The Linguistic Representation of Abstract Concepts in Learning Science: A Cognitive Discursive Approach

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Abstract

Learning scientific concepts can be challenging for many pupils and consequently much research has been carried out to locate and explain the social and cognitive processes involved in bringing about changes to learners' abstract conceptual understandings. This thesis contributes to this field by offering a text-world account (Werth 1999, Gavins 2007a) of how scientific concepts are constructed and linguistically represented in classroom discourse. More specifically, its first aim is to explore how a group of twenty, first year secondary pupils and their teacher construct and linguistically represent the abstract scientific concept of *heat energy* (and related concepts) in discourse. In so doing, it examines how the concept emerges and develops during a series of classroom activities, including a teacher-led demonstration, a simulated role-play and a group discussion/writing task, in addition to teacher and pupil interviews. By using the Text World Theory framework (see Gavins 2007a; Werth 1999) to focus on the linguistic choices and their corresponding cognitive effects, it becomes possible to explore the cognitive architecture of the pupils during the learning events and interviews. Thus, it is hoped that this study makes an innovative contribution to the field of cognitive linguistics and science education by explaining and exemplifying how learners' scientific concepts develop in naturalistic settings (Amin 2015). As a text-world approach to investigating classroom discourse is a relatively new area of exploration, the thesis also aims to examine the effectiveness of the text-world framework to explore multimodal, interactive classroom environments.

The class involved in this study belonged to a state secondary school in a large urban city in Scotland. There was a broad ability range amongst its pupils, many of whom spoke languages other than English at home. The data generated was the result of a four-month prolonged investigation with the class, which resulted in the video and audio recordings of 15 lessons, 8 pupil interviews and 5 teacher interviews. Part of this data was later transcribed and analysed using the text-world framework. This framework proves to be well-suited to the task of investigating the conceptual structure of the classroom participants, due to its ability to track and explore multiple conceptual worlds established through spatial and temporal shifts, as well as modality and metaphor. By applying the framework to the relatively unexplored context of the classroom, extensions to the framework are made that show how the classroom discourse, the knowledge frames of the pupils as well as the social and concrete world of the classroom, play a key role in the development of abstract thought in a classroom setting.

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Chapter 1: Introduction

1.1 Aims and parameters

To understand and adapt to the physical and living world around us, we develop abstract ways of thinking. Learning the natural sciences demands our ability to develop abstract scientific concepts that may be quite different to our everyday construals of the world. The aim of this thesis is to describe and explain how a group of secondary school learners' conceptualisations of *heat energy* and related concepts emerge and evolve during a unit of work. With a special focus on two secondary school science lessons and pupil (and teacher) interviews, it provides an account of how these concepts are constructed and linguistically represented in discourse using Text World Theory (Werth 1999; Gavins 2007a), a cognitive discursive framework.

Simply put, the purpose of this thesis is to provide a linguistic account of how a group of learners and their teacher are able to think and learn about scientific phenomena (energy, atoms) that they have never seen nor touched, in a multimodal classroom environment. As Boroditsky and Ramscar succinctly assert:

> Much scientific progress – whether it involves theorising about invisible sources, studying the behaviors of atoms, or trying to characterize the nature of private mental experience – depends on generating new ways of describing and conceptualising phenomena that are not perceivable through the senses (2002:185).

To explore and provide a plausible explanation of the conceptual architecture of a group of learners and their teacher in the classroom, this thesis has adopted the Text World Theory framework. Text World Theory is a cognitive discourse grammar that provides a model of how language in use can be experienced and understood (Gavins 2007a; Werth 1999). It is a cognitive model in that it is based on the premise that in order to understand any form of language we construct mental representations, or *text-worlds,* in our minds to achieve this.

Although the model draws upon many key principles of cognitive linguistics, what singles it out against other cognitive linguistics frameworks is that it provides an account of how both the immediate physical and social contexts affect text comprehension. Despite the fact that the text-world model has been readily adopted by linguists and stylisticians working on written, primarily literary texts, there has been relatively little attention given to the text-world study of oral interaction in group settings (exception to this, see Peplow et al. 2016; van der Bom 2015; Whiteley 2010; Whiteley 2011). Neither, to my knowledge, have there been many studies which focus on the interaction and interplay between the participants, oral and written texts, visual diagrams and physical objects found in a classroom. Therefore, the second aim of this thesis is to make a contribution to knowledge by developing this framework as a platform to analyse complex and dynamic multimodal environments from both a social and cognitive perspective. The methodological approach adopted, therefore, is a qualitative one which aims to examine and explain this complex world of human experience in a classroom setting. As this study focuses on a single class in one school over a four-month period, it is a case study. Over this period, 15 lessons were recorded in addition to 8 pupil interviews and 5 teacher interviews.

The context of the case study is a class of first year secondary school pupils (12-13 year olds) learning science, with their teacher Mr Dalel (pseudonym), in a mainstream state secondary school in a large city in Scotland. There were twenty pupils in total, and as the class was not streamed, there was a broad ability range amongst its pupils. Reflecting the relatively high number of pupils from immigrant backgrounds, the number of pupils in the class who spoke a language in addition to English was significant (13/20). The languages that the pupils spoke in addition to English included Arabic, Hindi, Punjabi, Urdu, Cantonese and Mandarin. Out of the twenty pupils, there were two pupils from China who had arrived recently to Scotland and had a limited knowledge of English. The analysis in this thesis reflects the multilingual nature of the classroom in that it sets out to interpret the meanings that all the pupils make, based on my understanding of the linguistic and to some extent cultural knowledge, they bring to each learning event.

The theoretical orientation for this study is based on the view that abstract knowledge is analogically built on more concrete domains of knowledge. This perspective is a break from mainstream cognitive science which sees abstract thinking as 'a purely a rule-driven information-processing phenomenon, inherently separated from the nature of the body of the living human animal, and the bodily experiences it sustains' (Núñez 1999:44). Instead, this thesis takes the view, encapsulated in Boroditsky and Ramscar's quote, that cognitive science involves the study of how the mind *experiences* thought. This goes beyond many current dominant views in cognitive science (Fodor 1983; Pinker 1997) and education (see Landauer and Lemaire et al. 2006), referred to in the literature as the computational theory of mind, that claims cognition can be solely understood as, and be reduced to, an information-processing computing machine. Despite the longstanding central role that this theory has played in education, the position taken by this thesis resonates with recent emerging trends in the field of cognitive science which is now beginning to recognise that the study of subjectivity and consciousness are legitimate and important areas of scientific exploration (Clark 2013).

By drawing on a range of research literature this thesis provides an interdisciplinary perspective on conceptual thought and development. Some of this literature includes: cognitive linguistics and Text World Theory; discourse studies; stylistics; and conceptual change research from the field of science education. A review of the central tenets of the key fields will be provided in Chapter 2.

1.2 Rationale

The rationale for this thesis is rooted in current debates in the learning sciences, that will be explored in Chapter 2, in which the classroom conditions that bring about conceptual change are discussed. Briefly put, conceptual change research (see Vosniadou 2008; Carey 2009) sets out to explain how concepts develop from everyday construals of scientific phenomena to construals held by scientists. It has been claimed that this research has been one of the most important domains of science education research of the past four decades in that it offers a

'powerful framework' for both research and for classroom practitioners (Treagust et al. 2017: 121). Although science educationalists have increasingly recognised the importance of language for the learning of science in that it can either provide suitable frameworks for analysing classroom discourse, or that learning science can be seen as an introduction into a new language (Duit 2007:4), it is only relatively recently that a firm connection has been made between language and conceptual change (Amin et al. 2015).

As is outlined in the literature review, significant progress has been made in understanding the sociocultural and socio-linguistic processes involved in bringing about a convergence of understanding between classroom participants (Roschelle 1992; Mercer et al. 2004; Chin and Osborne 2010). It is this recognition of the connection between the language of the classroom and its effect on learners' conceptual development that triggered my interest to pursue this as a research area. However, having had the responsibility of assessing a group of student teachers on their use of language and its effectiveness for developing conceptual thinking before embarking on a PhD, I concluded that although I could offer feedback on the sociocultural and sociolinguistic aspects of the students' language use, there appeared to be no framework to hand which offered a means of explaining how the discourse of the classroom affects the learners' *conceptual* thinking of scientific concepts.

This apparent gap in the literature is what this thesis aims to fill by providing a theoretical account of this relationship. The first research aim of this thesis is therefore:

1. **To examine the ways in which the abstract concept of heat energy (and related concepts) is constructed and linguistically represented by a group of learners and their teacher in a secondary school setting.**

As this is a new application of the Text World Theory framework, further aims of this thesis are to investigate its appropriateness and effectiveness. Therefore, the second and third research aims are:

2. **To examine the ways in which the Text World Theory framework can be applied to the analysis of the development of abstract concepts in discourse.**

3. **To examine the effectiveness of the Text World Theory framework for exploring the development of abstract concepts in a school environment.**

Knowledge generated by this thesis already contributes to the theoretical basis of an Initial Teaching Training programme at my workplace. This study does not, however, offer insights into the practical application of this knowledge into teacher training courses, but this is a clear implication of the findings generated.

In our current socio and political climate where there is an 'emphasis on measured outputs: on strategic planning, performance indicators, quality assurance measures' (Olssen and Peters 2005: 313), the value and importance of teacher knowledge appears to be ever more a necessity as, I would argue, it can empower teachers, by providing them with the confidence to negotiate and maintain control in our complex culture of performativity. Thus, it is hoped that this thesis will make a contribution towards building a more robust theoretical knowledge base about learning and language, on which both the research and practitioner community can build.

1.3 Structure of thesis

This thesis has seven chapters. Following on from the introduction, is the literature review, Chapter 2, which provides a chronological account of the key developments made in the field of conceptual change research, namely; 1. social interaction and its effect on conceptual change; 2. learners' ontological beliefs of concepts; 3. models, modelling and metaphor; and 4. metacognitive awareness and understanding. By drawing together elements from each of these aspects a proposed model of conceptual development is presented that reflects both the dynamic and to some extent accumulative aspects of learning reflected in this thesis. I have argued elsewhere (Zacharias under review), that to track the pupils' conceptual developments in the classroom, an analysis of how the pupils' ideas are linguistically represented in discourse using a Text World Theory framework, offers a potentially attractive method to uncover both the

mental and social dynamics of the learning environment. To establish a theoretical foundation for the three analysis chapters (4,5 and 6), section 2.6 of Chapter 2 reviews the central tenets of cognitive linguistics, the field to which the text-world model belongs. Finally, Chapter 2 concludes with an overview of the Text World Theory model, a summary of some of the most recent developments of this model's application to face-to-face interactions and classroom learning and finally, a proposal of what I hope are this thesis' contributions to the framework. The chapter concludes with a presentation the thesis' three research aims.

In Chapter 3, I outline my rationale for adopting a case study research design with a predominately qualitative naturalistic inquiry approach (Lincoln and Guba 1985; Denzin and Lincoln 2005), to investigate the linguistic representation of a group of learners' conceptual development of scientific concepts in a naturalistic classroom setting. Chapter 3 starts by outlining my epistemological position that informs the decisions made during the research process. It provides details of the research context: the school, the curriculum, the teacher, the pupils and the researcher. Section 3.4 highlights some key decisions made during the preliminary stages, namely, my motivation for wanting to undertake this research project, some of my initial research questions and issues that guided the construction of the research design. It provides an account of the ethical considerations, in addition to the key components of the pilot study, which lasted one week in January 2015. The chapter continues by providing details of the main data collection stage, including my reasons for selecting the lessons on energy transfer, an account of the main research methods used during the four-month period during which I paid regular visits to the school: classroom observations, pupil and teacher interviews and recording my observations as field notes.

There are three analysis chapters that primarily focus on the learning that takes place during two lessons, three pupil interviews and a teacher interview. Although the chapters focus on the conceptual development of the concept of energy transfer, each chapter has its own distinctive focus. Chapter 4 aims to

provide an account of how the scientific concepts of *heat, temperature, heat transfer, conduction* and *an insulator* are constructed and linguistically represented in the classroom discourse of two lessons at the start of a learning unit on 'heat and light', using the Text World Theory framework. The chapter is divided into a number of sections, each depicting a short learning episode within the lesson. The first episode describes and explains how the concepts of *heat* and *temperature* are re-introduced into the classroom discourse by the teacher, Mr Dalel, at the start of the lesson. In the second episode, Mr Dalel introduces the key concepts of *heat transfer* and *conduction* by means of a demonstration. This episode shows how these abstract concepts emerge from the concrete world of the here-and-now immediate situation. To further the pupils' understanding of the concept of *heat transfer*, Mr Dalel sets up a role-play situation during which the pupils' bodies symbolise the atoms of a metal rod that they had just seen in the demonstration. To explain how new meaning is created during the role-play, this episode applies Fauconnier and Turner's Conceptual Integration Theory (1998; 2003), which was originally adapted for the text-world framework by Gavins (2007a) and Browse (2013). In addition to the classroom episodes, a text-world analysis of a pupil interview is provided, during which the pupils Suzy (6) and Yelena (03) (pseudonyms) are invited to take part in a stimulated recall session of the classroom role-play. The aim of this interview is to gain a deeper insight into the perspectives of the individual pupils.

Chapter 5 focuses on a problem-solving task 'the snowman and his coat', which Mr Dalel presents to the class after they have been introduced to the concept of insulation. During the chapter the text-world analysis traces the development of the ideas of the class, as the pupils set out to solve the problem as a whole class and in smaller groups. It also analyses an interview of two pupils Rose and Sanja, who are invited to take part in a stimulated recall interview during which their conceptual understanding of the problem-solving task is explored in depth. In contrast to Chapter 4, which focuses on learning episodes that were teacher-led, Chapter 5 focuses on the dynamics between the pupils as they set about solving the task. Various aspects of the learning process are highlighted, namely, the pupils' epistemic stance, pupil participation, participant roles and how the

pupils draw from their episodic memories and knowledge frames to make sense of the situation. The chapter demonstrates how the text-world approach allows for a fine-grained analysis of the different conceptual levels involved in the knowledge-building process.

Chapter 6 examines how a group of four pupils linguistically represent the abstract concept of *heat transfer* during a discussion/writing task. The chapter is divided into three parts. The first part is a text-world analysis of an interview held with the teacher, Mr Dalel, during which I and the teacher discuss the pupils' learning of the concept of heat transfer. Topics emerge from this discussion which then act as a springboard for the main analysis found in part two of the chapter. The topics centre around how both the teacher and myself view the relationship between the pupils' conceptual understanding of *heat transfer* and their use of language. I argue that by incorporating the teacher's perspective and allowing it to help guide the main analysis, a more trustworthy understanding of the phenomenon at hand, namely the pupils' conceptual understanding, can be gained. During part two, the main analysis, I explore, using the Text World Theory framework, how a group of four pupils linguistically represent their understanding of the concept of *heat transfer* during face-to-face interaction and in writing. The outcome of the analysis is a revised model of Werth's linguistic knowledge (1999:96), an aspect of the discourse-world that is needed by the pupils as they carry out the classroom task. The third part of the chapter explores two pupils Karla and Zarif's understanding of *heat transfer* as they externalise and represent their understanding of the concept by means of visual representations.

Chapter 7 concludes this thesis by first summarising the key theoretical and methodological underpinnings of the research. The conclusions drawn from the previous chapters are then critically re-examined according to the central aims of the thesis. The potential impact and contribution that the findings have for both the fields of discourse studies, in particular Text World Theory and science education, are then discussed. The limitations of the study and some possible future research areas are then outlined.

Chapter 2: Literature review and background to Text World Theory

2.1 Towards a model of conceptual change

This research sets out to understand the content and processes of a group of secondary school learners and their teacher's conceptions from a cognitive linguistics perspective, during a series of lessons on heat energy. Whilst the focus of this study is on the discourse of the classroom, it is broadly situated in the field of conceptual change research, which has had a major influence on science education since the 1970s. Science educationalists working in this field recognise that learners' abstract scientific concepts differ from those of scientists and are interested in the nature of these differences and the nature of the processes by which learners' conceptions change to become more like those of the scientists (Driver 1989; Driver et al. 1994).

This thesis takes a cognitive perspective in that it takes the view that learners construct internal mental representations and undergo mental processes, which interact with external representations and processes that are part of the learner's social and physical environment. Its position resonates with recent work in conceptual change research, in particular with that of Amin, Smith and Wiser (2015), Amin, Jeppsson, Haglund (2015), Treagust and Duit (2015). Building on previous work in the field, Amin Smith and Wiser summarise their view of concepts and conceptual change as one, which involves:

> complex interactions between various forms of knowledge: propositionally expressed beliefs of various kinds (domain specific, ontological, and epistemological) and iconic representations that help ground understanding in perception and action (image-schemas, imagery and mental models) (2014: 77).

In brief, according to this view of cognition, the development of abstract (scientific) concepts involves the interplay and re-adjustment of different knowledge elements. This model of cognition is known in the literature as

embodied cognition and, as Amin et al. (2015) point out, is based on assumptions that can be traced back to both ecological theories of learning and perception (e.g. Gibson 1979) and Merleau Ponty's *Phenomenology of Perception* (1962). Aspects of this model can also be attributed to Piaget's focus on the sensorimotor system playing a central role in the formation of abstract concepts. The social, embedded nature of the model sits well with Vygotsky's (1978) socio-cultural theory of learning. This will be referred to and explained in section 2.3.1.

The structure of and rationale of this chapter is as follows. To fully understand the model of conceptual change that underpins this thesis, and to appreciate how my own cognitive-discursive analysis might contribute to the literature on conceptual change, sections 2.1-2.3 will review the key developments and ideas which contribute towards the proposed model outlined in section 2.4. It will, therefore, map out some of the key positions held within recent conceptual change research that are particularly relevant to understanding the model adopted in this thesis. It will take a loosely historical approach to review the literature, as this enables a greater appreciation of the main developments and how they relate to each other. The proposed model for investigating the conceptual developments taking place in the classroom is a cognitive-discursive model (Text World Theory). This thesis essentially adopts Werth's original Text World Theory framework, as outlined in his monograph *Text worlds: Representing Conceptual Space in Discourse* (1999), and applies this framework to the classroom context, which is a relatively new context of investigation for text-world theorists. To help orientate the reader who may be unfamiliar with the key principles of the framework, an overview of the text-world framework is given in section 2.7. In addition to providing an overview of the key principles, the section will critically evaluate Werth's original model and review some of the more recent developments in the field. It will highlight innovative features that text-world theorists have applied to their own work since the publication of Werth's monograph that are particularly relevant to this thesis. It will then argue that, despite the advancements made to the model, there are still aspects

that require further attention. Section 2.7 will establish some of the key developments that this thesis proposes to make towards the framework.

Text World Theory is a flexible model which borrows extensively from the larger field of cognitive linguistics. As my analysis provides a fine-grained account of how concepts are linguistically represented in discourse, it necessarily draws on concepts originally coined in the field of cognitive linguistics but used widely by text-world theorists. Therefore, although this review has set the cognitive linguistics discipline and Text World Theory frameworks out separately in sections 2.6 and 2.7 respectively, the text-world framework should be regarded as a cognitive linguistics framework that is well suited to analytical studies of discourse.

