL: That's [the ice] probably melted [unclear] the first one.*
- 6a:252 **TZ:** *Could have done.*
VG: *It [the tea] is probably affecting that [the ice].*
TZ: *Affected that.*
- 6a:253 *KG: Around the [unclear] like that it is probably more [unclear].*
- 6a:254 **TZ:** *Yes. Like a camper van.*
TZ: [TZ pauses the video clip here - please see 6b:40]
[Unclear] So if the cup of tea is transferring its heat energy to heating up the surroundings, ... who might might be able to explain why doesn't the overall temperature [unclear - TZ says the last two words very quietly]
- 6a:255 *AS: [Unclear - the noise from the classroom next door means that it is very hard to hear at this point]*
- 6a:256 **TZ:** *[Unclear]*
- 6a:257 *AS: Yes.*
- 6a:258 *KG: Because it is colder in the air, isn't it. It is colder in the air so -*
AS: It is letting more heat out.

- 6a:259 *VG: I was going to say -*
- 6a:260 **TZ: It is transferring its heat -**
- 6a:261 *VG: It is sort of - it is sort of like it is exposed, because - because of like it is not at room temperature yet, it is sort of like being overpowered - like it is all going down -*
- 6b:38 **TZ: So I think here they were getting confused - I'm not sure if they were getting confused but - trying to draw on the experience in class we had looked at changes of state and we had in a boiling tube a piece of jelly, which we - solid - which we heated until it turned into a liquid, which we continued heating until all around the room we could smell jelly vapour and so - it started boiling and then began to evaporate. So I'm not sure if they're trying, you know, making some type of link there. Their past experience - using those past experiences to apply to this context to try and explain what's going on. So that's probably what's going on there. [TZ restarts video clip 4]**
- 6b:39 **TZ: So I don't know whether it is my questioning there. "What's being transferred?" And I think they're linking it there to something physical. Again this idea of - of things evaporating. So ... so a gas has been 'transferred' [TZ mimes to emphasise the last word] to the surroundings - so it took a lot to pull out this idea of heat transfer. Because they can't see it. Because - yes - they can't see it, it is not something in front of them [TZ mimes something in front of her] ... and concrete. It is a rather abstract idea. [JR murmurs assent and nods] To get their heads around. So that is why I would imagine they were associating um the jelly because they understood that what's being transferred, at that point, was kind of jelly vapours. If that is a word to use [TZ smiles]. Um. And then trying to apply it to this - to this situation. [TZ restarts video clip 4]**
- 6b:40 **TZ: So actually at this point, you know, one person will make a suggestion - it is quite nice to see how they all feed off each other and they begin to actually change their ideas. And refine the way they're talking. Um. And their approach to this whole idea. Because one person ... said something, and they think actually maybe that makes sense, and quickly change their kind of ideas on a particular - on this. So they're no longer talking about like evaporation in terms of what's being transferred in that way, they're looking at heat and energy transfers really. [TZ restarts clip 4]**
- 6b:41 **TZ: [TZ listens through to the end of clip 4] OK [TZ smiles]. Overpowered. Going - Just ... I think they're probab - this whole concept is very difficult. [JR nods] So that's where you'll find some really ... this language - this kind of ... yes - this language this kind of - "overpowered" - which is not scientific language really. Um. But because they find it - they struggle to to to explain, that's when this I think comes in. [TZ restarts the video] Oh. That was it. OK [perhaps with a little sigh?] Was that the end of that?**
- 6b:42 *JR: So that's the 'tea' ones [JR indicates this on the video clip menu on the laptop screen]. We're into the living and non-living ones.*
TZ: OK.
JR: Are you OK?
TZ: Yes. Yes. Yes.
JR: Fantastic. [TZ plays CLIP 5]
- 6b:43 *CLIP 5: sway in the wind [ID 6a:324-335] 6a:324* **TZ: OK. VG?**
- 6a:325 *VG: Um, well, I did like the tree and the plant, because they're all living like. With the tree like, because it like intakes gases and breathes out gases and stuff like that. But like what FL said,*
TZ: [TZ pauses the video at this point - please see 6b:44] everything that is living was moving, but trees and plants don't really move.
TZ: [TZ pauses the video at this point - please see 6b:47] Like sometimes I -

6a:326 AS: Yes they do. They can sway in the wind.

6a:327 VG: Yes, but that's like the actual [VG looks out the window at the trees] -

6a:328 FL: Plant moves towards the sun [FL says this to VG and then looks at TZ]

6a:329 JP: Yes.

6a:330 VG: Yes I know, but the trees don't.

TZ: [TZ pauses the video at this point - please see 6b:48]

It is just like the wind - apart from that.

AS: Well they grow.

VG: - apart from that. [VG sits back in his chair, smiles and taps the table]

6a:331 JW: They grow towards the light.

6a:332 VG: Yes.

6a:333 JW: They grow towards the light.

6a:334 JP: A tree is just a bigger version of a plant really.

6a:335 VG: Yes.

6b:44 **TZ: Again I'm just picking up on what he's saying. "Breathes out gases." A tree breathes out gases. All these misconceptions. Um. And again that just highlights the need for us as teachers to really listen to their talk. And the dialogue from the pupils because ... you cannot allow to say, "It breathes out gases." And I think as teachers you've really got to listen to their - to their - what they're saying. Because on the surface is sounds fine. And when you're in the classroom setting, "Yes that's fine. Oh that's good. That's really good." [TZ is imitating herself or another teacher] And then you just move on, without actually addressing - to stop and think about what they've said. And actually that's a really ... um inaccurate perception or idea of what trees actually do. [JR nods] Because then I suppose. At that point we'll move on [last three words unclear], we had time, you could stop and say, "Well, if it breathes in gases, ... do trees have lungs?"**

JR: [JR nods] Yes.

TZ: As a - as a - as a - you know - a question for them to think about. You know, "We breathe, we have lungs, do trees have lungs?" So is it the correct terminology to link to a tree? So, you know, in that respect - yes.

6b:45 JR: And yet, there's there's there's something of an idea about gas gases being involved.