2. 2 Conceptual change research: its origins

Current theories of learning can be traced back to the work of the child developmentalist Piaget (1926, 1932, 1985). His legacy has left a profound influence on the way researchers and classroom practitioners conceive the human as a learning subject. Piaget was primarily concerned with how children, through observing and acting in the physical world, construct an understanding of it. For Piaget, it was the child, or more specifically, the child's cognition alone, which was able to make sense of the environment by acting on it and thereby coming to control it (Wood 1998). Through mechanisms of assimilation and accommodation, learners acquire new knowledge based on the knowledge that they bring with them to the classroom. His statement "l'intelligence organise le monde en s'organisant elle-mème" (intelligence organizes the world by organizing itself) (1937: 311), prefigures the central concern of successive research, that is also central to the investigation of this thesis, namely, how humans are capable of constructing knowledge of the world.

Piaget explained his observations by proposing that children pass through distinct developmental stages with different logico-mathematical conceptual structures, represented by propositional statements, and reach the ideal stage for scientific reasoning during adolescence and adulthood. His main contribution

to the model of learning endorsed in this thesis, is that he acknowledged that it is the individual learning subject who actively constructs their own knowledge, and that there is a dependent relationship between this knowledge and the knowledge that the learner brings to the learning situation. During the 1970s and 1980s, however, there was an increased sense of dissatisfaction with Piaget's developmental stage view of learning. Child developmentalists and conceptual change theorists noted that young children often display sophisticated reasoning abilities in familiar contexts and in areas that they know much about (Donaldson, 1978; Chi, Hutcheson and Robin 1989, Carey 1985). This led to the *continuity view* of conceptual change, which claims that young children are capable of abstract reasoning but frequently do not display this as they simply know much less. This is an important point that underpins one of the key assumptions made in this thesis, namely, that the cognitive processes involved in learning are available to all learners of any age or background, unless there is an underlying physiological condition that prevents this.

The acknowledgement that a learner's knowledge about a subject plays an important role in how able the learner is able to reason about it led to a domain-specific view of conceptual change (Carey and Spelke 1994). According to this perspective, scientific concepts (e.g. energy) often have radically different meanings depending on the scientific theory they are part of.

2.3 The process of conceptual change

The recognition that concepts take on their meaning depending on the theory they are part of, and that learners come to a learning situation with often very different concepts to the scientific view, led to what Amin et al. (2015) term 'the coherence' view of conceptual change or the 'knowledge-as-theory' perspective (Clark and Özdemir 2007). Influenced by Thomas Kuhn (1922-1996), author of the influential book *The Structure of Scientific Revolutions*, researchers (e.g. Carey 1999; Chi 2005; Ioannides and Vosniadou 2002; Wellman and Gelman 1992) endorsing this perspective are interested in how learners come to understand a new scientific theory as a *new system of interpretation*. Proponents of this view believe that there is an overarching conceptual structure

with ‘theory-like properties’ that constrain a learner’s interpretation of models and ideas (Clark and Özdemir 2007: 352). They claim that although learners’ theories, (also known as naïve theories or misconceptions), are different from scientists’ they are nonetheless coherent, organised, characterised by a distinct ontology and have explanatory powers. For these reasons, the principal means of documenting learner ideas has been interviewing the learners in clinical settings to uncover the underlying theories of the learners. These theory frameworks are either transformed into (Driver 1989) or are replaced by (Posner et al. 1982) more expert like theory-frameworks during instruction.

Despite the knowledge-as-theory view being the most favoured theoretical framework used to explain a learner’s developing understanding of scientific concepts, there exists now a substantial body of evidence to support an alternative framework referred to in the literature as the knowledge-as-elements (Clark and Özdemir 2007) or knowledge-as-pieces (Amin et al. 2015) perspective. Proponents of this view (Clark 2006; diSessa et al. 2004; Harrison et al. 1999; Linn et al. 2004) argue that learners’ pre-instructional views about a scientific phenomenon are fragmented and are interpreted through various elements including image schema like structures or ‘phenomenological primitives’ (p-prims) (diSessa 1993), propositional knowledge, narratives, imagery, concepts, and mental models at various stages of development (Clark and Özdemir 2007: 354). Learning science, according to this view, is a complex process, in which these elements are re-positioned and re-grouped in relation to each other, to allow for a more scientific interpretation of an object in focus (e.g. an atom or heat transfer) in the learner’s environment.

What unites both knowledge-as-theory and knowledge-as-pieces researchers is that they are both interested in the *processes* involved that lead to conceptual change in the learner. Overall, these approaches mark a significant departure from Piaget’s more narrow view of learning, which upholds that conceptual change is essentially brought about by the learner’s correct logical reasoning, expressed through propositional statements alone. It has been claimed, however, that the theory-as-knowledge perspective is more in line with Piaget’s

constructivism as it emphasises the continuous process by which knowledge is built on prior experiences (Clark and Özdemir 2007).

In sum, the present literature on conceptual change provides two seemingly incongruous models of conceptual change; one which views it as a series of changes from one coherent system to another, while the alternative view perceives it as a process of readjustment of basic knowledge elements. At the end of this review on conceptual change, in section 2.4, a model which merges elements from both models will be proposed that supports the position taken in this thesis. Before this, a critical review of the literature which explores in more detail *how* conceptual change is believed to take place in a classroom will be given in the following section.

Research carried out within a domain specific view of learning, whether it is the knowledge-as-theory or the knowledge-as-pieces perspective, has focused its attention on broadly four major lines of enquiry. As these are all relevant to the model of learning which this thesis proposes, the following will review these four areas of conceptual change research. These four areas include: 1. social interaction and its effect on conceptual change; 2. learners' ontological beliefs of concepts; 3. models, modelling and metaphor; and 4. metacognitive awareness and understanding.

2.3.1 Social interaction and its effect on conceptual change

Since the 1980s there has been an increased interest in the social interactions of the classroom and how these affect the processes of conceptual change. Influenced by the work of Vygotsky (1978), knowledge development has been seen to be a process of internalisation from the 'intermental plane', that is, mental processes occurring in social interactions between members of the class, to the 'intramental plane', the mental processes of the mind of the individual learner.

Socioculturalists tend to focus their research on which social interactions in class lead to a convergence of understandings, either between a more knowledgeable other and the learner or between peers. Influential work in this area has aimed

to classify features of talk that promote an eventual *convergence* in understanding between members of the class.

Chin and Osborne (2010) observed that the teacher can use questions as a type of 'cognitive ladder' to help develop the learners' thinking. Teacher questions can probe learners' prior understanding, help generate ideas, analyse data, generate predictions, make inferences, and make connections between ideas. Chin notes that not only do the teacher's discursive skills develop the individual learner's conceptual understanding but through the teacher's 'revoicing' (Chapin et al. 2003), or reaffirming of the learners' ideas the teacher is able to develop a sense of shared or 'common knowledge' (Edwards and Mercer 1987) within the class.

Other researchers who are interested in how learners' use of language might lead to a convergence of understanding, have drawn on the field of conversation analysis (Garfinkel and Sacks 1970; Goodwin and Heritage 1990), to study the types of conversational moves that lead to conceptual change within a group of learners. Roschelle's (1992) study shows that certain moves, which allow interlocotors to construct representations of their mental representations and encourage learners to establish a convergence within a group by displaying, confirming and repairing, facilitate conceptual change amongst learners.

Also interested in the features of talk amongst peers that might favour conceptual change, Mercer et al. (2004) conducted a comparative study in which they explicitly introduced the target classes the ground rules of a collaborative style of reasoning, known as 'exploratory talk', which are as follows:

- all relevant information is shared
- all members of the group are invited to contribute to the discussion
- opinions and ideas are respected and considered
- everyone is asked to make their reasons clear
- challenges and alternatives are made explicit and are negotiated

- the group seeks to reach agreement before taking a decision or acting

(2004: 362)

They found that these pupils were more able to find the connections between scientific concepts presented to them individually during concept mapping tasks, that formed part of the post intervention task, than pupils who had no training in exploratory talk. This, the researchers claimed, was direct evidence that supported the position that intermental activity had a direct developmental influence on the intramental plane of the individual.

Vygotsky's conceptualisation of language avoids direct acknowledgement, however, of the various *social purposes* learners and teachers engage with during the learning process (Wertsch 1991). To address this shortcoming in Vygotsky's theory, Wertsch proposed that instead of focusing on the decontextualized word, as Vygotsky had done, a more powerful unit of analysis should be the Bakhtian notion of an utterance. Although difficult to define, an utterance according to Bakhtin (1986) is the smallest unit of speech linked to the concept of voice 'the speaking consciousness' (Holquist and Emerson 1981: 434). A key insight, which has had a profound influence on socio-cultural studies of learning in science over the past two decades, is that the utterance is shaped by the social context it is a part of. Different social contexts include typical utterance types or social genres. The recognition that learning these different social genres and registers (Hasan and Halliday 1989) of science is key to 'building up "scientific" forms of consciousness [and] scientific ways of viewing the world' (Veel 1993: 12), has led to an interest in exploring both the conceptual and representational demands pupils have in conceptual learning in science. One notable study, drawing on Halliday's notion of social genre and register, concludes that a group of middle school pupils' conceptual understanding of heat expansion is directly influenced by their use of lexico-grammatical resources (Seah et al. 2011). The more 'expert-like' their use of the scientific language after a period of instruction, the clearer their understanding of the scientific concepts seemed to be.

This notion of social genres was used by Mortimer and Scott (2003:25) to develop their 'communicative approach' framework, which is a conceptual tool for teachers to identify episodes of a science lesson which are defined by their teaching purposes and moments in which either the multiple voices of the pupils are listened to, or when the univocal, authoritative voice of the teacher comes to the fore. The key elements of this framework are as follows: i. the teacher's teaching purpose, i.e. the aspects of the science curriculum that the teacher intends to introduce, and ii. what aspects of the social language of science does each classroom activity entail. Element ii. can be further divided into: a. 'authoritative language of science': descriptions, explanations, generalisations; or b. 'everyday language'. Leach and Scott (2003) maintain that the tension between the two discourse types (authoritative vs. everyday) leads to a discontinuity between the knowledge in the intermental plane and the intramental plane. Pupils become inevitably involved in constructing their own understanding of the authoritative view of science. This conceptual framework, devised by Mortimer and Scott (2003), is a useful approach to map out episodes in a lesson according to their teaching purposes and has therefore been used in the analysis of this thesis as a descriptive tool to orientate the reader to the socio-cultural terrain of the lesson before the main cognitive discursive analysis.

In contrast to the aforementioned studies, which focus on the features of classroom language that afford *convergence* in understanding, there has been a small resurgence in interest in what mental constructions of individual learners provoke cognitive conflict in social settings that have, in turn, been shown to benefit the process of conceptual change (Howe 2009). These studies represent the recognition that there exist mechanisms other than internalisation, which are necessary for conceptual change to come about in social contexts. This cognitive conflict has been explained by Howe in Piagetian terms that view learning as a process of equilibrium, a process of reconciliation between prior and newly acquired beliefs (Piaget 1932 and 1985). However, research in cognitive linguistics (e.g. Johnson 1987; Lakoff 1987) and recent research in genre studies (e.g. Bruce 2008:20), highlights the need for, and offers a more

nuanced account of, the cognitive processes involved in this knowledge-building process. As Bruce (2008:20) notes:

> different types of knowledge (such as knowledge about real-world entities, empirical data expressed in statistical number abstractions, or *abstract ideas* or theories) may each be cognitively organised and categorised in different ways (my emphasis).

This acknowledgement that there are types of knowledge, including abstract ideas which are susceptible to mental processes, seems to offer a new perspective on the Piagetian notion of cognitive conflict in that it is through these structuring and categorising cognitive processes that the socially situated individual is able to reassess their own ontological and epistemological belief systems. This position does not dismiss the fact that these mental processes may be under the influence of the social dynamics of the situation. What appears to be the case is that there are influences other than social ones that need to be accounted for when understanding certain types of knowledge. This recognition that certain knowledge types, including the mental construction and representation in discourse of abstract concepts structured and categorised by the human mind, has been well documented by scholars working in the field of cognitive linguistics (Johnson 1987; Lakoff 1987). It is to how the mind categorises concepts and its relationship to conceptual change that this chapter will now turn.

2.3.2 Learners' ontological beliefs of concepts

A shift in focus, towards uncovering the processes of conceptual change, led to the recognition that many of the learners' naïve theories were often very resistant to change during instruction. Researchers noted that this resistance appeared to be primarily due to the learners' ontological understanding of a concept. As this thesis focuses on a series of lessons on heat energy and heat transfer, a brief overview of some research carried out into learners' ontological views of heat and heat transfer, to illustrate this point, will be made.

When learning the scientific view of heat, the literature on conceptual change research suggests that the learners' concept of heat is frequently hotness (Driver et al. 2005; Wiser and Amin 2001). In contrast, the scientific concept of heat is exchanged energy. Due to learners' ontological commitment to heat as hotness: 'heat cannot be energy, they say, because energy is not hot' (Wiser and Amin 2001: 332), learners are often unable to differentiate between heat and temperature. Learners have been shown in interview situations to view temperature as the amount of heat possessed by an entire object and relate it directly to the size or the amount of material present (Driver et al. 2005). In relation to heat transfer, learners are frequently found to display the belief that some materials are better able to attract heat more than others (ibid.).

To account for learners' misconceptions from a cognitive perspective across a range of formal teaching contexts, it was argued by Chi (1992, 2005) that there exists a number of underlying commonalities or attributes across scientific phenomena (e.g. heat, energy, force) as well as their everyday counterparts. These phenomena can be categorised into 'basic categories of realities' (2005:163), such as concrete objects, events or abstract concepts. These ontological categories can be differentiated by attributes, which are either very typical for the entity, or only remotely plausible. To illustrate this, it is possible to colour an entity green, such as a door, but it is not possible to colour an event green, such as a tennis match. Only entities can be coloured but not events. That is, a learner's conception of a phenomenon may not match reality at the ontological level. If it is assumed that assigning phenomena to ontological categories is a fundamental human capability (Lakoff 1987), then many misconceptions can be interpreted as a discrepancy between the learner's conception and reality at an ontological level. According to this view, many learners' persistent misconceptions are essentially mis-categorisations across various ontological boundaries (Chi 1992, 2005).

Chi's claim that many robust misconceptions appear to be the result of a mismatch between the learner's conception and reality offers a plausible account for why many learners think, as Driver et al. noted, that heat is 'a subtle

substance, like air, that is capable of flowing into and out of objects' (2005:138). That is, many learners, including the learners in this study, appear to categorise heat as a substance and not as a process and in so doing assign to it various corresponding attributes (i.e. that it is a fixed point and moves from one point to another). Internal mental representations of such phenomena may, however, lack detail and precision and, to compensate for this, it is necessary for learners to engage with external (or internal) representations, or models, that form an essential part of any science classroom.

2.3.3 Models, modelling and metaphors

Since the 1980s there has been a significant interest in the role of models and modelling in the process of conceptual change. A model is taken here to be a structural analogue of an object or a process. It can be an external representation, either in the form of a diagram or a three-dimensional object, or it could be an internal mental representation, in the form of an image schema or re-enactment of a past or imagined event (imagery) of the scientific phenomenon. Much of the research has focused on the impact of ready-made models on the learners' thinking. Evidence suggests that models have had a positive effect on students' conceptual thinking in that they act as bridges between their pre-instructional concepts and the scientific version (Brown and Clement 1989). They provide learners the opportunity to explicitly compare similarities and contrasts between domains, thus acting as a bridge between learners' pre-instructional ideas and the scientific viewpoint. Furthermore, they can act as prompts for metacognitive discussions amongst learners (Wiser and Amin 2001) and have been shown to assist with learners' abilities to conceptualise abstract phenomena which are not perceptible to the eye (Fredericksen and White 1998).

A close relative to the model is the metaphor (Duit 1991), which has been singled out as a potential heuristic for bridging students' pre-instructional concepts to the formal concepts of science (Cameron 2003). A metaphor according to Cameron 'brings together two domains that are distinct and somehow incongruous, but whose juxtaposition can be made sense of' (2002: 674). For

example, in the metaphor *the atmosphere is a blanket of gases*, the Topic domain (the atmosphere) is understood in terms of the Vehicle domain (blanket). It is only recently that conceptual change research has begun to acknowledge the cognitive linguistic perspective on metaphor. Metaphor has been frequently viewed as a simple language embellishment: one of many possible tools in the classroom to aid pupils' understandings. However, there has been a small yet significant growth in interest in the claim that abstract concepts may not be understood literally but, in fact, metaphorically, through structural metaphors (e.g. ARGUMENT IS WAR; 'your claims are indefensible') (Lakoff, 1987, 1990; Lakoff and Johnson, 1980, 1999) and that to understand how pupils' concepts change, it is necessary to include this perspective into the debate (Amin 2008). Furthermore, this metaphorical understanding is grounded in our embodied experience of the world, which Lakoff (1990) termed as the *invariance hypothesis*. Ultimately, according to this hypothesis, the conceptual structures which map the Source conceptual domain (e.g. WAR) onto the Target domain (e.g. ARGUMENT) are themselves metaphorical extensions of image schemas: 'What is mapped [via metaphor] preserves image-schematic structure, of the source domain' (Lakoff 1990:54). Image schemas are basic gestalt-like structures that are distilled abstractions of our physical and social experiences of the world. These basic structures (e.g. CONTAINER and SOURCE-PATH-GOAL image schema) are so basic that they appear to be common to most cultural contexts (Grady 1999) (see section 2.6.5 for a more detailed coverage of image schemas). However, as these metaphors may be expressed in languages differently, learners may experience difficulties accessing these metaphors. For example, the metaphor *the atmosphere is a blanket of gases* (based on the underlying CONTAINER image schema) may be understood more readily by a group of Bangldeshi students if expressed as *the atmosphere is a canopy of trees* (Cameron 2003: 20). Although frequently used in science classrooms, the 'imaginative leap' required by learners for interpreting one concept in light of the other there exists room for misinterpretation (Kittay 1987). Indeed, more recently, a cognitive linguistic study on the use of metaphors by secondary students learning about climate change and the greenhouse effect concluded

that, although these metaphors were an important aspect of thinking and learning, pupils' creative extension of metaphors often led to simplifications and misconceptions (Deignan and Semino 2017).

Thus, while external ready-made models and metaphors have been shown to assist with learners' conceptual development, learners can experience problems making sense of the ready-made models in terms of their own intuitions (Amin et al. 2014). For this reason, there has been a growing interest in the benefits learners might gain from constructing their own models. One notable example is the work of Ainsworth et al. (2011) who have researched the affordances brought about by learners drawing their own external representations. They argue that as much of science is represented by illustrations, developing learners' visual competencies should be a priority. A rationale for using learners' drawings to assist with a learner's conceptual development is provided. Quillin and Thomas (2015) who, by drawing from recent research in the cognitive sciences (see Seel 2003; Jonassen et al. 2005), argue that the act of drawing an external model requires the learner to actively create or interpret their own internal mental models. The number of studies, however, aiming to explore how both constructing and using ready-made models interact with learners' own internal representations are perhaps not unsurprisingly scarce, due to the hitherto methodological difficulties. However, Text World Theory offers a suitable analytical approach to exploring this phenomenon and an application of this framework to pupils drawing their own models is explored in Chapter 6.

2.3.4 Metacognitive awareness and understanding

During the 1990s, researchers began to ask if there is a connection between metacognition, including epistemological beliefs, and conceptual change itself. The question posed was, if the learner is aware of the processes of knowledge construction, would this lead to the learner taking control of the learning process by actively changing their own conceptions? Epistemology is taken to be an area of knowledge which deals with the nature of knowledge including its sources, its structure, its justification and limits (Hofer and Pintrich, 1997; Sandoval, 2005).

A series of studies concluded that different epistemological beliefs in physics had an effect on what learners *attended* to (Vosniadou 1994, 2003, Vosniadou and Ioannides 1998). These studies concluded that there was a correlation between students' beliefs about science (i.e. whether they saw it was a set of unchanging facts or a complex system that is made up of explanatory hypothesis and theories) and what they focused on. The researchers concluded that those learners who had a simple epistemological position tended to value descriptions, and learners who had more sophisticated views about the nature of knowledge tended to pay more attention to explanations and anomalies between their ideas and evidence. These studies focused, however, mainly on the learners' views on the nature of scientific knowledge as a body of knowledge (i.e. a set of irrefutable facts) and less on learners' views on *how they* learned. In relation to this thesis this is an important point, as much of school science in the UK and beyond is presented to learners 'in textbooks with the popular, contemporary, cleaned-up and pre-justified accounts of the behaviour of the natural world' (Monk and Osborne 1997: 406), whose presentation of concepts is dependent on the epistemological beliefs of the teacher working within the constraints of an institutional organisation of a school system. The fact that much of lower secondary school science has not changed, at least with regards to the basic theories of *heat energy* and *heat transfer*, it is difficult to convince learners that science is a body of knowledge that undergoes change.

An aspect of epistemology which has had more scope for investigation in institutional pedagogical contexts, in which science is generally presented to learners as a body of knowledge that remains relatively stable is learners' personal epistemological beliefs about their own learning. In a meta-analysis study, it was found that teaching approaches which adopted and emphasised learners' metacognitive and self-regulated learning were the most effective (Zohar and Barzilai 2013).

Most studies on learners' personal epistemologies assume a domain and context independence of epistemological beliefs (May and Etkina 2002) and are predominately undertaken outside the classroom, in which learners' beliefs are

explored either through questionnaires or interviews (Zohar and Barzilai 2013). These studies are based on the notion that a personal epistemology is a relatively stable construct. This model has been heavily influenced by constructivist theories of learning which are based on the belief that new learning situations are interpreted through knowledge previously acquired by the learner and that learners are assumed to be either able or not able to apply this belief system to other contexts. That is, researchers are interested in how this metacognitive knowledge is *transferred* from one setting to another.

An alternative perspective, with a similar ontology to the knowledge-as-pieces perspective, focuses on personal epistemologies that have a more dynamic ontological nature. According to this view, the cognitive structure of a learner's belief and knowledge system is a range of epistemological resources. This perspective, although less established than the transfer model, is known in the literature as the resource-based perspective (Hammer et al. 2004: 2). The model upholds a 'manifold' view of a learner's cognitive structure, and focuses primarily on how epistemological resources are *activated* in a learner. Hammer et al.'s framework is based on previous work carried out in artificial intelligence and the cognitive sciences (diSessa 1993; Minsky 1986; Thagard 1989) and studies how the mind *experiences* 'fine grain-sized cognitive objects' during learning (2004:4). According to this model, these objects include sensory mechanisms, known as phenomenological primatives (p prims) (diSessa 1993) and local networks of propositions, which interact and combine to form larger ones. If the learner undergoes a similar experience several times then this larger network forms a stable cognitive structure known as a 'frame'. This frame, a set of expectations a learner has about a situation they find themselves in, is more likely to be transferred to similar situations if the learner has actively monitored their own thinking either alone or through scaffolding from the teacher (Hammer et al.2004:19). Hammer and Elby (2002) call for a more domain specific approach to researching metacognition and argue that more studies should be carried out in naturalistic settings as beliefs, they claim, are dependent on the domain and context they are situated in. The approach taken in this thesis seeks to address this gap in the literature in that the domain specific beliefs of the pupils are

explored by applying a text-world analysis, which aims to study how the learning mind experiences these fine grained-sized cognitive objects, to data generated in a naturalistic setting.

What emerges then from the recent literature is an account of conceptual change which is multi-faceted and complex. Despite its complexity, however, the literature acknowledges that the development of abstract thought in a learning situation, is dependent on how the mind structures and categorises the knowledge and beliefs associated with these concepts and that a learner's ability to process and represent these concepts is influenced by external models, both visual and verbal that the learners encounter. Furthermore, the development of abstract thought does not take place in a social vacuum but is influenced by teachers and peers. These aspects of the learning process are all explored in the Text World Theory analysis of the learning taking place in the classroom in Chapters 4,5 and 6. Less of a focus, is the pupils' formally expressed metacognitive views about their own learning processes, which are not explicitly dealt with in this thesis. This was mainly due to the time constraints on the pupil interview sessions. The teacher's beliefs and views about the pupils' learning do, however, emerge during the interviews and take a prominent position in Chapter 6.

2.4 Proposed socio-cognitive model of conceptual development

This review has presented two accounts of conceptual change; one which views it as a series of changes from one coherent system to another, while the other views it as a process of readjustment of basic knowledge elements. Recently, there has been an attempt to merge these two models together by proposing that the development of scientific concepts 'involves the gradual formation of increasingly organized *networks* of heterogeneous knowledge elements, including propositional representations such as language […], as well as image-schematic representations' (Amin et al. 2014:76), thus acknowledging both the accumulative and dynamic characteristics of the learning process.

According to this model that merges the two accounts of conceptual change, scientific concepts are grounded in image schemas (p-prims) narratives and imagery. Image schemas, as mentioned previously, form over repeated sensorimotor experiences in perception and action that are conceptual representations of the commonalities of these interactions with the physical world. More complex abstract concepts are understood metaphorically in terms of these basic image schemas (Lakoff and Johnson 1980). In contrast, imagery is movie-like re-enactments that take place in the mind's eye of the learner of past or imagined experiences with the physical and social world. Both these basic conceptual structures are able to interact with language and other symbolic representations (e.g. diagrams and illustrations), which are socially embedded, to form more developed conceptual scientific structures.

Although not as central to the learning process as Piaget initially claimed, according to the proposed socio-cognitive model, propositional language, that represents a learner's domain specific, ontological and epistemological belief system, can act as an initial placeholder which can gain meaning by being interpreted through basic conceptual structures such as image schemas, in addition to other internal and external models (Carey 2009). During instruction, these propositional structures become nested in a tightly knitted system of beliefs that lead to a coherent theory like structure of knowledge.

It is important to mention here how the proposed model situates itself within the field of current learning theories. Although, as established in this review, this socio-cognitive model has features which can be traced to both Piaget and Vygotsky, the position this model takes on how the learner is not separated from but is an integral part of its social, physical and psychological contextual environment resembles current ecological theories of learning and perspectives on language (see van Lier 2004). This perspective on learning takes a holistic approach to learning in that it is the relations between the learner and its social, physical and psychological environment that are studied. The ability to think abstractly enables the learner to understand, evolve, act in, adapt to and with this environment (Borghi 2005; Gibson 1979). This approach to conceptualising

learning is different to the more dominant constructivist models of learning that view context as a phenomenon that surrounds the learner, apparent in Piaget's individualistic conception of constructivism, in which it is the individual alone that constructs new knowledge, and in Vygotskian models of social constructivism, that strongly focuses on how the individual internalises the social world.

The model taken in this thesis, although not fully developed, provides a comprehensive, plausible account of *how* the processes taking place in the classroom bring about conceptual change. However, this model has not yet been applied to the analysis of naturalistic data. This thesis aims to fill this gap by analysing the discourse of a series of lessons and interviews with a Text World Theory framework. Being a cognitive discourse grammar, Text World Theory acknowledges that conceptual development and language use are inextricably linked. Furthermore, as the analytical approach taken in this thesis tracks the micro processes taking place in the classroom, it primarily concerns itself with the knowledge-in-pieces aspect of the conceptual change theory. That said, the fact that the Text World Theory model acknowledges the role that the participants' knowledge frames play, as will be demonstrated in the analyse chapters, it allows for a plausible theoretical explanation for how these dynamic micro processes of the classroom become part of more stable knowledge structures that accumulate over time. The Text World Theory model offers, therefore, a suitable framework for investigating and expanding on this model of conceptual change, this will be demonstrated more fully in section 2.7. By using a linguistic framework that can investigate how the cognitive processes of the mind are both structured by and represented in discourse, it is believed that a contribution to the Amin, Smith and Wiser socio-cognitive model might be made, in that it can provide an account of how basic knowledge structures are assembled and represented in discourse. Furthermore, this approach aims to acknowledge both the psychological *and* social aspects of the knowledge building process. By analysing how abstract concepts develop and are represented in classroom discourse in this way, a more comprehensive overview of the conceptual change process becomes possible.

2.5 Cognitive linguistic framework: prologue

If a comprehensive account is to be made of how scientific abstract concepts are constructed and linguistically represented in discourse, which is the main purpose of this thesis, it is necessary to have a framework for the analysis that acknowledges how abstract concepts are categorised, structured and how they come into existence in a classroom setting.

I believe that most suited to this task is a cognitive linguistics framework because it is able to account for how abstract concepts are categorised, structured and how they emerge in discourse. The following section will outline some basic tenets of cognitive linguistics, the field of linguistics to which Text World Theory belongs, to equip the reader with the necessary background, key claims and commitments that underpin the key concepts utilised in this thesis.

2.6 Cognitive linguistics: some key tenets

The field of cognitive linguistics originated in the late seventies and early eighties with the work of George Lakoff (e.g. 1987, 1990), Ron Langacker (1990, 1991) and Len Talmy (e.g. 1988, 2000), amongst others, who introduced an approach to studying language that views it as an instrumental tool that organises, processes and conveys information. Cognitive linguists align themselves closely with functional theories of language in that both approaches embrace, in principle, the relevance of language use to understanding linguistic structure. This key tenet sets cognitive linguistics, and indeed functional theories of language (e.g. Halliday's (1994) Systemic Functional Grammar), apart from the 'competence' perspective on language that is espoused by a Chomskyan Generative Grammar which proposes that the knowledge about language is fully independent of its performance. As Nuyts (2007:554) states, linguistic knowledge from a functional-cognitive perspective is 'knowledge for use'.

Cognitive linguistics is often classified as an approach as it 'is not a monolithic theory of language' (Tyler 2012:3), but is a collection of related theories about

language, language acquisition and language learning which are bound together by a set of key claims and commitments. These are outlined as follows:

First, cognitive linguists claim there is no autonomous, language acquisition device (LAD) that is responsible for language acquisition and processing. The traditional view treats language as a separate system that operates independently from other cognitive and social faculties and the rules and properties that govern language are, according to this view, different to the rules which govern other cognitive faculties. As Tyler points out, traditional approaches to language assume its rules are 'largely arbitrary, idiosyncratic and mysterious' (2012:4). Consequently, language learning has traditionally emphasised the need to memorise and master the rules and their exceptions. By conceptualising language as a rule governed system in this way, separated from other cognitive faculties, the content and language of a lesson traditionally are held to be two separate entities. Secondly, cognitive linguists are committed to the principle of generalisation which is a commitment 'to characterising the general principles governing all aspects of human language' (Lakoff 1990: 40). With this, cognitive linguists endeavour to locate a single set of cognitive processes which they claim operate across all domains of language.

The third point cognitive linguists claim is that knowledge is part of and interacts closely with other cognitive faculties. Radden and Dirven (2007: xi) neatly demonstrate this claim by pointing out that when we focus on a bird flying in the sky above us, we would normally describe the situation as 'a bird in the sky' and not 'the sky around the bird'. They use this example to illustrate that language and other cognitive faculties, especially memory, perception and attention are closely interrelated. This interdisciplinary orientation of cognitive linguistics is upheld with the cognitive commitment of cognitive linguistics which aims to provide an account of human language that accords with what is known about the mind and the brain, from other disciplines such as cognitive science and artificial intelligence, as well as from linguistics (Lakoff 1990). This makes it especially suitable for investigating the learning process as it embraces all cognitive faculties.

Cognitive linguistics is understood to be a usage-based approach to language for two reasons. First, that it is a product of our interaction with the social and physical world i.e. it has embodied meaning, and that our knowledge about language is both derived from and informed by the language we use (Evans and Green 2006:111). Second, it provides the speaker or writer a number of 'structural options' to describe their view or construal of a scene or situation (Radden and Dirven (2007: xii). I could describe the same scene, for example during a journey, as 'we haven't far to go' or 'we've only half an hour left'. However, language provides only a limited means of expression. To infer meaning from an utterance, the listener or reader needs to draw from their knowledge of the world to understand it. The language triggers a range of cognitive processes which enable the language user to fill in the gaps with the missing information (Littlemore 2009).

Most significantly perhaps, cognitive linguists view language as inherently meaningful. This central tenet that meaning permeates all levels of language gives way to the notion that all aspects of language are symbolic units which consist of form-meaning pairings that are motivated and explainable (Tyler 2012:4). However, certain linguistic structures such as grammatical patterns are acknowledged to be more abstract than other aspects of language, such as concrete nouns which describe an object that can be perceived.

In the pursuit of meaning in language descriptions, research in cognitive linguistics has fallen broadly into three categories; the experimental, the prominence and the attentional view of linguistic structures (Ungerer and Schmid 2006). The experimental view accounts for our experience of the world and acknowledges that our language choice reflects the way we perceive the world around us. Experiential aspects of meaning can be uncovered by analysing how ideas are expressed, especially through the use of figurative language including metaphors. Ungerer and Schmid (2006) point out that understanding figurative language becomes more important when the ideas are abstract. Johnson and Lakoff's work on image schemas, which strongly feature in the

analytical framework employed in this thesis belongs to this category of analysis (Lakoff and Johnson 1999).

The second category is the 'prominence' view of linguistic structures. This view is concerned with how the linguistic structures of an utterance are selected and arranged to express information. The most interesting and most prominent aspects of a situation are frequently foregrounded at the front of the clause as in: ***the car** hit the tree* (Ungerer and Schmid 2006). The concepts of profiling and figure/ground underpin this view and form the basis of orientational image schemas (Lakoff 1987), motion event frames (Talmy 2000) and Langacker's Cognitive Grammar system (1990 and 1991). Finally, the assumption that the language used reflects what our attention is drawn to in the real world underlies the 'attentional view' of language structures (Ungerer and Schmid 2006). This approach explores the reasons why some stages or aspects of an event or situation are expressed in language whilst others are not.

2.6.1 Mental representations

As previously established, the purpose of cognitive linguistics is to understand how humans are capable of conceptually organising their experiences and use language to represent and develop those experiences. For this reason, a cognitive perspective on language is particularly suitable for understanding how pupils might conceptualise a learning event. Most cognitive linguists generally adopt a representational view of meaning, in that for language to mean something it is understood to represent a concept in the mind (Werth 1999: 37). This is certainly not to deny that there is a real world beyond our conceptualisation of it, but that humans can only have access to this world through a subjective construal of an event, situation or phenomenon. Simply put, a thing in the world and the word are mediated by a concept, or mental representation (Werth, 1999: 37) This notion is central to a principled understanding of how humans are able to conceptualise through language.

The idea of a mental representation existed at least since the ancient Greeks, so long before the field of cognitive linguistics was established. Despite its long

history cognitive scientists continue to debate about the structure and content of mental representations. With the rise of behaviourism in the twentieth century, with its focus on the power of the environment on the individual, consideration of the introspective mind fell out of favour and with it any serious exploration of mental representations (Gardner 1985). With a growing dissatisfaction with the behaviourist paradigm and a burgeoning interest in cognitive science and Artificial Intelligence, however, a new dominant paradigm came into the fore, which likened the mind to a computing machine. Mental representations in this paradigm are viewed essentially as symbolic manipulations, in which the logical structure and not the semantics of these operations were of central interest (Gärdenfors 1996). Research influenced by this paradigm has aimed to find the underlying universal mechanisms which govern these operations and has focussed its attention on the syntactical patterns of language.

Despite the fact that this 'mind-as-a-computer' paradigm continues to play a major influential role in both the cognitive sciences and in the field of linguistics, it is no longer the only view. A shift in perspective from viewing language as simply a word-world reference system as Objectivist Semantics claim to one whose purpose is to communicate and share experiences 'necessitates investigating the cognitive, physical and social embodiment that shapes and constrains meaningful expression' (Rohrer 2007:26).

This claim, referred to in the literature as 'the embodiment hypothesis', which states that human physical, cognitive and social embodiment ground both our conceptual and linguistic systems has given way to an understanding of the mental representation as being visual, tactile, auditory as well as symbolic (Rohrer 2007, Werth 1999). This perspective acknowledges that our mental representations have a bodily basis and that there is not a sharp split between the mind and brain. Despite this advance in understanding the exact form of our mental representations remains to be of central interest to cognitive scientists and linguists. However, as Werth points out, what does appear to be the case is that our mental representations are closely linked to imagery,

scenarios of the imagination and to knowledge frames stored in our memories, which concurs with the socio-cognitive model of conceptual development outlined in section 2.4.

2.6.2 Language interaction and knowledge frames

Of particular relevance to this thesis is this close link between language and other mental faculties such as our memories, imagination and knowledge frames. As stated previously, much of the theory that underpins cognitive linguistics, including Text World Theory, has been derived from advances made in the field of cognitive science and Artificial Intelligence (AI). Borrowed from the field of cognitive science, for example, is the notion of a schema, which is essentially all the knowledge a person holds of a situation or an event (Emmott and Alexander 2014; van Dijk and Kintsch 1983). This notion was developed further in both the fields of cognitive linguistics and artificial intelligence. Scientists noticed that in order for a computer to be able to understand language it would need to be able to draw from a large knowledge base. The term 'knowledge frame', or simply 'frame', was used to denote this construct (Minsky 1975; Abelson and Shank 1977). Within this definition is the idea of a 'script', which represents how knowledge about a particular event, such as going to a restaurant, flying in a plane or carrying out a demonstration in a classroom is organised as a set of sequences. The notion of a frame was transferred to the field of cognitive linguistics. However, as pointed out by Werth (1999: 107), originally the idea was conceived to be a set of computational procedures until the idea was expanded and refined by Fillmore in his concept of Frame Semantics (1982, 1985) and by Lakoff with his concept of Idealised Cognitive Models (ICMs) (1987). As these two concepts are central to Werth's concept of frame in his Text World Theory framework they will be discussed in some detail in the following section.