6b:46 **TZ: Yes. They have an idea that gas is being - and I suppose they know, again, from their concrete [TZ taps the table] experience, that something that takes in gases breathes. An animal, human, all in their every d - but ... so, you know, they're trying to link something that is abstract - abstract like a tree - I know in the - what's the - how gases move in and out of a tree is still quite hard a concept and understanding [TZ frowns as she says this] - for pupils at this level to understand. Because they need to understand the structure of a leaf, and all what's going on [TZ counts these off on her fingers - JR nods]. So it is easier for them to say, "A tree breathes in gases." So, um, they show that there is that appreciation, but, you know, to probe them, to push them a little bit forw - more would get them to actually realise, "Well, maybe that's not the right way to say it." So.[TZ restarts CLIP 5]**

6b:47 **TZ: Again that's a good - and I think it comes up later. Yes they do move. But he's [VG] - he's really highlighting lots of misconceptions. Plants - trees don't move because again, in their own understanding, for something to move you've got to move from one place to another [TZ says these last 5 words very deliberately and mimes this movement with her hands]. That's moving. You've got to jump up and do something. But, you know, ... we they don't appreciate that over time plants obviously bend and move towards the light [TZ mimes this with her hand]. They don't - unless you're shown like a slow - a video clip in slow motion of a tree doing that - because it's not visible is it? [this question is rhetorical] It is not something that**

- you can see with your eyes [TZ mimes seeing this with her eyes]. So yes - [TZ restarts the video]
- 6b:48 **TZ:** OK again, yes it does move, no. And again, I think I just stood back [TZ mimes this by moving her body back in the chair and raising her arms] there and just sat back there not to interfere. Because they were setting up a - he's [VG] is probably in some type of cognitive conflict there, that actually - "Oh, yes I do appreciate - ". You know they're saying, "Well trees do move towards the light - plants." "Yes, but not trees though." [TZ smiles at JR]
 JR: *Mmm.*
TZ: ... And then, you know, he [VG] goes, "Yes, they [plants]do move, but not trees." [NG smiles] So actually he is in some type of dilemma there. Do plants move? Are trees different from plants? [JR and TZ smile - JR mimes putting his hands on his head as if in confusion] It is like a - it shows a - actually a, you know, that there is some type of conflict, and uncertainty, and - going on for VG. But, it's interesting ... because ... he he can't just accept that. And again, I think, probably what I'm getting from him is - for something to move you've got to physically move. Move in terms of 'pick yourself up and move to another - ' And I think that's where he's coming from. [TZ restarts CLIP 5]
- 6b:49 **TZ:** [TZ listens to the end of CLIP 5 - she appears to try to pause it as it ends] So [TZ smiles and sighs as she says the word 'so'] then he [VG] changes his idea!
 JR: *Yes. [JR smiles as he says this and shrugs]*
TZ: A tree is a bigger version of a plant. Yes [TZ smiles and says the word 'yes' with irony. JR laughs]. So does that tell us that pupils' concepts are easily swayed by the pressure - is it the pressure of other people? Other pupils ... have I said that right? Yes. So when they're in a group setting like this, they've got one idea, another pupil (or more than one pupil) holds another idea, so because they don't want to look silly do they then suddenly go, "Oh yes." And agree. And that's really interesting - because that's really interesting because he was so adamant prior to that - you know, "Trees don't move". [TZ shrugs] But he was easily swayed there. ... That was interesting actually. ... [TZ plays the next clip]
- 6b:50 *CLIP 6: respiration [ID 6a:341-378] 6a:341 KG: Miss I've just got a thing to say -*
 6a:342 **TZ:** [TZ holds her palm downwards towards KG] *Now don't change anything just yet. OK. [KG clearly still wants to come in here] Go on then.*
- 6a:343 *KG: Everything on it has to be living, because it has like germs and all that [VG seems to be agreeing] so -*
- 6a:344 **TZ:** *But the fact that it has something on it living -*
KG: No, I'm just saying -
TZ: *- does it mean that itself is -*
- 6a:345 *JP: [JP is speaking directly to KG] A dead person could have - something -*
- 6a:346 **TZ:** [Unclear - but TZ appears to be confirming - 'it is dead, on it is something living']
So let's come back to AS's - she made this really - really good statement that says that thing - that seven things - what did you [AS] call them again?
- 6a:347 *AS: I just called them the seven things.*
JR: [JR gets up and goes to check the video is still recording while TZ continues to watch]
- 6b:6a:348 *FL: We call them MRS NERG.*
- 6a:349 *JW: The seven things of life. Move, reproduce, -*
- 6a:350 **TZ:** [Several students are speaking at once - TZ says with a loud voice] *So, all things must - [TZ pauses and counts off on her fingers]*
- 6a:351 *Several students: Move.*
- 6a:352 **TZ:** *Move. [TZ continues to count off each characteristic on her hand]*
- 6a:353 *Several students: Reproduce.*
- 6a:354 *AS: [Pause] S - S - S - S - S -*

- 6a:355 FL: Sensitive! [FL points at TZ]
- 6a:356 TZ: **Sensitive to its environment.**
JR: [JR returns to his seat - the video continues to play]
- 6b:6a:357 VG: NERG. N.
- 6a:358 KG: Nutrition. They need nutrition.
- 6a:359 TZ: **Yes. [TZ nods]**
- 6a:360 JW: What is that one where it goes to the toilet? Respiration.
- 6a:361 TZ: **To the toilet. ...**
- 6a:362 Several students: Yes.
- 6a:363 TZ: **So far we've got - I remember**
TZ: [TZ pauses the video at this point - please see 6b:51]
it as **MRS GREN. [TZ counts off each one on her fingers] Moving, Respiration, - what is respiration? [TZ has a puzzled expression on her face]**
- 6a:364 Several students: Going to the toilet.
- 6a:365 TZ: [TZ pauses and has an unhappy expression on her face]
- 6a:366 AS: Or getting rid of waste.
TZ: [TZ pauses the video at this point - please see 6b:52]
- 6a:367 TZ: **Respiration is a chemical process that takes place in each one of your cells, which releases energy. ... OK. So a process that releases energy -**
AS: We don't really see energy.
VG: So it is like - it is a bit like -
TZ: - **So it is a process that releases energy in your food.**
TZ: [TZ says about three or four words over the top of the video - it isn't clear - appears to be] "**In your food.**" From your food.
That uses - the process uses oxygen and glucose - OK? So we've got Movement, Respiration, Sensitivity, Grrr - [TZ lengthens the word and waits for the pupils to complete it]
- 6a:368 Several students: Growth.
- 6a:369 TZ: **Growth, Reproduce or Reproduction -**
- 6a:370 JP and VG: Reproduction.
- 6a:371 TZ: **Excretion is where you get rid of waste [TZ is still counting off on her fingers].**
- 6a:372 AS: Ahhh!
- 6a:373 TZ: **OK?**
- 6a:374 JW: And then you've got N for Nutrition.
TZ: [TZ pauses the video at this point - please see 6b:53]
- 6a:375 TZ: **And then you've got N for Nutrition. So all - so something that's living shows all those seven life processes.**
- 6a:376 FL: Because technically fire does sort of reproduce. It gets bigger and bigger.
- 6a:377 AS: Yes.
- 6a:378 TZ: **OK. So, with that in mind [these last four words are said more loudly and TZ mimes with her hands a circle] - with that in mind, would that change [AS and KG are trying to speak over TZ] anything**
TZ: [TZ pauses the video at this point - please see 6b:54]
that you would - anything - or how you've arranged -
AS: No.
TZ: - **your cards on your table?**
AS: [Sharp intake of breath] Yes.
- 6b:51 TZ: **Did he [JW] say, that thing where you go to the toilet?**
JR: [JR nods and smiles - TZ is still looking at the laptop screen] Respiration.
TZ: **Respiration! [TZ and JR look at each other and laugh]**
JR: **Isn't that lovely!**
TZ: [Unclear - three words] Oh wow! Gosh. [TZ restarts the video]