2.6.3 Frame semantics

Fillmore's notion of frame semantics originated from his work on syntax and the semantics of verbs during the late 60s and 70s. In attempting to find a semantic description for verbs that were related closely in meaning (e.g. verbs of judging:

blame, accuse and criticize), Fillmore instead of developing a description in terms of truth conditionals, that was customary at the time, developed a framework that acknowledged the cognitive framework of the mind. As he once put: 'it seemed to me more profitable to believe that there are larger cognitive structures capable of providing a new layer of semantic rule notions' (1982:115). He articulated this further by describing this cognitive structure as being a form schematization, or as he called it 'scene' that draws on the speaker's/ listener's background knowledge that would be relevant in a particular situation. In his scene-frame paradigm, a scene includes 'not only visual scenes but also familiar interpersonal transactions, standard scenarios defined by culture, institutional structures, enactive experiences, body image' (Fillmore 1975: 124). In contrast, the term frame in this paradigm was used to refer to any system of linguistic choice, including particular groups of words, grammatical structures 'that can get associated with prototypical instances of scenes' (ibid.). As Cienki (2007) points out frames are not decontextualised independent linguistic structures but should be viewed as part of a paradigm 'integrarally linked to the idea of scenes' (2007:172). To a large extent, Fillmore's semantic frames fits under the attentional view in cognitive linguistics as linguistic choice involves taking a perspective on a situation, which is 'mainly provided by the cognitive ability of directing one's attention' (Ungerer and Schmid 2006: 204).

2.6.4 Idealized cognitive models

One further model which underpins much of Text World Theory (see section 2.7) and is useful when exploring any relationship between language and abstract thought are Idealized Cognitive Models, which are 'knowledge structures by which we negotiate our way through life, evaluating new experiences by means of comparison with idealised models of reality (Gavins 2007a:5). Lakoff's notion of Idealized Cognitive Models was based on his earlier work on gestalts. Both notions essentially uphold an experiential view of language and cognition in which 'thought, perception, the emotions, cognitive processing, motor activity, and language are all organized in terms of the same kinds of structures' (Lakoff 1977: 246). Lakoff developed his original idea of gestalts into his Idealized Cognitive Models. ICMs are knowledge structures, which instead of being a direct

reflection of an objective reality are influenced by cognitive structuring principles and as Cienki points out 'are idealised, in that they involve an abstraction, through perceptual and conceptual processes, from the complexities of the physical world' (2007: 176).

What is of particular relevance here, is that Fillmore's and Lakoff's frameworks acknowledge that our knowledge structures are influenced by certain cognitive structuring principles. Common to both frameworks is the link to Rosch's work on categorisation and prototypes (e.g. Rosch 1973), which argues that within linguistic categories there are examples that seem to fit better, are more prototypical, than other examples. Fillmore notes this connection in his work on word understanding. He makes the observation that understanding what a word means, involves evoking a prototypical frame of what the word or part of the word is like (1982). Lakoff makes reference to prototypes in his ICM concept when he states that a word is defined against an idealised view or model of the world according to which certain expectations hold.

2.6.5 Image schemas

Many of our basic Idealized Cognitive Models are structured through image schemas, which have been referred to in part one as p-prims in the knowledge-as-pieces view of learning. Briefly put, an image schema is 'a condensed redescription of perceptual experience for the purpose of mapping spatial structure onto conceptual structure' (Oakley 2007:215). Research on image-schematic constructs has traditionally been conducted in cognitive linguistics, but they have also been given some attention in semiotics, philosophy (Johnson 2005), developmental psychology (Mandler 2005), and more recently in artificial intelligence (Hedblom, Kutz and Neuhaus, 2016). Image schema theory underpins much of Lakoff and Johnson's (1980) Conceptual Metaphor Theory in which they aimed to explain the embodied origins of meaning and thought. As image schemas feature strongly in this thesis, a short overview of their properties will follow.

As Johnson (2005) notes, image schemas are crucial for our ability to create abstract concepts and reason with them. However, despite the widespread acceptance of the notion of image schemas amongst cognitive linguists and scientists, the exact properties of these structures have not yet been determined (Oakley 2000; Hampe 2005). Although they are frequently portrayed as being essentially distilled experiences stored in our long-term memories, an image schema is also, as Johnson reminds us, 'a dynamic recurring pattern of organism-environment interactions' (2005:19). Thus, for the purposes of investigating the role image schemas play in on-line learning situations, it is helpful to recognise Kimmel's proposed double ontology: image schemas 1) have features which are stable and have accumulated through repeated bodily interactions with the environment, and 2) they are fluid structures that are susceptible to the constraints and affordances imposed by the sociocultural context (Kimmel 2005:297). Kimmel's claim that image schemas are 'acquired or refined in more specific interactions with other bodies, social space, social interaction or rituals, and cultural specific artefacts' (2005:297), echoes the knowledge-in-pieces view of learning in that conceptual development involves a realignment of the learners' image schemas or p-prims. Drawing from Kimmel's work which acknowledges the context-adaptive aspects of image schemas, in addition to other image schema research (e.g. Gibbs 2005) that highlights the emergent nature of image schemas in online embodied interactions, this thesis aims to reinforce the knowledge-in-pieces important contribution to our overall understanding of the development of abstract thought in learning.

The most important basic image schemas, according to Johnson are 'CONTAINER; BALANCE; COMPULSION; BLOCKAGE; COUNTERFORCE; RESTRAINT REMOVAL; ENABLEMENT; ATTRACTION; MASS-COUNT; PATH; LINK; CENTER-PERIPHERY; CYCLE; NEAR-FAR; SCALE; PART-WHOLE; MERGING; SPLITTING; FULL-EMPTY; MATCHING; SUPERIMPOSITION; ITERATION; CONTACT; PROCESS; SURFACE; OBJECT; COLLECTION' (1987:126) (the usual convention to render image schemas is small capitals). Johnson in his later writing proposes that thought is frequently composed of complex image schemas that are made up of these more basic image schemas through 'a process of combination, superimposition and further elaboration or specification' (2005: 21), thus again

supporting Kimmel's claim that they are continuously being acquired and refined during our daily interactions. He also warns us that an over focus on the structural properties of image schemas might lead us to ignore the quality of the human experience of meaning (2005:28). He illustrates this point with the SOURCE-PATH-GOAL image schema: the experience of moving along a path may be one that involves a fast acceleration or a slow gradual starting up. This quality is expressed in the choice of language used to express our experience of motion, in particular in English, in our choice of verb (e.g. 'I strolled across the garden or I ran up the hill') and use of adverbs (e.g. quickly, effortlessly).

The language used to express image schemas reveals one further important schematic structure, namely the phenomenon of prominence. When looking at a painting, listening to music or following a demonstration by a teacher in a lesson, certain aspects stand out, or are more prominent than others. Cognitive linguists are interested in how linguistic expressions such as propositions can be explained in terms of figure and ground by drawing from the work of gestalt psychologists who studied the figure/ground distinction of sensory input. To illustrate this, let us consider: He walked into the kitchen. The locative preposition 'into' can be understood as a figure/ground relationship. As the man is the moving object it is seen to be more prominent than the kitchen, which is stationary. The man is therefore the figure or trajector and the kitchen is the ground or the landmark. The man's movement is a dynamic process happening over a period of time.

The motion description 'he walked into the kitchen' expresses both the SOURCE-PATH-GOAL image schema and the CONTAINER schema as expressed by the locative preposition 'into', which indicates that the kitchen is a container with a clear boundary between its inside and surrounding area.

The above shows how image schemas apply to prepositions. The analysis in this current thesis, (in particular, analysis Chapter 4) establishes how they also underlie many of the clausal structures used to structure the target abstract concepts of the lesson. For example, many of the expressions used by the teacher give *heat* (or *heat transfer*) the main attentional focus. Frequently, it is profiled as the trajector with the predicate as the landmark: 'heat travels

along the rod'. The analysis demonstrates how the propositional content of this language can be construed by the pupils in a manner of different ways depending on how the teacher presents it.

This section has reviewed some key tenets of cognitive linguistics that are relevant to this thesis to orientate the reader with the necessary metalanguage and concepts to follow the analysis. As investigating naturalistic settings requires the researcher to analyse situated language use in a social setting, a framework that allows the researcher to explore how *discourse* creates meaning is needed. Cognitive linguists have tended to concentrate their efforts on single sentences rather than longer stretches of discourse. The following section will review the Text World Theory model which sits within and draws upon the larger field of cognitive linguistics. It will first provide an account of some of the key principles as outlined by Werth in his monograph, to orientate the reader who may be unfamiliar with the theory, before critically reviewing the more recent developments and offering my own contribution to the theory.

2.7 Text World Theory: a cognitive discourse grammar

Text World Theory is a cognitive discourse grammar that provides a model of how discourse is both experienced and understood. It is the brainchild of Paul Werth whose work, which was developed during the eighties and nineties (see 1981, 1994, 1995a, 1995b, 1997), resulted in his monograph '*Text Worlds: Representing Conceptual Space in Discourse*'. This work was posthumously published in 1999. Although Werth's inspiration for his theory originally came from his interest in text linguistics, his theory is essentially a cognitive linguistics theory as it draws primarily from this field to explain how the mind understands and experiences texts by creating conceptual spaces. Since the publication of Werth's monograph, there have been a number of revisions and extensions made to his original framework (see for example Gavins 2007a). These have been related to the metalanguage and how it reflects certain assumptions. Other developments have been motivated by an awareness of particular shortcomings of the original framework that have been noted by scholars when applying the framework to different genres and contexts. This section aims to present

Werth's original framework, highlight various aspects of Werth's framework that have been extended, and indicate possible innovations to the framework that this thesis proposes to make.

The two main key questions that Werth set out to answer in his monograph were: how do we make sense of complex utterances when we receive them as listeners, and how do we as speakers (writers) put together a complex utterance in order to express particular concepts? (Werth 1999: 7). Text World Theory can be seen to belong to the attentional view of language and cognition as it provides an explanation of why particular aspects of an event are expressed in language whilst others are not. The underlying assumption of the theory is that language reflects what is perceived to be relevant in the real world (Ungerer and Schmid 2006: 2-3). Having said this, the theory draws on some key constructs of cognitive linguistics (e.g. image schemas, foregrounding), which belong to the experimental and prominence views of learning. For this reason, it can be regarded as a very powerful framework for describing and explaining how discourse is both experienced and understood.

Central to this theory is the construct of a text-world, which is, in brief, a mental scenario or partial assembly that we create that contains just enough information required to understand the utterance it corresponds to (ibid.) These mental scenarios can be quite sketchy and brief or well developed and defined, depending on the nature of the discourse and the participant's engagement with it. Werth's notion of text-world fits Fauconnier and Turner's definition of a mental space, which they define and describe as 'small conceptual packets constructed as we think and talk, for purposes of local understanding and action' (1998:137). They are interconnected and can be 'modified as thought and discourse unfold' (Fauconnier and Turner (1996: 1). The deictic and referential elements in the discourse activate relevant parts of the memory, knowledge structures as well as frames which, as outlined in section 2.7.4, refer to an individual's 'representation of a specific context' (Werth 1999: 112). These structures are used to interpret the discourse and are consequently modified during the process.

What singles Text World Theory out from other theories in cognitive linguistics is that it embraces context. Although Werth acknowledges that the study of context is difficult, it cannot be ignored as it is an integral part of human experience (1999: 19). The theory acknowledges the physical and social settings with its construct of the discourse-world (see 2.7.1). Furthermore, it provides an explanation of how the discourse-world affects text comprehension. This makes it a particularly suitable framework for investigating and explaining the patterns that emerge in classroom discourse. One further aspect of the framework that needs noting is Werth's claim that it is capable of accounting for all cognitive processes that may arise from engaging with any discourse type (Werth 1999: 17; Gavins 2007a:7). In other words, it has been shown to account for the production and interpretation of written texts and more recently to face-to-face interactions, which is of particular relevance to this thesis.

Since the publication of his monograph (1999), scholars have tested Werth's original claims and augmented and extended the theory through its application to a wide variety of texts. Central to this endeavour is Gavins' work *Text World Theory: An Introduction* (2007a) which, by applying the framework to a variety of texts ranging from lonely hearts advertisements, car maintenance manuals to political speeches, has made the theory more accessible to a wider audience by explaining and clarifying its key principles and tenets. Text-world theorists tend to be concerned with its application to prose (for example, Gavins 2000, 2001, 2003, 2005a, 2005b, 2007a, 2010, 2012, 2013; Hildalgo Downing 2000; Whiteley 2010, 2011;) and poetry (for example, Gavins 2007b 2010, 2012, 2013, 2014; Gavins and Stockwell 2012, Giovanelli, 2013; Hidalgo Downing 2002; Lahey 2003, 2004, 2005, 2006, 2007) as well as drama (Cruickshank and Lahey 2010). It has also been applied to political discourse (Browse 2013; Gavins 2007 (109-123) film (Lugea 2013) and multimodal texts (Gibbons 2012).

Despite Werth's claim that the framework can be applied to any type of discourse, the majority of studies have applied the framework to written texts. Recently, however, there have been a number of noteworthy applications to face-to-face interviews (van der Bom 2015) and face-to-face reading groups

(Whiteley 2011; Peplow et. al. 2016; Canning 2017). In *The Discourse of Reading Groups: Integrating Cognitive and Socio-Cultural Perspectives*, the authors (Peplow et al. 2016) use the framework to explore the emotional responses of the participants of a reading group as they discuss a novel by integrating a text-world framework with socio-cultural approaches (Mercer 2000, Mercer and Littleton 2007 and Littleton and Mercer 2013) to discourse. They provide a convincing account of how Littleton and Mercer's (2013) notion of interthinking, the process of thinking together, can be developed further and made more applicable to joint interpretative acts, such as those taking place during reading groups, by integrating a cognitive model. One further application of the text-world framework to face-to-face interactions has been on its application to interviews with Chinese migrants to the UK in order to explore their identities. Many of van der Bom's (2015) novel insights and innovative applications of the theory have been applied to my own analysis (see 5.12). In particular, her insights and solutions to the methodological challenges of analysing the written transcripts of events after they took place.

Given the versatility and explanatory power of the framework as a way of accounting for the conceptual scenarios taking place during discourse processing, it is perhaps not surprising that scholars have started to apply this framework to the classroom. Most notably, is the work by Giovanelli (2010, 2016, 2017), who has in his work demonstrated how it can provide a 'sustainable teaching methodology' (2010:215) to the teaching of literature and poetry in the classroom. He justifies his claim by referring to the key principles of stylistics, namely that it is *rigorous, retrievable* and *replicable* (Simpson 2004:2). Stylisticians who uphold these principles, provide evidence for all their working by defining their terms and providing evidence from the text that they are working with. The metalanguage of Text World Theory framework and its consequent 'precision of reference' (Widdowson 1992: xii), implies that it is for both the teacher and learner an empowering pedagogical tool, which can demystify the reading process (Giovanelli 2010). Further applications of the framework to pedagogical contexts include work on the use of pupils' own visual representations to respond to texts in the classroom (Giovanelli 2017), and the

use of the framework as a means to build teachers' and learners' awareness of grammar (Cushing 2018) and learners' identities (Ahmed 2018). Outside the field of English studies, there has, as far as I am aware, not been any attempt made, other than this thesis, to apply Text World Theory to the classroom.

The above has provided a brief account of how Text World Theory sets out to be a cognitive discourse grammar which draws on the key principles of cognitive linguistics, outlined in section 2.6. Werth's model aims to describe and define the tracking processes that readers and listeners undertake when engaged with discourse. Werth proposes that his model aims to be fully contextual in that it is both the text and its context that is being engaged with during the language event (1999:46). This makes it a suitable framework for undertaking an investigation on classroom discourse, as it is flexible and acknowledges the physical and social environment of the classroom, and how this affects the comprehension and production of classroom texts. The following will outline the key components of the framework and exemplify these parts, with examples from my own classroom data, in addition to highlighting a few areas that Werth's original framework and subsequent studies since his death have not yet fully developed, in order to pave the way for how this thesis might contribute to this line of research.

The basic architecture of Werth's original Text World Theory framework (1999) can be represented using this simple diagram (see Figure 2.1). These component

Discourse-World	**Text-World**	**Sub-World**
Writer/Speaker and Reader/Listener Background knowledge	Places, Events, Objects, People, Activity/Description	Shifts in time, space, viewpoint or attitude

Figure 2.1. Adapted version of the Text World Theory architecture (Cushing and Butler 2015)

parts of the theory's architecture will be now explored more fully in turn.

2.7.1 Discourse-worlds

The discourse-world is 'the situational context surrounding the speech event itself' (Werth 1999:83). The discourse-world is made up of the participants, the text, all the elements that the participants can perceive, as well as all the knowledge and beliefs about the world that the participants bring to a situation. However, as Werth maintains, it not only consists of sense input but also 'what the participants can work out from their perceptions' (ibid.). This implies that the participants draw from their knowledge frames in order to conceive of (perceive, remember or imagine) a coherent 'state-of-affairs' (1999: 84), when either producing or interpreting a given discourse. In face-to-face situations such as a lesson or interview, the participants share the same temporal and spatial parameters in other words the same discourse-world. According to Text World Theory convention, a split discourse-world exists when the producer and receiver are separated (Gavins 2007a: 26), as was the case when I, the researcher, was reading the transcripts of the lessons and interviews that took place in a different place and time to the analysis. The following diagram illustrates a generic discourse-world of the classroom that I observed:

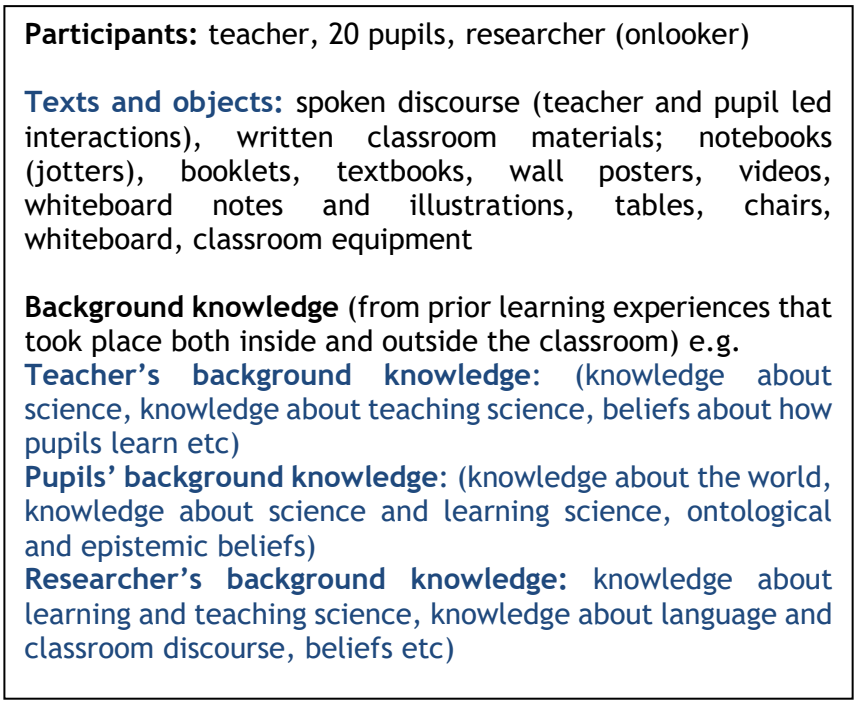


Figure 2.2. Discourse-World of Mr Dalel's classroom

2.7.1.1 Participants

The participants of the discourse-world steer the flow of the discourse. In other words, 'they are responsible for the shape and direction that a specific discourse takes'(1999:17). In the classroom context of this research they are the pupils and the teacher whereas in the interview situation the participants were the pupils, the teacher and myself the researcher. The participants occupy 'privileged positions', in that they are referred to directly in the discourse (1999: 82). The discourse-world may also consist of non-participants, who play no direct role in the creation and maintenance of the discourse. Werth refers to them as onlookers or overhearers. During the lessons, as I did not directly steer the flow of the discourse I could be regarded as an onlooker.

2.7.1.2 Knowledge

In order for participants to understand each other, or for a text to be understood, Werth claims there needs to be a certain amount of shared knowledge. This knowledge is either mutual (private) knowledge or general (public) knowledge. General knowledge is the potential knowledge base a community, bound together by a common purpose, would have access to. Science teachers may share a general (public) knowledge base as they belong to the same community. Werth divides this knowledge into two types; cultural knowledge and linguistic knowledge. Although the two types of knowledges are closely interlinked, cultural knowledge refers to 'the non-linguistic information available to individuals or groups living in a particular society' (Werth 1999:97). Werth uses the cognitive-linguistic concept of a frame (see section 2.6.3) to provide a plausible account of its structure. Linguistic knowledge is the knowledge users of the language require to know how to use language in various situations and contexts. This aspect of knowledge will be explored in more detail in Chapter 6.

In contrast, mutual (private) knowledge is a by-product of the on-going discourse event. This can take the form of perceptual knowledge which is derived from

the participants' perceptions of the immediate surroundings. It is stored in the participants' short-term memory. Experiential knowledge is related to perceptual knowledge in that it forms after the perceptual knowledge of the participants becomes more permanent and established.

Since Werth's death, there have been a number of contributions made to the discourse-world level of the framework. As established in section 2.7.1 the discourse-world consists of all the objects available to the participants in their surroundings, plus their own inferences made possible by applying their memories, knowledge, beliefs, dreams, hopes, intentions and imagination (1995:52). It has been observed, however, that Werth does not offer a plausible explanation of *how* these mental faculties affect the discourse-world (Whiteley 2010: 20; van der Bom 2015: 18).

To address this shortcoming, many scholars have concentrated their efforts on the emotional response of readers and how their beliefs, feelings and attitudes affect their engagement of texts (e.g. Lahey 2005; Gavins and Stockwell 2012; Whiteley 2010; Marszalek 2016). Their work in this area has extended Werth's original framework by explaining emotion in relation to the Text World Theory framework. Although this area of work could potentially have many interesting applications to the classroom, especially with regards to exploring motivation, this has not been a direct area of inquiry due to the constraints of this study.

One reason for Werth's lack of an explanation of how the various mental faculties affect the discourse-world, is that his distinction between memories, knowledge, beliefs, dreams, hopes, intentions and imagination is somewhat ambiguous. This is perhaps not surprising considering the time Werth's work was published and the extensive work that has been carried out in the area of cognitive science since (see Shapiro 2014), indicating that much work still needed to be done at the time Werth's work was written to clarify these distinctions. For example, as observed by van der Bom, in Werth's discussion of knowledge he refers to episodic memory, and that his description of this type of memory is somewhat vague (2015: 19). Recent research in the area of psychological sciences has demonstrated that the distinction between

knowledge and episodic memory is in fact not clear cut and these two categories are indeed inextricably interwoven. Episodic memories can be defined as experience-near summaries of previous experiences or events in a person's life (Conway 2009). Although some neuroscientists view them more as processes (e.g. (Tulving, 1983, 1985) and as part of a system, other scientists tend to view them as mental representations and are interested in their structural properties and their functions (Conway 2009). Episodic memories have some distinct properties that are worthy of note here. First, they contain non-literal, 'summary records of sensory-perceptual-conceptual-affective processing' (Conway 2009: 2306) and they are often represented in the form of visual images (ibid.). They always have a perspective; either the person's memory is close to the original (field) or it is re-enacted as the person observing the event (observer) (ibid.).

Of particular relevance to this thesis is the role of episodic memory in the acquisition of new knowledge. Learners who have difficulties in retaining episodic memories have been shown to have problems in learning new knowledge, as learners tend to retain knowledge about new topics in their episodic memories (Herbert and Burt 2004). Research has shown that episodic memories are an essential part of gaining more long term conceptual knowledge, which is formed by abstracting out elements from episodic memories into a more generic conceptual space (Conway et al. 1997). As learners become more familiar with a topic they become less reliant on, although not entirely detached from, their episodic memories and draw more heavily from knowledge frames that are more generalised and conceptual in nature (Herbert and Burt 2004: 78). In text-world terms, each time a past situation is expressed in propositions and appears with a participant's knowledge of the world, including private past experiences (episodic memories), a text-world is formed (Werth 1999:112). Repeated instances of similar text-world configurations form a situation type, or frame. As noted in sections 2.7.2-3, Werth uses Fillmore's definition of a frame, which he defined as a configuration of concepts related in such a way that to understand any one of these concepts an understanding of the entire structure is required (Fillmore 1982:111). This notion of a frame is helpful here, as it

provides a plausible account for how situated events and episodic memories are related to more generalised abstract structures. Although the abstraction mechanisms are still unclear, in Chapter 5, I explore these underlying mechanisms by referring to recent developments in cognitive science (e.g. Barsalou 2009), to explain certain patterns that emerge during a problem-solving activity, thus developing Werth's original account of knowledge, memory and frames.

One further aspect of Werth's original framework that requires developing is his position on the role of memory and linguistic knowledge. Although he acknowledges that the two are interlinked, his explanation of how is limited. Developments in the field of narratology, text comprehension and cognitive science have explored this relationship by accounting for how a reader's memory is involved in the comprehension process (van Dijk and Kintsch 1983; Macnamara and Magliano 2009; Bortolussi and Dixon 2013). According to this view of text comprehension, a reconstruction of a text after it has been read is drawn from three levels of representation. These are the surface structure, the text base and the situation model. The surface structure is the equivalent of the verbatim memory of the discourse. It has been demonstrated that the surface structure is maintained while the reader is processing the structure, but is forgotten relatively quickly once the reader has understood the sentence. The mechanisms involved in processing the structural knowledge, that lead to an understanding, must rely on what Werth describes as linguistic knowledge, that is knowledge underlying language use (Werth 1999:98).

The second level of representation, the text base level represents the semantic content or the 'conceptual meaning' of the text (Steen 2017:282). Although the memory of readers for this level of representation is longer than the surface structure, it is not always reliable. Readers have been shown to claim sentences are in a text, when they are not because they plausibly could have been. The third level of representation is the situation model, which necessarily relies on the reader's own world knowledge. This level of representation depicts the state of affairs projected by the text. Drawing on their own knowledge frames, readers

make inferences about the objects and entities in the text even if these details are not in the text itself and readers often distort elements in the text to match their own cultural expectations and schemas. Interestingly, it has been found that the situation model is maintained in the memory for the longest period of time. These three levels of representation are illustrated in the following diagram for the sentence 'the woman sat by the window'.

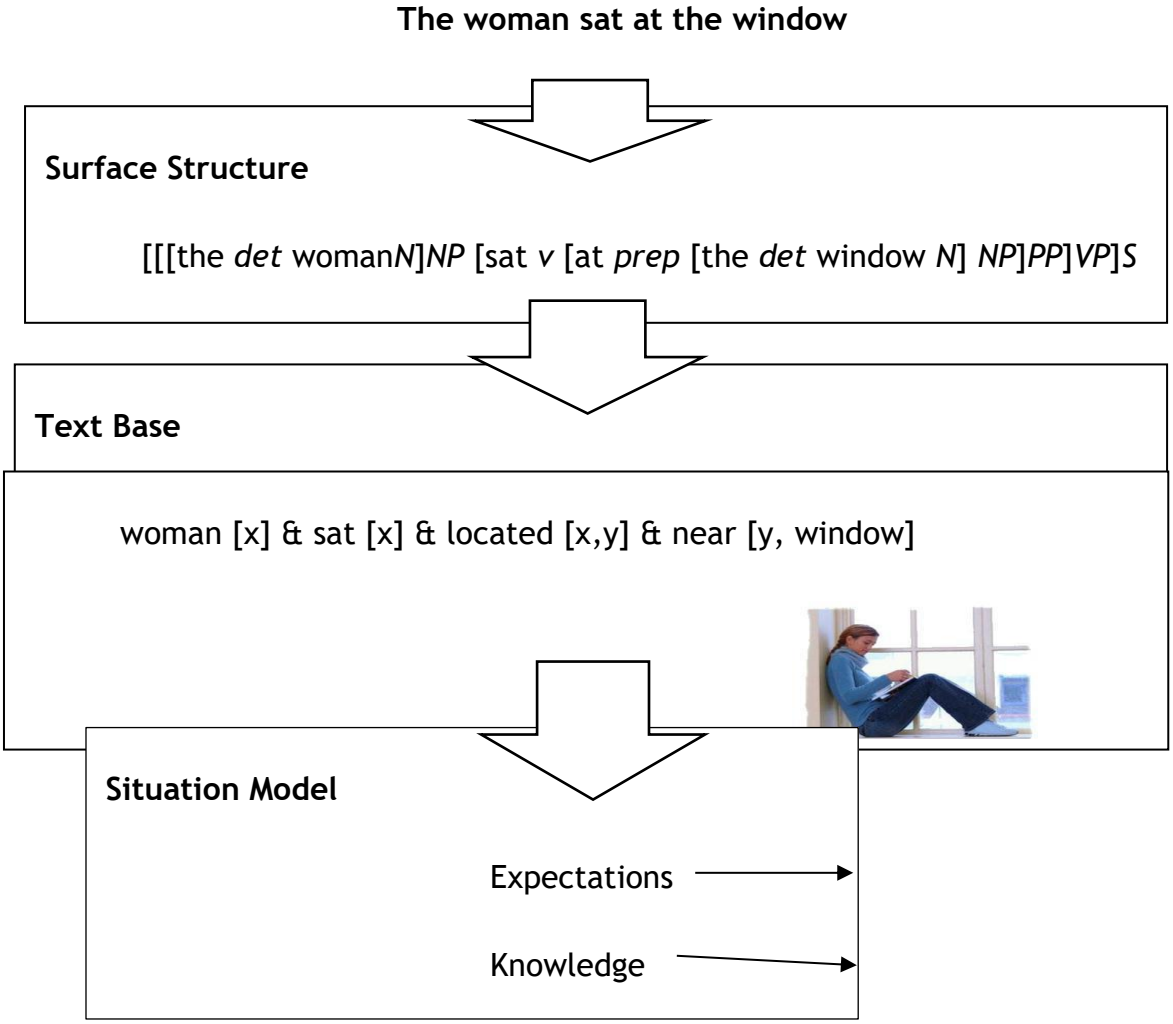


Figure 2.3. Three levels of representation of text (adapted from Bortolussi and Dixon 2013:27)

Interestingly, Werth (1999: 74) refers to the situation model in his monograph and draws parallels between the situation model and the text-world: 'their [van Dijk and Kintsch] equivalent of a text world is a situation model (Werth 1999:67)). However, although he acknowledges van Dijk and Kintsch's approach

in that it explains how the discourse is processed by the human memory processing system, he categorises the approach as 'psychologically orientated' (Werth 1999:75). Werth goes on to provide a linguistic account of the development of conceptual spaces, which becomes his Text World Theory framework. However, Werth does not explicitly integrate van Dijk and Kintsch's situation model into this framework.

This model of memory, linguistic knowledge and text comprehension (see Figure 2.3) provides a nuanced account of the functional role of memory in the reading process, and it appears not to conflict with Werth's original framework. The assumption made in this thesis is that although this comprehension model was originally applied to reading, the three levels may be applied to text processing in face-to-face interactions. Therefore, this model is applied to the language produced during a group discussion/writing task in Chapter 6, in order to explore the relationship between the pupils' linguistic knowledge, memory and understanding of the concept.

2.7.2 Text-worlds

Central to Werth's framework are text-worlds. He defines text-worlds as 'conceptual scenarios containing just enough information to make sense of the particular utterance they correspond to' (1999:180). He continues by claiming they are the conceptual representations in the text producer's or text recipient's minds. In short, text-worlds are 'situations depicted by the discourse' (Werth 1995a: 53), that have been negotiated by the participants during the on-going discourse event. Text-worlds, like frames and scripts (see section 2.6.3), are essentially text-driven (Gavins 2007a:61); Werth 1999: 48). This means that different linguistic expressions found in the text evoke different text-worlds.

Furthermore, a text-world is a deictic space. The discourse supplies the deictic and referential elements which specify details about the objects and characters, the time and the place depicted by the discourse. Werth refers to these terms

as world-builders. In Werth's (1995a) list of world-builders the following elements were included:

Time (t): time-zone of verbs; adverbs of time; temporal adverbial clauses, e.g. it was a dark and stormy night, in 1979, at two minutes past midnight on April 7th, 10 seconds after the Big Bang, as soon as John realised

Place (l): locative adverbs, NP with locative meaning, locative adverbial clauses, e.g. on the table, at Lewes in the country of Sussex, there was an old barn…., where the sea meets the sky.

Entities (c - characters and o - objects): noun phrases, concrete or abstract, of all structures and in any position e.g. my friend Susan, these are the voyages of the Starship Enterprise, a policeman who had lost his way, the square root of -1, your attitude to market forces.

(Werth 1995a:76)

Gavins developed Werth's original construct of world-builders by explaining how these deictic and referential terms are used to construct and communicate our conceptual embodied systems to others. Our understanding of where a piece of discourse is situated in time, space and how we relate to who and what features in that discourse is referenced to as the origo, our zero reference point of subjectivity (I, here, now) (Gavins 2007a: 36).

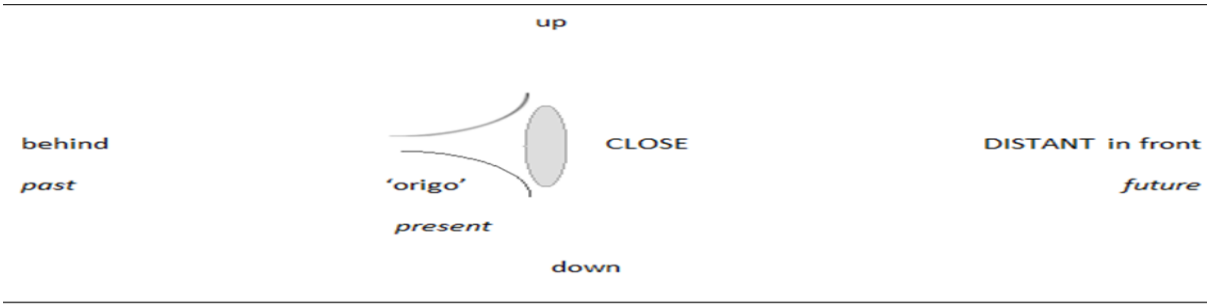


Figure 2.4. The perception of space and time (Gavins 2007a:37)

As claimed by Gavins (2007a: 36), world-building elements first establish the spatial boundaries of the text-world with the use of locatives (*on the front desk*),

spatial adverbs (*here, there, outside*), demonstratives (*these, those, that*) and verbs of motion (*come, go*). World-building elements are also used to establish the temporal parameters of the text-worlds by using locatives (*three lessons ago*), temporal adverbs (*yesterday, today, tomorrow*) and different uses of tense and aspect (*the light bulb was using all the energy* and *the light was switched off*). Besides deictic elements used to establish spatial and temporal boundaries, other elements in the discourse can also be used to construct a text-world. These include pronouns (I, you), definite article (the) and definite reference (the Bunsen Burner, Adam). The crucial role that world-building elements play in the knowledge construction process is illustrated by the following extract from lesson one (18.03.15), in which the teacher asks the students to come to the back of the classroom where he has a demonstration set up to show them the effects of heat transfer on a metal rod.

73 **T:** come to the back here gu:::ys (4.0) come to the back come to the back
74 everyone stop what you are doing. (4.0) right boys and girls (.) I've got one ro:d
75 rod here. what's a rod, a rod is just a straight bit of something. (.) this one's
76 made of mEtal, does anyone know what sort of metal it is?

77 **P:** copper,

78 **T:** copper. how do you know. what colour's copper.

79 **P:** it's browny red

80 **T:** it's browny red. (.) right that's copper. copper rod. (.) see that the

time: present

location: come to the back here, I've got a rod here, see that there

participants (enactors of text-world): guys, you, boys and girls, I, anyone

objects: one rod, a rod, a straight bit of something, this one's made of metal, what sort of metal, it, copper

Figure 2.5. World-building elements of lines 73-80 from lesson one

The world-building elements in this extract are made up of deictic and referential information. The deictic information defines both the temporal and spatial entities in relation to the participants' zero-reference point of subjectivity or origo in the discourse-world of the classroom. In the above example, these include: locatives (the back), spatial adverbs (here, there), demonstratives (this, that) and verbs of motion (come to). The referential information is used to specify who and what is present in the discourse-world and the relationship between them (e.g. guys, you, I, anyone, one rod, a rod etc.).

In the discourse-world of the classroom, the participants, the speaker or hearer, (the teacher and pupils) actively construct a conceptual space, or text-world, of the situation defined by the deictic parameters and fleshed out with the referential information on the entities. In this extract, as with many face-to-face interactions, there is a strong emphasis on what the participants mutually perceive (i.e. the metal rod) or have experienced (the colour of copper),or predict to happen. The building of text-world out of the concrete here-and-now discourse-world entities, with such world-building elements, will be shown in my analysis to be a crucial part of developing learners' abstract thinking.

When lines 73-80 are read, as by the reader of this thesis, the participants (the text producer and the text receiver) belong to 'split discourse-worlds'. The producers of the text are in a separate time zone and location to the recipient of the text, the reader. As the reader may not have directly experienced the situation, he or she will need to evoke a conceptual space, or text-world, of a new situation that can only be achieved by the imagination and by drawing from memories of similar situations.

A note here needs to be made regarding the term 'character' that Werth used to refer to a person in a text-world. Gavins (2007a) refers to characters as 'enactors', a term borrowed from Emmott (1997:182), who pointed out that a reader's understanding of a character changes over time depending on their interpretation of the character during various stages of the reading process. For this reason, the term enactor has been generally adopted by text-world theorists

to help make this distinction between the different representations of the character entity of the text-world. This thesis will also adopt the term enactor, for the reason that the 'people' entities of the text-worlds created are often projections of the participants from the discourse-worlds and cannot, therefore, be described as characters, a point made by van der Bom (2015) in her analysis of face-to-face interviews.