- 6b:52 **TZ:** Respiration is going to the toilet and getting rid of waste [TZ says this then looks at JR and smiles]. [Pause] It is amazing isn't it! [JR nods] ... Wow. And I wonder where they got that idea from? [TZ sits back in her chair and crosses her arms] ... They just haven't got a clue. I mean, I didn't - at the beginning of the year I didn't teach them, because [TZ explains in a sentence why she wasn't present at this time]. But I just don't know how they would have associated respiration with getting rid of - getting rid of waste. I've no idea. [TZ restarts clip 6]
- 6b:53 **TZ:** OK, I [unclear] heard someone going, "Ohhh!"
JR: [JR smiles and makes the same sound] Ohhh!
TZ: Excretion. [TZ and JR smile] ... Yes. And I probably should have probably followed up with what type of waste, what we're looking at. At that point. [TZ restarts the video]
- 6b:54 **TZ:** So the reason why I think I went through looking at MRS GREN is so that they can have like a check list to work out, "Well, if I've put things on this side - the living side, do all of them follow the processes?" So if they don't, then they are going to have to move. But they still held some kind of - they was - what they were good at was trying - not wanting to move (some of them) from what - how they had organised their their um ... their placemats. I don't know if it's resistance to change. But you know some of them were still saying, "We could say that it does this or it does that", in terms to fit that model of what's living or not living I think. Um. Yes. [TZ restarts the video]
- 6b:55 **TZ:** [TZ listens through to the end of CLIP 6] Mmm. [TZ goes to play the next video] Oh, the river trying to be - [TZ looks at JR. TZ and JR smile]
- 6b:56 *CLIP 7: river [ID 6a: 411-419] 6a:411* **TZ:** So bearing that in mind, with that kind of thinking look back at your boards and begin to re-change [TZ mimes this with her hands] your ideas of what's living and what's not living.
- 6a:412 *Several students: [Unclear as all speaking at once]*
- 6a:413 **KG:** *One thing that doesn't follow MRS NERG - isn't it like bacteria and stuff like that? It can't reproduce by itself it has to like go on other people? [TZ sits back]*
JP: *[Simultaneously with KG and others] Well what I put in my living. [Unclear] Person, mushroom, fire. -*
VG: *[Sits up] All living?*
JP: *- sea, dog, leaf, plant, sun, bicycle, water, river, wind, and [unclear].*
- 6a:414 **VG:** *[To JP whilst TZ continues to talk with KG] How is fire living? How is wind? [Unclear - but could be 'How is river?']*
TZ: *[To KG whilst JP talks with VG] So that is thinking about viruses. Yes? They need to go in. [TZ changes the volume of her voice] But, but just thinking - thinking about what is in front of you [TZ looks over at JP and VG who are still talking] look at the cards that you've got -*
- 6a:415 **JP:** *River. I put river on living because you know if you were to dig a tunnel to the side [JP mimes this with his hand] of a river. Then it would go that way which -*
- 6a:416 **TZ:** *But - but - If we think about a river [TZ holds her hand up and counts off on her fingers] does it reproduce? You're saying you've got that [TZ mimes with her hand several 'tunnels' to the side of a river] - Does it have got chemical reactions? Does it respire?*
- 6a:417 **JP:** *Respire. What does that mean. I've forgot.*
- 6a:418 **TZ:** *Where there's a chemical reaction between glucose -*
JP: *Oh. Probably not.*
TZ: *- and oxygen.*
JP: *No.*
- 6b:57 **TZ:** [TZ listens through the whole of CLIP 7 which then stops] ... I mean that was quite amazing to see that he still wanted to pursue this idea that a river was living. And I suppose I was interested in - to see - to try and look at his thinking there.

Because he was saying, "Well, the fact that all the mini rivers [TZ mimes these with her hands] that come off a main river is the fact - like it's reproducing because it is making more of it. So I think that comes down to the idea and the understanding of what is reproduction?"

JR: *Mmm.*

TZ: Are you just making more of it, or are you creating something new that is unique? I think that's - that's highlighting that misunderstanding of what we mean by reproduction. It is not - reproduction is not just reproducing more of it. I suppose it depends on what type of reproduction we're looking at. I mean he [JP] could have argued that asexual reproduction, couldn't he. [JR nods] Um. So yes, it is just this whole understanding of - yes, that was just very strange! [TZ and JR laugh]. Very strange. [TZ goes to play the next video] Seeds. ... Oh, seeds, gosh.

6b:58 *CLIP 8: seeds [ID 6a:420-436] 6a:419 TZ: Right. So. So, on that basis, on that thinking, -*

AS: [Holding up the seed card] So a seed doesn't live.

TZ: - so on that thinking [TZ says this again with emphasis and is looking at AS], does it - does it - are those, are some of those things - Now a seed is quite interesting isn't it. Because with a seed - with a seed - ... under what circumstances do we kick start it -

6a:420 *FL: It needs to be boosted.*

6a:421 *JW: So basically the water and the soil fertilize it to grow, is it -*

TZ: [TZ leans forward as if listening carefully and then pauses the video - please see 6b:59]

KG and FL: [Unclear - KG and FL say something together quietly]

6a:422 **TZ:** *So - Who's ever grown cress seeds? [TZ changes the pace with which she says this and smiles slightly]*

6a:423 *KG: Me. [In a bored tone]*

JP: No.

6a:424 *JW: Me. Because -*

6a:425 **TZ:** *My daughter got some from -*

KG: [To JP - unclear]

6a:426 **TZ:** *Do you need to - do you need to put cress into soil*

TZ: [TZ pauses the video here - please see 6b:61]
for it to grow?

6a:427 *Several students: No. No you don't.*

6a:428 *JW: We put it in -*

6a:429 **TZ:** *What did you just put it in?*

6a:430 *KG: Cotton wool, tissue, -*

TZ: [TZ pauses the video here - please see 6b:62]

JW: Yes, that is what we did. Water.

KG: - just water, soil, [unclear].

6a:431 **TZ:** *OK. So something is - the fact that a seed is lying dormant until something comes and -*

JP: Chain reaction.

TZ: *- kick starts the reaction -*

AS: [Unclear] water.

TZ: *- for ex [TZ puts her hand palm up towards AS] - for it - to be water. So in seed's respect it is water. So actually it's dormant, but once it's starts to gr - starts to sprout and starts to grow, does it -*

FL: So it is living.

TZ: *So you've got - you [FL] make that decision. OK. So relook at your things and then - your cards - and then think about all the things - Does it fill up all those seven [TZ counts them off quickly on her hand] life processes.*

?: [Unclear]

TZ: [Loudly] *If it does, then it must be living. If it doesn't it can't be. So who's made a change?*

6a:432 **AS:** *Well with the seeds, you're saying they're living, but they don't like get rid of waste.*

6a:433 **TZ:** [Pause] *By itself?* [Pause] *Oo. A seed, if we cause it to grow, if it starts to grow -*

KG: *It makes little shoots [KG mimes this with her hand]*

NG: *- if it starts to grow - like a plant. If we get like a seedling, is it living?*

TZ: [TZ pauses the video here - please see 6b:62]

6a:434 **AS:** *Yes.*

6a:435 **TZ:** **OK.** [Pause] *Right, so, who's made changes?* [VG yawns]

6a:436 **JP:** *I have.*

6b:59 **JR:** [Long pause] *I think he [JW] says, "It is the water and the soil that fertilize it to grow."*

6b:60 **TZ:** **Yes** [TZ has a puzzled expression and extends this last word - she then looks over at JR. JR and TZ smile]. **OK.** [Pause - TZ is still smiling] **Just.** [Pause] **This** is showing that they have some knowledge, what they're doing is, whatever knowledge on this topic - they're just chucking that in. So maybe not working through, or sifting through in their heads ... "What is it that we know maybe about plants?" Or anything really. Is it appropriate, or do I just chuck it in, because it might sound nice and [TZ and JR laugh] a big long word. **Fertilises.** You know. That [TZ indicates the laptop screen] shows you he [JW] doesn't really understand um about plant fertilization, what's going on, where seeds fit in, and all this [TZ puts her hand down quite heavily on the table]. **Yes. Mmm.** [TZ restarts CLIP 8]

6b:61 **TZ:** **So** that actually, the idea of soil being really important in the growth of something seems very important. Because they're really ... [TZ sighs] in terms of misconception, I had a year 10 pupil saying, "For plants to - plants need soil to grow, to get bigger. And it works alongside photosynthesis." Still in Year 10. [JR nods] **This** idea of the soil - so yes, that really just - highlight this huge misconception about the purpose of the soil. So actually that conjures up in my mind - "It is the soil itself that that does the -" - in this res - well for that Year 10 - "that does the growing." You know. It is the soil itself that makes the seed grow [TZ emphasises these last words with her hand on the desk]. [Pause] **So** yes, I don't think, maybe as teachers then, we are quite clear about the role of soil - what's inside the soil, which is important. **So** yes, that just highlights again a common misconception. [TZ restarts the clip 8]

6b:62 **TZ:** **I** mean the reason I've talked about cress was, it is just a classic one, you don't dig it into soil. Cotton wool, add some water, hey presto. **Um.** **So** that kind of - the reason why I used that was to move away from this idea of soil and looking at the growth of seeds and what causes a seed to grow. That's why I chose that example there. [TZ restarts clip 8]

6b:63 **TZ:** **I** mean that's quite - a seed is quite a difficult one.

JR: *Fiendish isn't it.*

TZ: **Because** there I suppose maybe I was leading them down the wrong way. We were looking at a seed, and on the card it wasn't a seed once it started to - you know - [JR nods] starts developing into a plant or - you know - a flower or whatever. **Um.** **So** actually, maybe just a seed by itself in terms of looking at it - and I think that's a really difficult one to get their heads round [JR nods] really. **I** mean even ours, in terms of what we - maybe my understanding of it there is maybe leading them down maybe the wrong road. **Because** I'm thinki - I was talking to them about once it starts to grow [TZ's hand hits the table quite hard - she has an expression which may indicate some frustration]. **So** that's hence [TZ points at the laptop screen] why **FL** was still saying about, "Wow, a seed, [TZ taps the table] does it excrete?" **And**