2.7.2.1 Function advancing propositions

Function advancing propositions are non-deictic terms which function to fulfil the speech act on which the text-world is founded (Werth 1999: 190). As Werth claims, 'they advance the discourse in order to fulfil whatever purpose it is meant to have' (Werth 1995a: 59). Werth uses the following example to illustrate this text-world feature:

a. While the news was on, John finished his dinner

b. While John was eating his dinner, the phone rang

(Werth 1999: 190)

The two 'while' clauses are deictics which establish the temporal parameter of the situation and introduce the world-builders 'the news' and 'John'. In contrast, the independent clauses 'John finished his dinner' and 'the phone rang' modify the conceptual space by advancing the plot with the verbs 'finished' and 'rang'. Function-advancing propositions do not only apply to narratives but to all speech acts, including those found in classrooms as shown in the following table:

Table 2.1. Function advancing propositions (Werth 1999:191)

Text Type	Predicate type	Function	Speech Act
Narrative	Action, event	Plot advancing	Report, recount
Descriptive scene	State	Scene-advancing	Describe scene
person	State property	Person advancing	Describe character
routine	Habitual	Routine advancing	Describe routine
Discursive	Relational	Argument advancing	Postulate, conclude
Instructive	Imperative	Goal advancing	Request, command

Werth divides function-advancing propositions into two groups. The first group represents changes in states and the second in steady states. The changes of states predications, either concrete or abstract, represent an action or process that is a 'path statement' (Langacker 1985, 1987a and 1987b) that maps movement from a source to a goal. The text-world analysis of the heat transfer demonstration in Chapter 4, draws on Langacker's notion of a 'path statement' to analyse the profiling effects of the propositions. Text-world theorists (e.g. Gavins 2007a) have adopted the Systemic Functional Linguistics terminology (Halliday and Matthiessen 2004) to denote predicate types and refer to changes of states predications using the term material processes. These processes are typically used in a science classroom to describe events e.g. heat is travelling along the rod. This adoption of Halliday's terminology reflects the fact that Cognitive Grammar and Halliday's Systemic Functional Linguistics are considered to be usage-based grammar systems that share many key principles. Most importantly, they acknowledge context and propose that knowledge about language cannot be independent of language use.

The second group consists of steady state predications. Werth further divides this group into state, circumstance and metonymy modifications. Current Text World Theory adopts the Systemic Functional Linguistic terms intensive, possessive and circumstantial relational processes to refer to these concepts as the terms correspond in meaning. Steady state predications (relational processes in Hallidayan terms) specify how two or more entities in a text-world relate to each other. Intensive relationships are expressed as x is y, possessive relationships as x has y, and circumstantial as x is in/on/with y (Gavins 2007a: 43). Intensive, possessive and circumstantial processes can be further subdivided into attributive or identifying relational processes. Here, attributive relational processes describe one entity as an attribute of another (e.g. the rod is brown). When one text-world entity identifies the other it is an identifying relational process (e.g. this is heat transfer).

During the demonstration, for example, the teacher uses both steady state (e.g. it's browny red line 79) and changes of state (e.g. we are doing an experiment)

function advancing propositions to propel the discourse forward and fulfil its purpose. In Text World Theory, function advancing propositions are shown diagrammatically (see Figure 2.6) with horizontal arrows representing steady states and vertical arrows changes of states.

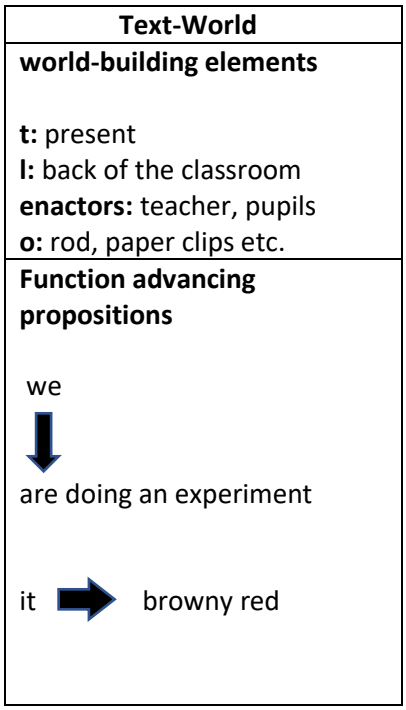


Figure 2.6. Example of world-building elements and function advancing propositions

Although the function advancing proposition 'we are doing an experiment' does not belong to a deictic category (Lyons 1977:705 see Werth 1999:173), the continuous aspect expresses how the teacher wishes to represent the situation in that the experiment will last a duration of time. Werth's account of propositional language acknowledges how this language is central to the building of conceptual knowledge of the events and states surrounding the participants. It fits well with the theoretical model of conceptual change that this thesis adopts, which also acknowledges the importance of propositions in that they act as 'placeholders', that become nested within a network (see section 2.5). Werth's account, however, provides a plausible account of how these propositions become placeholders in the first place.

2.7.3 Sub-worlds

Teachers and pupils when engaged in learning need to construct and manage multiple mental representations often within a short space of time. These mental representations are frequently complex and are not characterised by a clear correspondence between the deictic properties and function advancing propositions. Werth referred to these more complex mental structures as sub-worlds and categorised them in the following way:

Deictic: departures from the basic deictic 'signature' of the conceptual world, e.g. 'flashbacks', 'direct speech', 'window', onto other scenes

Attitudinal: notions entertained by the protagonist, as opposed to actions undertaken by the protagonist in the discourse

Epistemic: modalised propositions expressed either by participants or by characters

(Werth 1999: 216)

Participants of a classroom initiate several sub-worlds, which are formed by shifts in time and space, modal constructions (attitudes, beliefs, forcing of obligation and necessity) and hypothetical and imaginary situations. Although a more detailed account of the structure of these sub-worlds will be made in the analysis chapters, a brief summary of the key features of these sub-worlds will be made here to orientate the reader.

During a lesson or an interview there are moments when one of the participants, usually the teacher in a lesson or the researcher in an interview would shift the basic parameters of time and place. These 'flashbacks' would serve as reminders and were often triggered by the word 'remember'.

Attitudinal sub-worlds can be either desire (want worlds), belief (belief worlds) and purpose (intend worlds) (Werth 1999: 227). As might be expected desire worlds that are triggered by predicates such as 'want', 'hope' or 'dream' do not appear to feature strongly in a science classroom. In contrast, belief worlds do.

Werth's approach to knowledge and belief differs radically from traditional treatments in semantics and logic. He uses the following example to illustrate his account of belief worlds by asking the reader to imagine there are two competing manufacturers of computers: Pears and Bananas and them to consider the following 'belief-context sentence':

John believes that a Pear is better than a Banana.

(Werth 1999: 234)

Werth invites the reader to imagine that John originally believed Banana to be a superior computer but after reading various computer magazines and observing his colleagues using Pear he changes his view and believes that Pear is actually better than Banana. What is important here is not whether Pear is in fact better than Banana but that Pear is accepted as being a better computer. It is John's attitude towards the proposition which triggers the belief sub-world and not a truth value of the statement.

Occasionally, classroom discourse features purpose worlds which refer to participants' intending future actions deictically placed in a future time zone. These sub-worlds are frequently triggered by the teacher stating what he will do in the future either during a demonstration or at the end of a lesson when he informs his pupils of what they will learn in the following lesson.

Of particular relevance to the study of scientific discourse is the construction of hypotheticals, which are unrealised remote worlds generated through language. The notion of remoteness is often expressed by the verb-tense morphology (1999: 239). Belonging to this category is the language of predictions, which feature strongly in scientific discourse. Werth would have categorised this as an 'assumption shift' which correspond to the 'entertaining of different conditions in order to work out potential consequences' (1999: 243).

Some of the most notable changes to the original framework have been made by Gavins (2005, 2007) in relation to Werth's model of the sub-world. Gavins criticises Werth's use of the prefix sub-, which she suggests implies a subordinate

relationship of the sub-world to the text-world which is not always the case. To address this issue, she adopts Emmott's concept of a frame switch (Emmott 1997: 147) that offers a less hierarchical account of a reader or listener's experience of the shifts within a text. Gavins proposes the term world-switch instead of Werth's original term sub-world, which this thesis will also adopt. A world-switch, however, only refers to a shift in spatial or temporal parameters and not attitudinal or epistemic shifts. When both the spatial and temporal parameters are shifted (e.g. when the teacher refers to yesterday's lesson that look place outside), this is referred to as a 'spatial and temporal alteration combined' (Gavins 2001). Included in Gavins' notion of world-switch are instances of direct speech and direct thought because they 'change the basic time-signature of the text-world' (Werth 1999: 221).

One further significant alteration to Werth's original sub-world categorisation is Gavins' construct of a modal-world. Werth originally accounts for modality with his attitudinal and epistemic sub-worlds. These categories were reconfigured by Gavins to form a more inclusive system comprising of deontic, epistemic and boulomaic modal worlds (2001, 2005). As this thesis explores modality in some depth, especially with regards to the role that epistemic modality plays in the knowledge construction process (see Chapter 5), the following will outline and establish some of the key features of this reconfiguration.

Gavins broadens and reconfigures Werth's original, somewhat narrow categorisation of modality (belief, purpose and desire) to become more inclusive and in line with the work on modality that was being carried out at the time. Drawing on the work of other researchers (e.g. Palmer 1986 and Simpson 1993) Gavins divides propositional attitude into three main categories: 'deontic', 'boulomaic' and 'epistemic'. Deontic modal-worlds include those propositions which are concerned with the text producer's attitudes to duty ranging from permission, to obligation and finally, to the most forceful notion, requirement Gavins (2005a, 2007a: 99; Simpson 1993:48). Boulomaic modal-worlds express a degree of commitment towards propositional content through the use of lexical verbs (want, wish, hope, desire), modal adverbs (hopefully, regrettably) and

adjectival and participial constructions (BE…THAT; I'm hopeful that you'll pass: BE…TO; it's good to sit down). Giovanelli (2013:70) extends Gavins' treatment of boulomaic modality by differentiating between those deontic constructions related to intensions that place the speaker under an obligation to carry out an additional act (I'd like to collect your homework in), and those that are located in the speaker's internal conceptual system and are part of the speaker's dream or fantasy world (I wish I had thought of that). The final category consists of propositions which relate to the text producer's knowledge and beliefs; the epistemic modal-world. Epistemic commitment towards the truth of a statement can be expressed through the modal lexical verbs (know, think, suppose), epistemic modal adverbs (certainly, possibly, doubtfully) and BE..THAT and BE…TO constructions (it's certain that, it's supposed to). In addition to including what Werth had originally identified as belonging to the epistemic domain, namely, conditionality, hypotheticality and indirect speech, Gavins' model also includes focalised narratives.

During a communicative exchange, the participants build up a common ground, which is 'the totality of information which the speaker(s) and hearer(s) have agreed to accept as relevant for their discourse' (1999:119), by following the discourse meta-principles of communicativeness, coherence and co-operation (1999: 51). Werth defines discourse as 'a deliberate and joint effort on the part of a producer and recipients to build up a 'world' within which the propositions advanced are coherent and make complete sense' (1999:51). He later adds that 'discourse is a joint venture for building up common ground' (1999:85) and that new information can then be added and shared between participants. This process is known as updating or incrementation (1999: 130). Relevant to this thesis, the notion of common ground has recently been applied to the analysis of online discussions (Canning 2017), during which the participants establish the relevant common ground by feeding into the discussion different elements of their own discourse-world knowledge. According to this model, as the participants share their knowledge (mutual knowledge), the co-constructed text-world is enriched with multiple perspectives. This enriched text-world feeds back into the discourse-worlds of the participants (2017: 183). Since

Werth's death, his concept of common ground has been criticised in that he never specifies the relationship between the common ground and the text-world (Whiteley 2010). Van der Bom offers a plausible re-interpretation of the concept by suggesting that the common ground should be seen as 'the accumulation of text-worlds in combination with the discourse-world of a given discourse' (2015:27). The difficulty scholars have had with the concept appears to stem from the ambiguity of the distinction between shared knowledge and the knowledge only known by an individual. Some scholars, including Gavins (2007a), claims the concept is unnecessary and has dispensed with it entirely. Despite the lack of clarity between these knowledge categories, I have found it a useful concept when considering the social dimensions of the classroom, as it has enabled me to highlight the power of individual pupils' contributions in a group setting and conceptualise the accumulating knowledge that is shared amongst the members of the class.

This section 2.7, has presented and outlined some of the key features of the text-world framework, as well as highlighting areas of the original framework that are problematical. The section has also explored how this thesis intends to develop the framework further as it is applied to the context of the classroom.

2.8 Conclusion and aims of thesis

This chapter has reviewed the literature from the field of conceptual change research that specifically looks at the factors which are thought to bring about conceptual change. It has reviewed the two dominant models within this field, namely the knowledge-as-theory model and the knowledge-as-pieces model and has proposed a model of conceptual change which merges elements from both these models. That said, as the primary research site for this investigation is the classroom, the focus of investigation is to track the processes taking place that may bring about changes in how pupils construe and choose to represent the abstract concept of heat energy and related concepts. Therefore, the knowledge-as-pieces part of the model is foregrounded in this investigation. One further notable point needs to be raised with regards to terminology. Due to the moment-by-moment tracking approach to the investigative process and the

interpretative nature of the chosen framework for analysis, it becomes difficult to detect any actual changes in conceptual thinking. The preferred term therefore is development rather than change as the term is felt to reflect the dynamic and complex nature of the systemic processes involved.

To investigate the conceptual developments taking place in the classroom (and interviews), I am proposing to use a Text World Theory analytical framework, which is situated in and borrows extensively from the broader field of cognitive linguistics. For this reason, a review of some of the key tenets of cognitive linguistics, that are relevant to this thesis, were made to orientate the reader. This review has described and explained some of the key components of the Text World Theory model (2.7). As it is an extensive model, a full description of the model in the review is not possible therefore, further aspects of the model, highlighting its close partnership with the field of cognitive linguistics will be made in Chapters 4, 5 and 6. This review has also highlighted some problematical areas of the text-world model that can be re-interpreted by applying recent insights from cognitive science, especially with regards to memory (see section 2.7).

My rationale for using a worlds approach is that it is a model that appears to be well suited to the investigation of mental states as it provides a plausible account of how the mind organises, structures and classifies knowledge, including abstract knowledge, and how participants within a discourse space keep track of discourse events by constructing and moving between conceptual worlds set up through temporal and special shifts, modality, hypotheticality and metaphor (see 2.7). As it is a contextual model, it is not only able to account for how specific kinds of knowledge are activated by participants interacting and engaging with the discourse of the classroom, but it also provides an account of how the physical environment of the classroom is directly involved in this process. By mapping out these processes by using a text-world analysis approach, I am aiming to identify, the possible specific constraints imposed on all participants, including the pupils in the classroom. By carrying out a linguistic analysis, using this framework, it becomes possible to investigate how the

dynamics of the classroom are involved in the participants' construal of the events as they unfold, thus shedding light on the developmental process of abstract concepts by a class of pupils and their teacher in a school environment. Therefore, the first research aim of this thesis is:

1. To examine the ways in which the abstract concept of heat energy (and related concepts) is constructed and linguistically represented by a group of learners and their teacher in a secondary school setting.

As far as I am aware, this is the first time the Text World Theory framework has been applied to the investigation of the development of abstract concepts in the classroom. As this is a new application of the Text World Theory framework this thesis aims to investigate its appropriateness and effectiveness. Therefore, the second and third research aims are:

2. To examine the ways in which the Text World Theory framework can be applied to the analysis of the development of abstract concepts in discourse.

3. To examine the effectiveness of the Text World Theory framework for exploring the development of abstract concepts in a school environment.

Chapter 3: Methodology and Research Design

3.0 Introduction

To understand the processes involved in a classroom that bring about conceptual development and more precisely, to examine how a group of learners and their teacher represent abstract concepts linguistically, which is the main research aim of this thesis, it is vital to choose a methodology that allows the researcher the opportunity to witness and be a part of a naturalistic learning environment. A case study with a predominately qualitative naturalistic inquiry approach (Lincoln and Guba 1985; Denzin and Lincoln 2005), enables the researcher to do just this, namely, to gain proximity to the participants as they experience this learning process. It allows for a clear understanding of how these concepts develop over the course of a learning period and how the physical and social micro-dynamics of the classroom form an integral part of the process. This approach, which allows the researcher to observe and record the moment-by-moment interactions as they take place in a naturalistic environment is vital, if a rigorous account of how the participants construe the learning events is to be made.

The following chapter is divided into several sections. This chapter will start with an outline of my epistemological position that underpins the choices made throughout the research process. Sections 3.2-3 highlight the stages involved during the data generation period. It presents these in chronological order to orientate the reader, before providing more details about the preliminary stages of the field work in section 3.4. This section explains my motivation for wanting to undertake this research project, and highlights some of the initial research aims and issues that guided the construction of the research design. Following this, further details of the preliminary stages will be given, which will include an account of the ethical considerations that formed an integral part of the research generation process and a description of the key components of the pilot study, which lasted one week in January 2015. The following stage of the process

is the main data generation and collection stage. Sections 3.8 and 3.9 will describe and explain the main research methods employed; 3.9.1 observations, 3.9.2 teacher and pupil interviews and stimulated recalls, 3.9.3 fieldnotes and 3.9.4 transcribing. The final section will explore in depth the steps taken to ensure the scientific trustworthiness of the study. Although the data generation and collection period spanned approximately four months (mid January – mid May 2015), the frequency of visits to the school varied during this time.

3.1 Research paradigm

This study seeks to understand the nature of the development of abstract concepts by a group of participants in a naturalistic classroom setting. Essential to the understanding of this phenomenon is the importance of clarifying some of my key assumptions and 'basic belief system which guides this investigation' (Guba and Lincoln 1994:105). In this section, I will therefore outline my epistemological position. Closely related to the methodological approach taken, which is guided by this position, is this thesis' understanding of what constitutes learning, as both processes are concerned with the nature of reality, how we come to know this reality, and the knower's relationship towards this reality (Krauss 2005: 759).

As indicated in the literature review section, the view of learning endorsed in this thesis is one in which the subject's internal structures (e.g. conceptual metaphors, image schemas), that are extensions of sensorimotor experiences, engage and interact with objects (either real or imagined) in the subject's environment. In science, many of these 'objects' are things that we have never seen nor touched before (e.g. atoms). When a subject's engagement with these objects reoccurs over time this becomes meaningful for the subject (Johnson and Lakoff 2003). In other words, we learn about our environment through our physical and mental interactive engagement with it.

This view of understanding and learning, which is mirrored in the methodological and analytical approach taken in this study is known in the literature as *experiential realism* (Lakoff and Johnson 2003). It is essentially a cognitivists

approach to understanding reality and how the active subject, through their perceptual and cognitive architecture comes to understand that reality. It is a commitment widely accepted by scholars who take a cognitive perspective on texts and language (Stockwell 2009:2, Gavins 2013:6).

As this study required me to establish a research design to capture and generate language in a naturalistic setting to be later analysed, I drew from the qualitative research paradigm of critical realism whose philosophical principles are closely aligned with that of experiential realism (Maxwell 2012: 4). To set up a principled research design, it was first necessary to understand the relationship between my epistemological commitment and the methodology and methods that would underpin my research. Critical realism draws on elements from the paradigms of positivism and constructivism (Healy and Perry 2000). Positivism concerns itself with one concrete reality that exists externally to the knower and the aim of investigation is to uncover the nature of that reality through observation and measurement. The position or stance of the investigator is irrelevant as data, in order to be meaningful, is not open to multiple interpretations but is meaningful in itself as it is taken to be direct evidence of this external reality. Quantitative methodologies feature strongly in this paradigm.

Constructivism does not share this ontological assumption of the world as for constructivists there does not exist one single external objective reality other than our own perceptions of it. For a constructivist, meaning lies in our own cognition alone and for this reason there exist multiple realities. What lies beyond our own linguistic representation of the world cannot be known, in other words, there does not exist a reality beyond discourse (New 2003). For this reason, qualitative methodologies that explore a phenomenon in its local naturalistic context and that uncover these multiple realities as they emerge from the investigation, are the norm.