- that's where she was still kind of - her understanding was still unclear. Probably from my direction there. Yes. [TZ restarts the video]
- 6b:64 **TZ:** [Clip 8 stops quite quickly] Shall I come onto one of these now? [TZ indicates the clips about the teddy bear and torch]
 JR: *Please.*
TZ: The teddy bear. I like this one! [TZ plays clip 9]
- 6b:65 *CLIP 9: pupils [ID 6a:565-575] 6a:565 TZ: Where's your torch?*
- 6a:566 *AS: There [AS points to the lines]. The little lines. [With a slightly incredulous tone]*
- 6a:567 **TZ:** *Oh. Those are the torch.*
 JR: *[JR gets the drawings the pupils have made and gives them to TZ who looks at them]*
So the the, the light falls onto the teddy [TZ is pointing at AS's drawing] -
 AS: *Yes.*
TZ: *OK. And then you can see.*
- 6a:568 *FL: On my one you can't see the details of it because when you first turn on like your pupils [FL seems to be miming her pupils getting bigger] and then after a while they get bigger.*
TZ: *OK.*
FL: And ... after - because I didn't draw any features of the teddy because as soon as you hit it [FL mimes a flicking motion with her wrist indicating perhaps moving the light beam downwards such that the light hits the teddy] you would see a faint outline.
- 6a:569 **TZ:** *So you're saying again this idea that light falls onto the teddy*
TZ: [TZ pauses the video at this point - please see 6b:66]
[TZ looks up at FL as she says this] and then you'd be able to see.
- 6a:570 *FL: Eventually.*
- 6a:571 **TZ:** *Eventually. OK. KG.*
TZ: [TZ pauses the video at this point - please see 6b:71]
- 6a:572 *KG: It might be things like [unclear]*
- 6a:573 **TZ:** *OK, so you've got this idea that light, from the torch bounces off of something, hits the teddy and then we can see it.*
- 6a:574 *KG: Yes.*
- 6a:575 *JP: So it is like a triangular motion.*
- 6b:66 **TZ:** What was quite interesting with this one is that the classic research finding about how pupils understand how we see things was drawn out in this example [JR nods]. And it was just really quite classic saying that light must - it must fall on the teddy [TZ looks at the drawings] - I think there were some of them were saying, you know, two [TZ turns over some of the drawings - two refers to the number two the students were asked to write onto their second drawing to distinguish it from their first one in 6a:515]. ... That was two. You know in this resp - you know some of them are showing that [TZ looks at JR] the eye didn't play a part of it at all. [JR nods]
- 6b:67 *JR: It is almost as if, with this one [TZ points to one of the drawings TZ is holding] with this one that he drew it because you told him to draw an eye.*
- 6b:68 **TZ:** Yes. It's just the fact that the light goes onto the teddy and then that's it. Again it is shown in this one [TZ show a drawing to JR - unclear which one] - the torch. And then this is a classic one.
- 6b:69 *JR: Is that the 'one' [indicating the first of the two drawings]*
- 6b:70 **TZ:** Yes, this is the first one. That light goes into your eye and then that light travels from your eye to the teddy [TZ is probably talking about VG's first drawing - please see appendices]. So very - shows all those classic like misconceptions about how we see. [TZ restarts the video]
- 6b:71 **TZ:** [Clip 9 stops after a moment] So yes, really interesting there. [TZ plays clip 11]

- 6b:72 CLIP 11: blind you [ID 6a:577-584] 6a:576 **TZ: Right. Don't make any changes. So. We've got these ideas. I think there's a consensus of [TZ sweeps her hand round the table] - consensus of ideas - apart from maybe JW's I think - apart from - no, VG's - VG: Yes. Then I just realised that - TZ: - this idea that light - Don't change.**
- 6a:577 VG: No. I've just realised that it shouldn't have gone light to the teddy so then you can see.
- 6a:578 **TZ: Alright [Said quietly]. OK, why have you [VG] changed, before I've even talked, why have you made that change?**
- 6a:579 VG: It just that it seemed a bit more, sort of like, logical. In a way, because you can't really shine it into your eye and be able to see - like you could like sort of like shine it in front of you because if you're holding the bear you'd be able to see it. But you couldn't like shine it into your eye and be able to see, because it would sort of like blind you.
TZ: [TZ pauses the video at this point - please see 6b:73]
- 6a:580 **TZ: OK [TZ says this with a puzzled tone]. OK. So that's a really good - What VG is beginning to explore there is good thinking and he's changing his ideas.**
TZ: [TZ pauses the video at this point - please see 6b:74]
I think, lots of are quite correct in saying that light will fall onto the object [TZ has taken up KG's drawing and points to what she means on it], but if light is just falling onto the object, how do we actually see it?
- 6a:581 AS: With your eye. [AS points at her eye but doesn't appear to be indicating that light enters the eye, her tone indicates that this is obvious]
JW: It is the reflection.
KG: [Turns round and looks at the camera behind her]
- 6a:582 JP: [Unclear] reflects off that [the teddy] into your eye. [JP mimes this]
- 6a:583 FL: If you look [unclear - noise from the next classroom makes this difficult to hear]
- 6a:584 **TZ: How - so how - so I think we need to come back to VG's idea - we need to come back to VG's idea that if light just travels into your eye, that's no good. Are we saying that because - somehow [FL picks up the torch] we have to get the image into our eye. But for light just to be travelling into our eye that's not going to be doing any good is it.**
- 6b:73 **TZ: So that's his breakthrough really, he has actually drawn it and then in his own head he's said, "Well this doesn't make sense, because that will blind you. And then you couldn't see." ... Again - I mean that's a common sense kind of approach to it isn't it. Actually trying to unravel what he's drawn and actually coming to a - a reason why he must change his idea of what he's drawn. [TZ reaches for VG's drawing] Because he drew - he drew this - the idea that light travels into your eye and then from your eye it goes to the teddy. The idea that it will blind you [TZ says these last two words with a slightly incredulous tone] - so I mean that's a nice [TZ smiles] way to put it. [TZ restarts clip 11]**
- 6b:74 **TZ: So yes, what was nice about that one is that he changed his own ideas before I even got to it. And actually began to explore it with them. So that was self-correcting. There's a term. [TZ starts clip 12 - she misses the end of clip 11 out]**
- 6b:75 CLIP 12: opposite side [ID 6a:588-598] 6a:588 **TZ: So, OK. So the picture of it. So actually light must travel - the light from the torch is travelling in all directions - JP: Yes.**
TZ: - if light hits the teddy - FL: [Unclear]
TZ: - OK, but the light that hits the teddy then must do something - must do what VG?
- 6a:589 VG: Sort of like bounce -
JP: Reflect.
VG: - reflect and bounce back to -
- 6a:590 **TZ: Into your - [TZ pauses]**

- 6a:591 VG: Eyes.
- 6a:592 TZ: Eyes [TZ sits back a little as she says this]. OK. So on the opposite side now, based on that ever so small discussion, how might you change what you've drawn?
- 6a:593 KG: Can't I just do it on there [add to her original drawing], just do another little line?
- 6a:594 TZ: No. Do it a completely new [TZ mimes turning the page over with her hands] - just a sketch. How might you change your ideas? [Pause]
- TZ: [TZ pauses the video at this point - please see 6b:76]
- 6a:595 AS: Urr. I can't really draw. ...
- 6a:596 KG: [Unclear]
- FL: Because light tries to go through, and if it sees something there'll be a shadow.
- 6a:597 TZ: Well don't forget that we get shadows because light travels in straight lines. OK?
- 6a:598 FL: [Unclear]
- 6b:76 TZ: OK. There they were quite - um - ... [TZ looks at JP's drawing] OK, JP still holds - didn't really change his - still presented that idea that light travels into your eye and goes to the teddy. JP.
- 6b:77 JR: And he's [JP] drawn an eye and scribbled it out [JR points to JP's drawing which TZ is holding] and then drawn it there - it captures really -
- 6b:78 TZ: He is still very uncertain in his thinking. [TZ takes another drawing] This is slightly more clearer but obviously she is trying to say it falls onto the teddy and from the teddy to the eye. [TZ takes another drawing] Um. This one, again shows that kind of idea. [Unclear - three words?] these lines here with these curved lines - the idea that maybe in his head he may not appreciate that light travels in straight lines. So with the curve - so it brings out a whole heap of things there. Um. [TZ looks at another drawing] This one again is very confusing [TZ looks at both sides of this drawing] ... because - Oh, no actually - this one shows the - is showing this idea that light is going everywhere [TZ looks at JR]. And ... the one that hits the teddy gets reflected back up towards the eye.
- 6b:79 JR: Is this [unclear - JR indicates a pupil on the screen - unclear which one]?
- 6b:80 TZ: Yes. Yes. Um [TZ takes another drawing]. AS. [Pause while TZ looks at AS's drawing] Um. [Long pause] Oh yes, this idea that light is travelling in all directions, kind of hits the teddy, but showing that actually in order for us to see it must enter the eye. And also on that one [TZ indicates a different drawing - unclear which one] in order for us to see it must enter the eye. This idea that it must go to the eye - enter into the eye, for us to see is lacking I think from there. ... Again, ... near the eye [TZ turns the drawing she is holding over - unclear which one this is from this angle] but not actually in the eye. Very important for their understanding [TZ puts all the drawings together, taps them on the table to align the pages and places them on the table in front of her]. But it's changed [TZ looks at JR]. It has definitely changed. For most of them [TZ and JR smile]. [TZ goes to play the last video] The last one. [TZ crosses her arms]
- 6b:81 CLIP 13: swop around [ID 6a:604-612] 6a:604 TZ: Would you put the direction would you think the arrow - the light is travelling.
- 6a:605 AS: Ahh. I think it goes that way and then back that way.
- TZ: [TZ pauses the video at this point - please see 6b:82]
- 6a:606 KG: If that makes any sense! [KG shows turns her drawing towards TZ for TZ to see]
- JP: [Unclear - JP whispers something to VG and they both look at JP's drawing]
- 6a:607 TZ: OK. So anyone that's slightly different? [TZ takes JP's drawing] So we've still - JP has still got from the eye -
- JP: To the torch.
- TZ: - the light is going from the - So this tells me - what this tells me - that light is given out by your eyes and goes to the torch and then -
- 6a:608 JP: Oh! OK. So they need to be swapped around.

- JR: [TZ is looking through the drawings - JR pauses the video] Sorry. I just [unclear]
[Please see 6b:83]
- 6a:609 **TZ: So, so - OK** [AS shows her drawing to TZ].
- 6a:610 AS: Miss, I've got that the light travels to the teddy bear and then travels back into your eye.
- 6a:611 **TZ: OK. So. Does that make sense?** [TZ emphasises this with hand movements]
[Unclear - could be 'because that is what we're saying']
- 6a:612 VG: That is what I did.
- 6b:82 **TZ: Again, "I think it goes that way."** [TZ is quoting FL - TZ smiles as she says this - 6a:605 was attributed by JR to AS though it is unclear from this camera angle who is speaking, it is unclear if I have made a mistake or TZ - though of course much more likely that I have] FL is just showing that she is uncertain about the direction in which light is travelling. So very useful to get them to put in the arrows, to show - so that they're thinking around there with a direction. [TZ restarts clip 13]
- 6b:83 **TZ: No, no, no, no.** [As in no problem - TZ is still trying to find JP's drawing]
JR: [Unclear] JP.
TZ: Yes. He's [JP] still had this idea.
- 6b:84 JR: [Pause] And then I think at the end of that he did change -
- 6b:85 **TZ: Yes. He went, "Oh, yes, yes, yes."**
- 6b:86 JR: So maybe that was the moment he scribbled out -
- 6b:87 **TZ: Yes. So he did realise - again, it is just really ... interesting there ... no matter how much you go over it you can't just assume as a teacher that they understand these ideas. Um. How we're getting - how we're actually getting in their heads to actually understand what they understand. And I think again, the only way we can do that is by the dialogue. Group work is a very powerful way. And if you set it up right, they will be on task, they will be discussing ideas. And for you to go round and listen. Um. It ties in with a bit - I went to - I found a book yesterday about using performance in science. And looking at acting out some of the key concepts, key ideas which is - which I would like to use more in my practice. And today we used a simple thing called two truths and a lie about the topic we've been looking at, and I was able to go round and listen to their two truths and a lie. And that was really interesting. And then when we shared back to the class one girl said her truth was, no, her lie was, "a com - an element" - No, it was her truth. "An element is made up of one atom." [TZ looks at JR who nods] Just one atom. So I was able to pick that up and say, "Well that's nice, but what might we put into that sentence to make it a bit more scientific?" So one person picked up, "One type." And I said, "Excellent." So that will give us a more - a better definition of what we think an element is. Just to clarify. Again, it is the finer points that you're looking at. [Pause]**
- 6b:88 JR: And the - encouraging them to bring a lie there.
TZ: Yes.
JR: Partly sometimes to see - they might bring something that could be actually truth! [JR and TZ smile]
TZ: Yes. Yes.
JR: And they might think it's a lie. Also to encourage them to - to, to, to use that imaginative thing.
- 6b:89 **TZ: Yes. Yes. And their task was to identify the two truths and which one was the lie, and why was it a lie. And it was nice - something different because I find ... you know, science classrooms can be a little bit dull. "Oh just come in, sit down." Do they have to sit down? You know, we can learn so much from practitioners in drama and other areas that I can bring in to make what we're doing alive - to explore this dialogue. And I'm really keen on exploring the dialogue and listening. Because it challenges me, as you said, to think on your feet.**