In contrast, critical realism originally formulated by Bhasker (1975, 1998), assumes that there is a reality beyond what we can directly perceive but the only way we have access to it is through our bodily, perceptual and cognitive

experience of it. In other words, it acknowledges the role of subjective knowledge in a given situation, in addition to independent structures that place constraints and affordances on the acting subject (Wynn and Williams 2012). As the subject experiences realities differently depending on whether they are either physically in the same spatiotemporal space (in text-world terms in the discourse-world), or indirectly experienced through language and therefore are imagined, realities have different ontologies and are said therefore to be stratified (Bhasker 1975). The inference process for a critical realist is reductionism, which is 'the movement between the knowledge of phenomena expressed through events to the creation of explanations', which account for unobservable causal events that are believed to exist but cannot be observed (Zachariadis et al. 2013:4).

Critical realism, compatible with experiential realism, provides therefore an over-arching theoretical framework for the empirical investigation of phenomena occurring in a naturalistic setting such as a classroom, which can be later analysed and explained using the Text World Theory framework (see section 2.7). With regards to methodological approaches, critical realists embrace both qualitative and quantitative methodologies and are guided in their choice by considering the ontological nature of the phenomenon in question and the situation it is likely to occur in.

3.2 Research design: a case study approach

Central to this investigation is an understanding of the complex world of human experience in a classroom setting. For this reason, to gain proximity to this experience, it is necessary to adopt a research methodology that enables the researcher to explore and provide an explanation of the interactions of structure, events, actions and context to identify causal tendencies within the system (Ackroyd 2010). Most suited to this purpose is a case study approach, a form of empirical inquiry, which investigates 'a contemporary phenomenon within its real-life context' Yin (2009:13). It aims to uncover the 'particularity and complexity' of a single case (Stake 1975: xi), which in this thesis was a class of twenty pupils and their teacher Mr Dalel. A case study methodology with a

predominately qualitative naturalistic inquiry approach allowed me to document the moment by moment events of the classroom and draw from several different sources of empirical data. More specifically, an exploratory longitudinal case study design was adopted. It was exploratory, in that its purpose was to understand a phenomenon that would only manifest itself in a naturalistic setting, and longitudinal because data was collected over a four month period. This enabled an in-depth study of particular features of each contextual element, that had a higher chance of manifesting themselves over this period of time.

Deciding to concentrate on a single case study enabled me to understand the highly contextual nature of the phenomenon under investigation. I was in a position to understand the structural and cultural elements of the context that would have on that phenomenon, conceptual development, that I was investigating. These elements of the research are illustrated in the following illustrations:

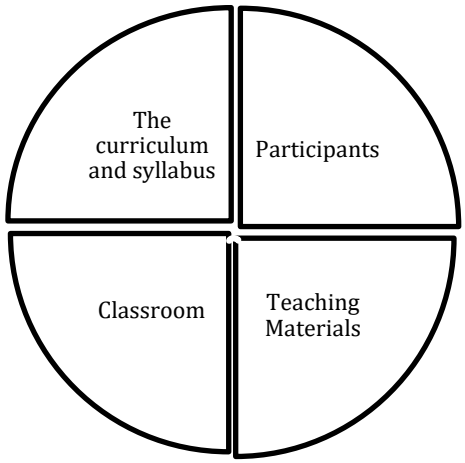


Figure 3.1. The context

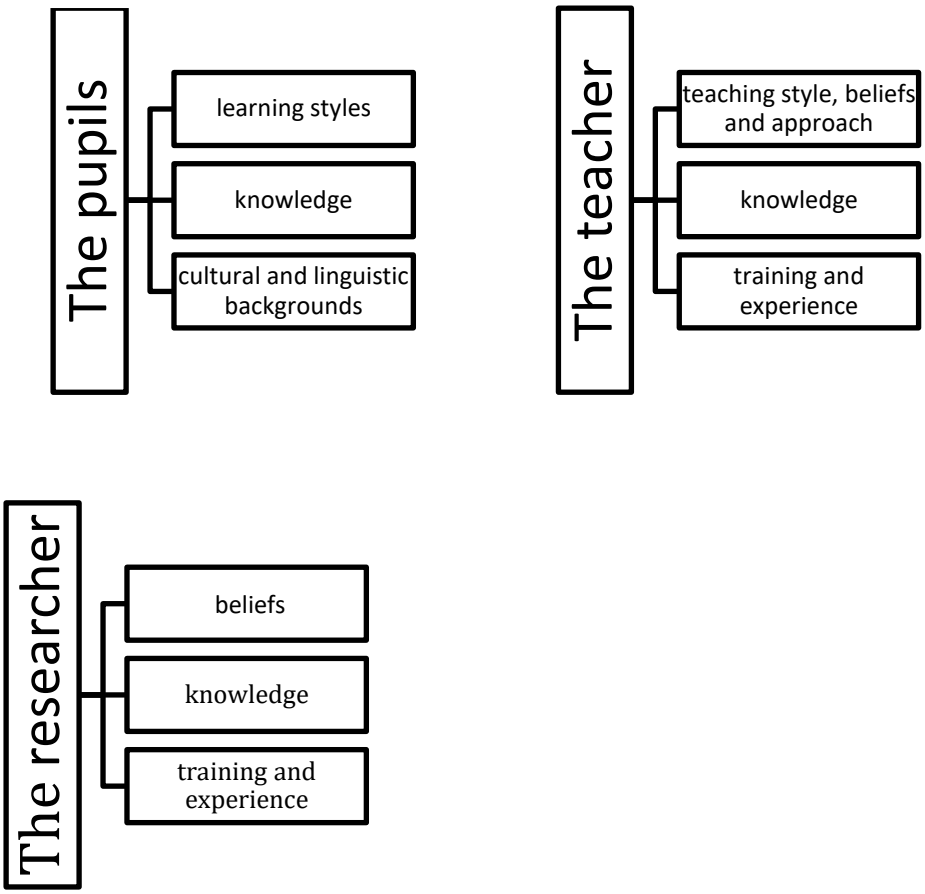


Figure 3.2. The participants

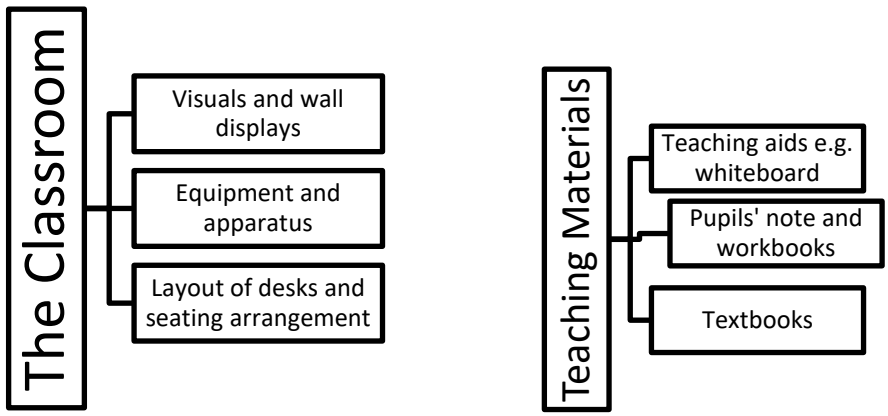


Figure 3.3. The classroom and teaching materials

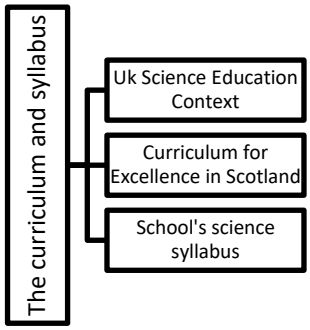


Figure 3.4. The curriculum and syllabus

Case studies often aim to answer questions at a more abstract or conceptual level. Firestone (1993) refers to this as 'analytic generalisation'. Therefore, a further reason for choosing to carry out a case study was that insights provided by this case study may be adapted and compared to other case studies provided the contextual differences are taken into account. As classroom environments share many near universal features, for example, they follow the same or similar curriculum and often use the same textbooks, the learners and their cognitive capacities are assumed to be true of all groups of learners, the findings from my case study research can contribute to our theoretical understanding of conceptual development in all science classrooms. In this study the classroom data, once collected and transcribed, is analysed using a Text World Theory framework which can be later adapted and applied to other learning contexts thus creating a more sustainable model to be used for analytical work in the future.

A qualitative approach not only reflects the understanding that subjectivity is part of all human activity (Lincoln and Guber 1985, 2003) but also allows the researcher to gain close proximity to 'the subjectively lived experiences' of the participants (Alder and Alder 1994:380). Importantly, this approach recognises the human-as-instrument as the key data collection instrument for a number of reasons; humans are sensitive, can adapt, are responsive and can understand events holistically (Lincoln and Guba 1985). These capabilities were translated into my own study at various levels. To be able to integrate myself into the

classroom environment, I needed an awareness and sensitivity towards the needs of both the teacher and pupils. On occasion, I was required to respond and adapt quickly to unexpected circumstances. Further details of how I positioned myself as a researcher during this process will be discussed in section 3.5.1.3). As I was interested in the pupils' conceptual development this required me to observe and process several features of the lesson at once.

Adopting a naturalistic approach allows for the research design to evolve as the investigation unfolds (Stake 1975). The prolonged contact with the class and the time after each lesson to review the data gave me the opportunity to make small alterations to my research design. Overall, these alterations led to a more focused line of inquiry, as indicated by the adjustments made during and after the pilot study (see section 3.5).

Despite chiefly adopting a qualitative approach, as a supportive methodology, I use the corpus tool (Lextutor v 8.3) in Chapter 6 to quantify and explore the usage of five words in the classroom discourse prior to a group writing task, during which Mr Dalel told the pupils to use these five words in their writing. The rationale behind this decision was to explore and establish the linguistics knowledge (Werth 1999: 96) required by a group of pupils as they carried out the group task. The underlying principle that steered a decision to employ a corpus tool to explore the words' usage is that knowledge of language emerges from situated language use (Evans and Green 2006: 111) and by employing a corpus approach to explore language use would add some depth and rigor to the analysis. This approach sits comfortably within the overall research design as it recognises and aims to explicate the underlying causal tendencies taking place during the learning event. Further details of how this tool was used, is given in Chapter 6.

3.3 Chronological timeline of the research process

The data generation and collection stage, that included the preliminary stages, the pilot study and the main collection stage span the time period from autumn 2014 to summer 2015. I should note that although the data gathering stage

appears on paper as a separate unit, cut off from the rest of the thesis, decisions made prior to this stage were made a long time before autumn 2014 and consequences of these decisions and ones made during this stage were felt long after the event itself. As Vygotsky reminds us:

> "the search for the method becomes one of the most important problems of the entire enterprise of understanding the uniquely human forms of psychological activity [...] the method is simultaneously prerequisite and product, the tool and the result of the study (1978:65).

The methodological approach taken in this study is simultaneously the process and the product in that the choice to work with this particular school, had an impact on which participants were involved in the study and on which learning units became the focus of the study. The analysis outlined in Chapters 4,5 and 6 is the outcome of my interpretations of the data collected. For this reason, the methodological approach is an integral part of the thesis as a whole. A summary of the main stages in the data collection process are illustrated in the following diagram:

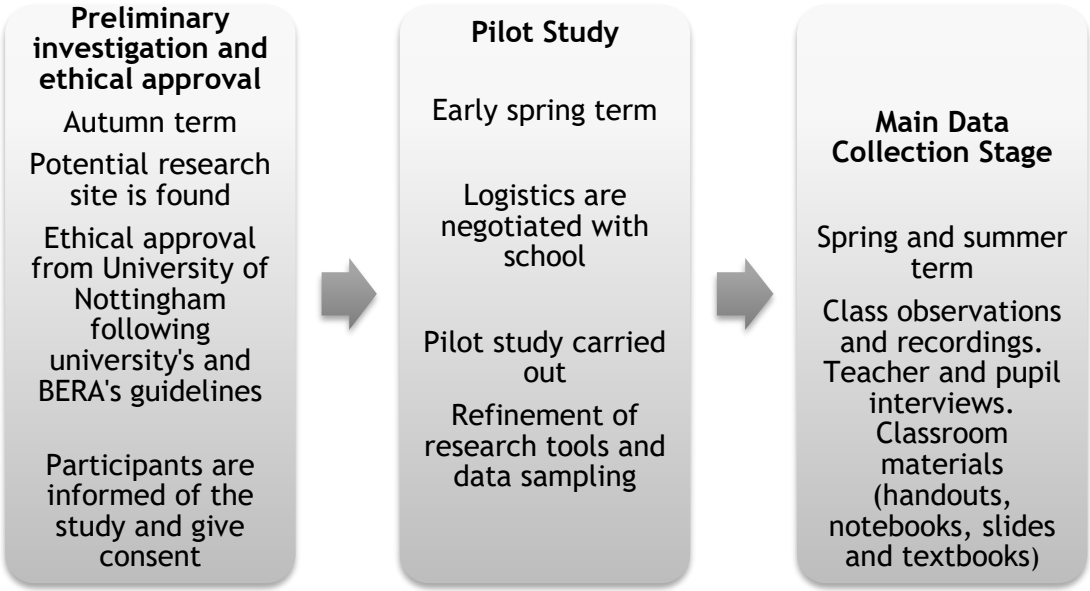


Figure 3.5. Chronological timeline of research process

3.4 Preliminary stages

One of the central tenets of science education is that learning science involves a shift towards a different more 'expert' like understanding of abstract scientific concepts. My initial and current interest in this phenomenon lies specifically in the nature of this shift and how this shift in understanding occurs within an instructional discourse space. This interest arose whilst I was a teacher trainer on a PGCE programme for science teachers from Malaysia who were being trained to teach their subject through the medium of an L2, namely, English. I was responsible for providing feedback on their micro-teaching. My two central questions during the observations were 1) how is the teacher supporting the pupils' developing an understanding of the key ideas and concepts during the lesson and 2) how were they using language to achieve this goal? What I noticed was that being placed in a position of evaluating both the conceptual and linguistic dimensions to the lesson simultaneously meant that I had to devise my own framework of analysis, as there did not appear to exist one in the mainstream literature that I could use. However, this proved to be far from easy, as most dominant theoretical frameworks in the field of education tend to separate content from language. I later found during the preliminary stages of this research project that applying knowledge of Halliday's (1994) metafunctions (ideational, interpersonal and textual) and exploring the different lexico-grammatical patterns of language use of the teacher and pupils exposed many of the conceptual and representational demands the pupils had. However, it did not offer a plausible explanation of the cognitive processes taking place in the classroom which would account for various patterns found in the discourse. This apparent gap led me to draw ever more extensively on the field of cognitive linguistics during the latter stages of the data generation stage and then throughout the analysis stage of the research process.

Thus, the data generation stage was conducted in parallel with drawing together various theoretical strands from the field of science education, in particular in the field of conceptual change research and from the field of educational linguistics and cognitive linguistics. The initial analysis of the data, that occurred during the pilot study and the early stages of the main data collection stage,

was the point of intersect between observing the data as it emerged on site, and interpreting it according the theoretical frameworks applied from the reading process.

My initial review of the literature, mainly situated in the sociocultural paradigm that I engaged with at the time, conducted before the data generation stage led me to formulate the following initial research questions that I used to frame the pilot study:

- *In what ways do the teacher and pupils use classroom talk to establish, manage and orchestrate the learners' conceptions and the 'scientific position' in a secondary school science classroom?*
- *How does the teacher and pupils' use of talk in these episodes change over time?*

Once this initial theoretical line of enquiry had been established I commenced the data generation stage to provide me with data to propel forward my investigation. Whilst applying for ethical approval, I approached several secondary schools by letter and e-mail. Through a contact I had made with an English as an Additional Language (EAL) classroom assistant, I had some names of teachers she had worked with. After approximately four months of approaching schools one teacher, who had been recommended by the assistant, replied to say that he wished to take part in the research. I conducted an initial interview with the teacher in Summer 2014 to provide him with more details about the nature of my study. The interview allowed me the opportunity to listen to his reasons for wishing to take part that will be outlined in the section 3.9.2.1. Furthermore, I was able to negotiate a timeline of the research that would sit well with the school's plan for the following year and would allow me to generate the data I required to carry out my research.

I had no prior engagement with the school, which could have led to issues with negotiating roles, and therefore have consequences when ensuring the trustworthiness of the data (see section 3.10 for a more detailed account of how scientific trustworthiness was maintained). Further to this, the school had a well-established science department, with an engaged teacher who showed

commitment and interest in my research as well a large pupil population from a wide social and cultural background.

3.4.1 Ethical considerations

Adopting an ethical approach to this study was seen as paramount importance. Three key ethical principles that underpin codes of practice in many countries, including the UK, were used throughout each stage of this research process, namely, i) respect for persons, ii) beneficence i.e. the obligation to maximize possible benefits and minimize harm and iii) justice i.e. addresses the needs of those who ought to benefit from doing research (Farrell 2005: 4). Furthermore, in accordance with BERA's guidelines (2011), this study is committed to respecting knowledge in that its research aims to provide an accurate account of the Text World Theory framework, show how it has been refined over time, and extend it legitimately.

This research involved both adults and children but instead of viewing the children as 'human becomings' (Philips and Alderson 2002:6), the children involved in this study were understood already to be competent participants of their everyday world who were able to make their own decisions about whether they wished to be involved in the study or not (Mackay 1991). Therefore, in addition to ensuring that this research met all legal requirements, in terms of gaining consent from the institutions and individuals concerned, I adapted the language I used with the children (for example in the consent forms I had written for them) to ensure I had implemented the three key principles for all the participants involved.

After receiving formal ethical approval from the University of Nottingham ethics committee that is in line with the British Association Research Association's (BERA) guidelines, and notifying the relevant Scottish authority, I visited the school in January 2015 to negotiate access to the pupils' written and spoken work during class time, and during the interviews to be conducted in a room situated in another part of the school building. As the research involved me being

alone with the pupils, I had applied and received the Disclosure and Barring enhanced certificate prior to my engagement with the school (June 2014).

My initial contact with the school, teacher and pupils required me to develop a relationship with the participants based on trust. I had the opportunity to visit the school three times and sit in with the class during the autumn term. This provided us all with the opportunity to familiarise ourselves with each others' patterns of work and routines, which facilitated the process of informing the pupils in January of the nature of my investigation. To ensure that the pupils were aware of the full implications of the research, I spoke to them as a class and answered their questions. Letters to their parents were distributed together with consent forms. The letter and consent form were translated into Mandarin for Julien who had arrived in Scotland from mainland China four months previously. The rector of the school and teacher were also given letters informing them of the full implication of the research and consent forms.

As I intended to video and audio record the pupils during the lesson and during the interview sessions, I needed to ensure the participants that the main purpose of recording was to provide me with an accurate record of the event. Confidentiality was ensured as far as possible throughout the process by either using pseudonyms, or by using the term 'pupil' (or P1, P2 etc.) or 'teacher' and by referring only to short excerpts from the lesson rather than full transcripts. To reduce any undue stress or embarrassment felt by the participants, I always checked before any interview that they were comfortable being recorded, that the interviews were voluntary, and that they could withdraw at any point. One pupil had not given consent to being part of the research. Consequently, I tried to ensure that the camera was never pointing in his direction and that any learning episodes which featured the pupil were disregarded.