JR: *Yes.*
TZ: And think about how am I going to respond to that. Which is very difficult, as you can see! [TZ and JR laugh]
 6b:90 JR: *Thank you so much for doing that.*
TZ: I hope that was -
 JR: *I know we've gone -*
TZ: No. [In the sense of 'no problem' - TZ is smiling]
 JR: *- massively over with that bit, -*
TZ: Yes. That's fine.
 JR: *- I hope you don't mind, I was just finding that really helpful. And we can really cut down this second bit.*
TZ: Yes.
 JR: *Would you be OK for me to -*
TZ: Yes, yes.
 JR: *How are you feeling with the time? Because I'm conscious that that's the hour.*
TZ: That's fine. Finish off what you need to [TZ nods].
 JR: *Can we go on for a little bit longer?*
TZ: Yes.
 JR: *What would be reasonable for you? As I imagine you must be getting tired after [JR smiles]*
TZ: Well I've got a meeting at half past, so about fifteen minutes?
 JR: *Shall we go on for ten - fifteen - ?*
TZ: Yes.
 JR: *Lovely. But please just say when you're - [JR smiles] Thank you so much.*
TZ: That's fine. I hope that's what you wanted.
 JR: *That's exactly what I was looking for! It is really helpful to see which bits you pick, you focussed on. How you read it.*
TZ: Yes.
 JR: *And that will be enormously helpful. [JR looks down at the questioning route - please see interview 6c for the continuation of this interview]*

[End 6b]

Interview 6c

6c:1 JR: *I've got all sorts of bits and bobs I could explore. I won't - you know, I'll just pick a few things out. Um. One thing I was wanting to ask about is, you mentioned conceptual conflict at one point.*
TZ: Yes.
 JR: *Sometimes, in some of these clips, I felt that there were - that that sometimes students were taking you on -*
TZ: Yes.
 JR: *- and sometimes you were taking on the student. Sometimes you had really [JR mimes something going back and forth between pupil and teacher] long sort of exchanges like that.*
TZ: Yes.
 JR: *And I just wondered - Is that what it's like?*
TZ: What do you mean?
 JR: *In classrooms, do you sometimes get almost conflict building up between - over ideas, I don't mean sort of nasty conflict - I mean -*
 6c:2 **TZ: Yes. Yes. I think so, and I think if there is a really difficult concept to understand. If they hold one, then you come with another, and it doesn't match - you get it when it doesn't match what they hold. Um. But I thought [TZ shrugs] blady bla bla, and if you present them with some evidence - that's when you have to argue**

- your point [JR nods] to try and convince them, maybe what they're thinking is not entirely correct. Today we were looking at compounds and we looked at Sodium, Chlorine, Sodium Chloride, Salt. So they were saying to me today, "Are you telling me [TZ mimes a pupil speaking with an incredulous expression] that I'm eating a poisonous gas and a really reactive metal?"
- 6c:3 JR: "That is exactly what I'm telling you!" [JR is miming the teacher speaking to this pupil] Yes. Yes.
- 6c:4 TZ: And then it comes down to this whole idea, well what - what - what that came down to - well what did we - what were we talking about, this in the context of the compound's properties is very different from the elements that make up the compound. But that was the bit of cognitive conflict, because they just couldn't get their heads around actually that they're taking in something that is made from two very - potentially dangerous elements.
- 6c:5 JR: And within that conflict -
TZ: Yes.
JR: - what I'm hearing is that there's an element of using arguments to -
TZ: Yes.
JR: - do that. Are there other ways that you might try and persuade students?
- 6c:6 TZ: Again - um - If it is something that we could do a quick practical on, -
JR: Yes.
TZ: - modelling, um acting, getting them to come up and er act out the things we're looking at, just going back to the textbook to read, -
JR: Yes.
TZ: - getting them to talk to another person to share their ideas, - So just a range of ways in which you might try to go back. And again, it is all about, supply them with the evidence, and getting them maybe to think through and talk through their ideas. And, you know, at the end of the day you still might gets [sic] kids saying, "Well actually I'm not sure." or "I don't know." And then it is thinking of a different way to illustrate that concept. Maybe looking at the concept in a different context would also be useful.
- 6c:7 JR: So sometimes it doesn't work?
- 6c:8 TZ: Yes [TZ says this with a sigh]. Sometimes I don't - I think once you've done all of that - they still [TZ shrugs] - they still hold that idea -
JR: [JR shrugs] Yes.
TZ: And so again, as I said just before, you might need to go - same idea and go to a different context - using a different context to illustrate your answer. So today we used Sodium Chloride as one example, and then we used ... err ... what was the other one? The first one was ... I think it was Carbon and oxygen. Carbon monoxide. As another example to try and illustrate this idea. And also water. The elements that make up water. Again, "Wow, made from two gases!"
- 6c:9 JR: Crazy isn't it.
- 6c:10 TZ: Yes. So, again, - but sometimes there is also going back - if you get that situation, you're working with a pupil one-to-one [TZ mimes as if the pupil is sitting next to her] I would stop and get them to go back - to back track with some of the ideas that might - that they might need to have before you get onto a particular concept, to see whether ideas further o [on?] - further up or the pri [prior?] ideas are not concrete enough, or - they're not thinking about them in the right way, which will have an impact on any concept - any further concept you're working with, or trying to develop. So trying to pick at what point they - they - they've developed a misconception.
JR: Yes.

- TZ:** And then - because it will lead to further misconceptions later on. And then trying to address that to see if that will help them alter their - their - their position of what they're thinking about.
- 6c:11 *JR:* And would there be a sort of losing battle sometimes - where you might - you know, it is like "This is not working." And -
- 6c:12 **TZ:** Yes. Yes. Yes. [TZ shrugs] I've had times where actually, "I just don't understand miss. I just don't get it. I just can't - ". So no matter what you've done, stood up-side-down [TZ and JR smile], you know, done cartwheels - [JR laughs]
JR: You've been juggling at the front. [JR mimes this]
TZ: Juggled - you know. [TZ smiles] And you're still left with scratching your head. At that point, I think - at that point I've learnt now for me to say, "Actually, well you go away - you mull it over ... You kind of think about it. ... And then come back to me." [JR nods] And usually that process sometimes is really important. Because they need to reflect on what they're trying to understand or trying to unpick for them to make sense of it. And let the brain take it's natural course of processing information. And then more often than not they'll come back and say, "Actually I understand it now, I didn't understand because - ", and they will come to their own reason why they don't understand and actually present themselves as having understand the concept or idea and applying it correctly. [JR nods] So I just think as teachers you can only do so much.
JR: [JR nods] Yes.
TZ: And I think we all work individually - I always believe that we can't open the kid's head and stuff it in. I know we're trying to stuff in the ideas and knowledge [TZ looks at JR], but at some point the kid or the pupil needs to explore for themselves. Needs to work their way through this muddy water [TZ mimes moving through the water] themselves ... and make sense of things that we're looking at and learning - where it is very difficult and challenging. I know as a student I work like that. I've sometimes got to, if I'm learning things, I've just got to leave it. And for some reason subconsciously the brain is still processing and looking. So when you come back at it with fresh eyes it makes more sense.
- 6c:13 *JR:* I really like that, yes.
- 6c:14 **TZ:** So that is what thought we would do. And I think I've learnt over the years -
JR: Yes. Yes.
TZ: - you can't push them anymore. Yes. So that's my answer to that. [TZ laughs]
- 6c:15 *JR:* This was a sort of little [JR looks at the watch on the table] group ... and a sort of weird set up with cameras everywhere and things, how does that relate to what you do in your - you know - your -
TZ: Classroom.
JR: - your normal daily life in the classroom? Or not?
- 6c:16 **TZ:** [Pause] I like ... yes it does because I'm working on looking at and really pushing my practice to encourage dialogue. And ... I'm really working towards um assessing pupils' understanding of concepts and ideas through whether it is using mini-whiteboards, drawing pictures, [JR nods] and discussions. So, you know, usually if I'm working in that way I'll set up a task and move them round the classroom. When it's on a whole class level you can only spend two three minutes with each pair or person, because otherwise that whole task might drag on for the whole lesson if you will - which is a shame, to take that richness from what they're saying. So I find that really difficult, because you can just get caught up with one person [JR nods] because you're unpacking what they're saying. So actually it is about - I use lolly pop sticks to try and spread out when I'm taking feedback about when we share ideas back. So I try to get a spread, a range, from a variety of people. To check understanding, to talk about it, to look at it at a class level.
- 6c:17 *JR:* The lolly pop sticks would be the -

- TZ: Names.**
 JR: *Oh. [JR is surprised - because of expecting some sort of traffic light system for assessing pupils ideas]*
- 6c:18 **TZ: The names. I just put their names on so it is random. So I don't - I get a spread - a random spread. So when I take feedback -**
 JR: *Yes.*
TZ: - from - when we do discussional [sic] work, I get a range of across the -
- 6c:19 JR: *I'm having trouble following. So you've got lolly pop sticks with all of their names on.*
TZ: Yes.
 JR: *And you give those to -*
TZ: No. I have them, and I just -
 JR: *Oh I see, and then you pick it, and that's the person you're -*
TZ: You just pick. And that's the person - so I try to do that, you know, just to spread it across. You know. But -
- 6c:20 JR: *Where did that idea come from?*
- 6c:21 **TZ: Um. I think that's a Dillon Williams kind of AFL [Assessment for Learning] 'no hands up' kind of technique - [JR nods] which the kids, you know, - I like it - I try not to jump on every band wagon, but I like it because it does mean that everyone has got to participate. And it's fair. And, you know, I try to be as fair - you know, if I picked you up in this round I don't put you back in. But once we start another one I put everyone's name back in the pot and re-pick. So in terms of how we would work, yes it is - I would work similar to this, more on a whole class level, but what would be different is the amount of time you spend with each pupil, each group, to really listen to their conversation. So as a teacher, I find that difficult. Because, you know, if you're trying to think of all the things like pace, and this and that, listening to one pupil speak is not going to cut it really is it! Which is a shame, but that's just the realities in which we work in. [TZ and JR smile]**
- 6c:22 JR: *It is such a pleasure talking with you. [TZ laughs] Do you - and I'm conscious of the time, I'm going to stop with two last quick questions - Just as I come towards the end of this research, is there - is there anything about the whole process that you'd like to say. About you know, we've had that interview [JR indicates the laptop and hence the first expert micro-teaching interview], we've had this - these two interviews in effect.*
- 6c:23 **TZ: I just found - I found it really fascinating and I think it's given me the time and space to reflect on A, how I probably talk to the pupils, I've noticed that [TZ laughs] I probably use lots of hands! [TZ mimics herself using her hands a lot - TZ smiles] You know I'm not sure if that's a -**
 JR: *The poles [JR mimes the poles of the Earth mimicking how TZ had done this during interview 6a:186].*
TZ: The poles, yes! [TZ mimics herself doing this and both JR and TZ smile] It is just really quite animated. Which I suppose is really good I think. But also it showed me, in terms of this whole process, of listening and reflecting on what the pupils say. And actually, you know, not to be scared to maybe film the lesson [pause] and sit and watch it. Maybe not at this level of detail, but just watch to pick up on any misconceptions that you can [unclear]. So there is a - as a means to move your teaching forward, people do encourage you to watch yourself, but not - I wouldn't say I'm watching me - probably I am - but I'm listening to conversations that's going on. So using the videos is really [unclear - 'powerful'? - one word] to capture that, because you can't be everywhere all the time.
- 6c:24 JR: *Yes. There is just so much happening.*
- 6c:25 **TZ: There is so much. You don't really appreciate what is going on in a classroom [TZ and JR laugh] - because it is just - if you begin to try -**
 JR: *Even when we work in them! Yes.*

TZ: Yes. When you work in them. Because, you know, you're over there [TZ points to one side of an imaginary classroom in front of her], and there is a conversation about work that is going on over here [TZ points to an imaginary conversation which is taking place behind her head]. You know, you just hear snippets of it. And um. And you know, I'm still working on, is there a way which you can enjoy the dialogue? And be in control. And listen to everybody. ... I don't know. I don't know. I don't know. ... I'm still working towards that at the moment. But, you know, it is very important to listen. And that's the key I think that I've learnt. Listening, picking up on the s - and correcting ... [TZ mimes several things with her hand] even if we think, "Ah, I'll just let that slip." Plants um breathing ... gases [TZ and JR smile]. But you can't, because that will just escalate into something really massive. And so yes, it is very important to listen. That's what I think the whole process has shown me. It really has been useful.

6c:26 *JR: It has been such a pleasure. Thank you so much for everything you've shared in - you know that wonderful interview [JR indicates interview 6a on the laptop] there and it has been great talking with you. [TZ and JR smile] Many thanks.*

TZ: No. Thank you.

JR: Unless there is anything else you'd like to say? Shall I -

TZ: No. Yes. Really useful.

[End 6c – End of transcript]