One further important aspect of the research process that was negotiated and planned with the teacher during the initial interview and pilot study was the logistics. Initially, we considered the possibility of the pupils being interviewed during their breaks or during tutor time. However, it soon became apparent that this would infringe on the other teachers in the school. Therefore, we agreed

that as I would need to withdraw between 2-4 pupils on a weekly basis this could be done during the first 15 minutes of every Wednesday's lesson. The pupils were selected and invited to participate via a rota and therefore missed a maximum of 20 minutes of class learning per learning unit. Although not ideal, the teacher was very supportive of my research and ensured that the pupils caught up with the lesson on their return from the interview.

With regards to the equipment, I used two flip cameras and a very powerful microphone, which could be placed in a concealed spot on the work bench at the side of the room. Pupils seemed often unaware of its presence. I audio recorded group work with my phone, which being a familiar object to the pupils meant that they quickly got used to its presence.

3.5 Research Site

This study took place in an urban non-denominational, co-educational school in a city in Scotland with a population of approximately 500,000. The school reflected the city's relatively high proportion of its ethnic minority population which stood at 12% of the total population in 2011 (Scottish Government, 2014). At the time of the study, the school had a population size of approximately 1000 pupils with pupils attending the school from 12- 18 years of age. The average attainment of the pupils in national tests was average in 2008 when compared to other schools in Scotland (these statistics were taken from the school's most recent inspection report that will not be referenced to secure the anonymity of the school).

This study was based on the first year of secondary Curriculum of Excellence Science (2010) programme. The S1 (first year secondary) pupils from one class of twenty pupils had four lessons of general science a week. The main phase of the data collection stage of this project coincided with the class covering two topics: Cells and Inheritance and Heat and Light. Each topic took approximately six weeks to cover and there was an end of unit test given to the pupils at the end of each unit to provide information to the teacher, pupils and parents on the pupils' attainment. In addition to the two main topics, I had access to two

lessons as part of the pilot study on Chemistry Matters. The pupils in S1 in the school are not streamed so consequently the class had a broad ability range. Pupils from more than the five 'associated' primary schools enter the school so consequently there is a broad range of social backgrounds, despite the school being situated in a relatively prosperous part of the city.

3.5.1 The participants

3.5.1.1 The pupils

The class consisted of twenty pupils (eleven girls and nine boys). One girl moved to a different learning group at the end of the Genes and Inheritance topic. I did not have access to the pupils' attainment scores in other subject areas but from interviews with the teacher the class performed averagely well as a whole. There were three to four pupils who consistently stood out as above average in terms of test scores in science and classroom participation. The pupils came from a culturally and linguistically diverse range of backgrounds, details of which are noted in Table 1. This information was collected at the end of the study via means of a questionnaire. The majority of the pupils lived in bilingual households, with Arabic, Punjabi and Urdu being the most frequently spoken language other than English:

Table 3.1. Languages spoken by the pupils at home

Number/pseudonym **M- male F-female**	**M/F**	**What languages do you speak at home?**
1. Mahta	F	At mother's I speak English At Father's I speak Arabic
2. Aarav	M	Hindi, English and Punjabi
3. Yelena	F	Arabic and English
4. Imran	M	English and Urdu
5. Alia	F	Arabic and English
6. Suzy	F	English and Cantonese
7. Zarif	M	Punjabi and English
8. Amil	M	English and Urdu
9. Sama	F	Punjabi or Hindi, sometimes English
10. Zafar	M	Urdu, English and Punjabi
11. Sanja	F	Arabic and English
12. Lucy	F	Chinese (Mandarin)
13. Julien	M	A little English, Mandarin

14. Pupil did not consent to take part		
15. Haaqiz	M	English
16. Rose	F	English
17. Kate	F	English
18. Rory	M	English
19. Zara not present	F	
20. Klara	F	English

As the pupils came from a number of different primary schools, their experience of learning science varied, not only in what subjects they had covered but also in whether they thought they had been taught at all (see Table 3.2). There are two possible reasons for this. First, although science is part of the Scottish Curriculum of Excellence from the ages of 3 – 18, the coverage of the subject remains patchy. Second, primary teachers in Scotland teach topics, for example 'Land Grabbing', which cover a range of disciplines (e.g. literacy, numeracy and science). Therefore, pupils might not always recognise that they are 'having a science lesson'. Despite this, some of the pupils were quite articulate in describing what they had learnt (see Table 3.2).

Table 3.2. Primary school science background of pupils

Number/pseudonym	Did you learn any science at primary school?	If so, what subjects did you learn?
1. Mahta	yes	Forces, in P5 we made clouds in bottles
2. Aarav	no	
3. Yelena	yes	The body, breathing system, digestive system, names of bones and the heart
4. Imran	no	
5. Alia	no	
6. Suzy	yes	The body
7. Zarif	yes	Light and reflection
8. Amil	yes	Light and reflection
9. Sama	no	
10. Zafar	no	
11. Sanja	no	
12. Lucy	Reflection of light in water and sound	
13. Julien	no	

14. Pupil did not consent to take part	Circuits, Magnets and Lights	
15. Haaqiz	no	
16. Rose	no	
17. Kate	left form blank	
18. Rory	illegible	
19. Zara not present		
20. Klara	no	

3.5.1.2 The teacher

The teacher was an established and well-respected member of the school and had taught science in secondary schools in Scotland for over 23 years. His subject specialism was biology although he appeared to be equally comfortable teaching physics especially at an S1 level. His broad knowledge base and ability to convey this knowledge to the pupils and reflect on this knowledge was consistent throughout the data collection stage in both the classroom and interviews.

In addition to his considerable amount of experience in the classroom, he had earned himself a Master's in Education some years prior to this study. He had a special interest in literacy and had focused his research efforts during his dissertation on the difficulties pupils face when reading in the science classroom. The teacher and researcher's common interest in literacy in science lessons became a frequent topic of conversation in the interviews. The fact that he spoke Punjabi at home made him aware of some of the challenges his bilingual pupils faced, although he himself admitted that he could spend more time devoted to helping the pupils overcome these difficulties.

He was well respected and liked by his pupils and he rarely had any behavioural issues from the pupils. He spent a considerable amount of effort planning his lessons to ensure variety and progression. Overall, the qualities of the teacher were reflected in the positive climate of the classroom, which the teacher had created.

3.5.1.3 The researcher

My identity as a researcher is strongly influenced by my present and past teaching experience. I have taught English as a Second language for over twenty years to both adults and children and live in a bilingual household. This explains my strong interest in the knowledge construction process in both the L1 and L2. I have a degree in Chemistry and a PGCE in Science with a CLIL (German and French) specialism. In addition, my experience as a teacher educator initiated my passionate interest in the research focus, especially regarding how the various discourses in the classroom are an integral part of the way the participants think about the concepts being taught.

I had no direct influence in the planning of the lessons that I was a participant of during this study. However, the teacher mentioned a couple of times that my presence had made him more self-aware and critical of his own teaching. He was fully aware of my past history and present research interest made clear to him in my introductory letter and initial interview, which strongly influenced the way we interacted with each other both in the pupils' presence and when we were on our own. As the teacher was aware of my experience as a science teacher we could easily talk about themes related to lesson objectives, planning, anticipate pupil difficulties and outcomes.

The pupils were also aware of my role and previous experience. Their familiarity with visitors to the school and from both the university and other organisations meant that they were relatively unfazed by my presence. This enabled me to be able to slip between my main role as a researcher and occasionally as a science specialist, when it was deemed to be appropriate.

3.6 Situating the science lesson in a wider school curriculum context

The school followed the new Curriculum for Excellence programme, which was introduced into schools in Scotland for the first time in 2010-11. The teacher told me that the content although 'packaged' differently to how it was previously taught prior to the change, is essentially the same for learners in S1.

The two topics taught during the data collection stage were 1. Cells and Inheritance, which was part of the 'organiser' Biological systems and 2. Heat and Light, which was part of the 'organiser' Planet Earth (CfE 3.04a), Forces, Electricity and Waves (CfE 3.11 a and b). The lessons which formed part of the pilot study 'Chemistry Matters' were part of the organiser Materials.

Table 3.3. Organisers and subtopics of Curriculum for Excellence in Scotland (Education Scotland 2010)

Organiser	Subtopics
Planet Earth	Biodiversity and Interdependence Energy Sources and Sustainability Processes of the Planet Space
Forces, Electricity and Waves	Forces Electricity Vibrations and Waves
Biological Systems	Body systems and cells Inheritance
Materials	Properties and Uses of Substances Earth's Materials Chemical changes
Topical Science	Topical Issues

3.6.1 Topic: heat and light

The main focus of this thesis was on two lessons which formed part of the 'organiser' on Heat and Light. For this topic, the pupils were expected to understand the principles of Heat Transfer (conduction, convection and radiation) and the properties of light. A list of the learning objectives of this unit are in appendix one. The first six objectives on this list formed the basis of in the two lessons studied in this project:

1. Distinguish the difference between heat and temperature
2. State that heat flows through a solid by conduction
3. Explain conduction in terms of vibrating particles
4. State that a material which lets heat flow easily through it is a good conductor
5. State that a material which does not let heat flow easily through it is an insulator
6. State that air is a bad conductor of heat and is used for insulation

Education Scotland (2011)

3.6.2 Class materials

Although the science department followed the curriculum it appeared to take a fairly autonomous approach to compiling and managing the classroom materials. The teacher informed me that the materials the department used had been collected over the years and that the staff shared these materials. For each topic there was a booklet compiled by the department that was given to each pupil at the start of the unit. This would indicate on the front cover which Curriculum for Excellence Units the topic was part of, a list of can do statements (see appendix one). Furthermore, it had approximately 20 activity sheets that would provide a structured writing template for the pupils to complete during a class experiment or demonstration or it would provide some data and information that the pupils would need to analyse and write about. At the back of the booklet there was an 'evaluation of learning' sheet for the pupils to fill in and a vocabulary sheet with the key words of the topic which the pupils were supposed to record as they worked through the unit. In addition to the booklet, the pupils had their 'jotters', a note book which the pupils used to record the main objectives of the lesson, key memorable information, answers to reading tasks from the class course books and ideas and notes that the pupils wrote down during group work.

With regards to other artefacts that were used during the lessons, the teacher and pupils had access to a range of equipment and apparatus that were used during demonstrations and experiments. In addition, the teacher made frequent use of a whiteboard at the front of the classroom.

3.6.2 Teaching methodology and approach

Throughout the data collection stage, the teacher employed a range of teaching methods and practices. The following section will review what these methods and approaches were and how they reflect the accepted norms of good practice within the science education community, including those in the Curriculum for Excellence.

School science teaching is an activity which is based on how science educators see the world, and the manner in which the knowledge generated about learning, teaching and assessment is verified (Rodrigues 2013). According to this view, it can be construed as a sociocultural phenomenon, which has developed over time and is based on a set of collective and individual beliefs and principles.

The methods employed by the teacher during this project are practices that I have used in my own teaching and have seen used in other science lessons. Furthermore, it became apparent during the time I spent with the class and teacher that we shared many common core beliefs about how to create optimal conditions for children to learn. These were often reflected in the choice of activities that the teacher had planned during these lessons.

Throughout the data collection stage, I was witness to a broad range of classroom activities including amongst others; teacher demonstrations, experiments carried out by pupils, Simulation-Role-Plays, poster presentations, pupil discussions, designing representations of molecular cells (out of sweets!), video presentations, problem-solving activities, reading and writing tasks. The teacher demonstrated through his often skilful use of these activities that his beliefs about good practice in the classroom were in line with those set of in the Curriculum for Excellence framework:

- active learning
- development of problem solving skills and analytical thinking skills
- development of scientific practical investigation and inquiry
- use of relevant contexts, familiar to young people's experiences
- appropriate and effective use of technology, real materials and living things
- collaborative learning and independent thinking
- emphasis on children explaining their understanding of concepts, informed discussion and communication.

Education Scotland (2010)

The constant shifting from more teacher-led activities, such as class demonstrations, to more collaborative type tasks, and individual problem-solving activities, reflected an underlying sociocultural theoretical position underpinning the teacher's classroom practices. According to this standpoint,

pupils are motivated to make new meaning with ideas and concepts from their culture (CHAT: cultural historical activity theory, Wells 2001). In this view of learning, based on the ideas of Vygotsky (1978) and Bakhtin (1986), new meaning is achieved through activity whereby the learning is mediated through physical and semiotic artefacts in a social setting.

In conclusion, 3.6 of Chapter 3 has outlined and highlighted some of the key features of the context of the research project, namely, details of the school and the science curriculum that the science department within the school followed. It has provided profiles of the participants of the project; the pupils, the teacher and the researcher. And finally, it has situated the learning context of the study within the Curriculum for Excellence framework in terms of the content being taught and the methods and approaches employed by the teacher.

3.7 Pilot study and changes to original research design

The pilot study took place during the last week of January once I had received consent from all the participants involved. One key aim of the pilot study was to work through the original negotiated work cycle and adapt this to ensure a smooth running of the main data collection stage. The pilot study week included three, full 45 minute lessons, one pupil interview involving three pupils, and one teacher interview. The pupils were finishing the topic 'Chemistry Matters', during the pilot study, so were reviewing the material they had previously covered.

The process of reviewing the data that I collected during this week, led me to make a number of changes to my original research plan. Originally, I intended to focus on the participants' talk. Whilst this was the main mode of instruction and communication in the classroom, I came to the conclusion that it was the line of development of the *concept* that needed tracking irrespective of the mode. I decided to include examples of writing and drawings into the analysis as being equally important. As I had anticipated analysing the pupils' written work I had already received consent to do so. Second, I noticed that it would be difficult to describe and highlight key changes in the participants' talk over time.

I therefore amended my initial research questions to focus on the changes in language use according to the purpose of the learning episode.

Therefore, the initial research questions that guided the initial stage of inquiry were adjusted to reflect these changes:

- In what ways do the teacher and pupils use classroom ***language*** to establish, manage and orchestrate the learners' conceptions and the 'scientific position' in a multimodal and multilingual secondary science classroom?
- How does the teacher and pupils' use of ***language*** in these episodes change ***according to the pedagogical purpose***?

  (changes to original questions highlighted in bold)

Towards the end of the main data generation stage and during the analysis, the main research aims of this thesis were established (see section 2.8).

During the initial negotiations, the teacher tentatively agreed to record in a log the main learning objective of each lesson, and provide some feedback on what he thought were key aspects of the lesson that the pupils had found most challenging and interesting. I had intended to use these comments to guide me with the selection of extracts to show the teacher and pupils during the stimulated recall sessions. However, due to constraints on the teacher's time, I needed to adjust the method of communicating with the teacher. Consequently, I arrived at the lesson five minutes early in order to ask the teacher what the key aim of the lesson was. Feedback from the teacher was obtained either through short exchanges after the lesson, or during our interview sessions.

3.7.1 Pilot lessons

During the three pilot lessons, physical factors were noted such as size and layout of classroom, work patterns of pupils (where they move when doing practical work), which had all a bearing on where I eventually decided to position my recording equipment. The workbench around the classroom allowed me to position one flip camera towards the front, where the teacher normally stood and the other camera close to all the tables where the pupils worked in groups.

3.7.2 Pilot interviews

During the pilot interview with the pupils, I selected a question and answer session that took place during the previous lesson to show them as a stimulated recall task. I decided to conduct a semi-structured interview, as it gave me the opportunity to trial certain question types but allow us the flexibility to respond to the pupils' initial responses in depth. My planned questions focused on the teacher's input. I asked questions (e.g. what do you think he meant by …?) to elicit their understanding of the purpose of the session. My main aim with the interview was to measure the potential of what I might be able to achieve in the short time I had with the pupils, in terms of their readiness to respond, and my ability to design questions and tasks that would elicit a meaningful response. I became aware that I could also use the sessions to probe the pupils' understandings of the concepts being taught, as well as including short feedback sessions on the lessons that they had been part of.

During the pilot interview with the teacher, I showed him the same extract that I had showed the pupils. Also, by means of a semi-structured interview I was able to elicit his perspective on the learning event. I used this technique of showing the teacher and pupils the same learning event throughout the interview process as it provided the means of gaining more than one perspective on a single episode.

3.8 Longitudinal case study: main data collection stage

The main data generation stage took place between early February and mid May 2015. Data was generated during the course of two learning units 'Cells and Inheritance' and 'Heat and Light'. Eleven lessons from the first unit were observed, the pupils were interviewed four times and the teacher was also interviewed twice. During the second learning unit on 'Heat and Light' five lessons were observed, the pupils were interviewed five times and the teacher three times (see appendix C- the data collection log). It had been agreed with the teacher that in order to familiarise myself with the learning culture of the class, I would visit the school more frequently for the first learning unit. As the

focus of my research became more refined, I was able to be more selective of the lessons I observed in the second learning unit.

The pupils had a science lesson four times a week. Due to my own work commitments, I was able to visit the class at least once or twice a week, and on some occasions three times a week. During the Wednesday morning class, I was able to take a small group of pupils to a nearby room to conduct the interviews. The teacher was generally available after school had finished to be interviewed. Having time available during the day on the Wednesday, I had the opportunity to carry out an initial analysis of the data to prepare me for the interview with the teacher in the afternoon. There was usually a space of one week between the lesson and the interview with the pupils. On a couple of occasions, I had to either postpone or rearrange visits due to extended assemblies or school trips.

3.8.1 Sampling and selection process

In section 3.5, a description of the research site was given that included a description of the school, the teacher and the pupils involved. This section will look at the sampling procedures taken both prior to and during the investigation.

As the teacher responded fairly enthusiastically to my proposed project and the pupils showed curiosity and interest during our first meeting it could be said that this was a convenience sample (Brymen 2001; Wellington 2000). Although I had been looking for a suitable school for over four months, I decided not to carry on with my search as the teacher's interest in my research coincided with his own professional interests as a teacher, especially with regards to literacy in science. The decision to stay with the school was also made for other reasons besides the teacher's and pupils' responses.

The school was a mainstream school with mixed ability pupils, with a high proportion from different linguistic and cultural backgrounds. I was interested in working with either first or second year secondary pupils as during these years the pressure of examinations meant that I would be less of an intrusion. The teacher made the decision in the end which out of four possible classes I should work with. He told me that the pupils although mixed ability, did not have any

major behavioural issues, which might have interfered with the study. This from the perspective of the teacher was also important as it meant that he could concentrate on the teaching, without being distracted by classroom management issues.

During the investigation, pupils were selected for interviewing. An explanation of the selection process is relevant here. During the pilot stage, I invited all the pupils to participate in the interviews and to my surprise all of the pupils, except the one who had originally declined to take part, were willing to take part. This facilitated the interviewing process, as it meant that I could interview the pupils in their work groups. This enabled me to ask the pupils during the interview to comment as a group on some group work that had taken place in class (e.g. Chapter 6). It also meant less disruption for the class and teacher as the working groups were not split up during the first few minutes of class. The groups were interviewed on a rota, which allowed for a near full range of student abilities and personalities. There were two occasions when I asked a group of pupils to be interviewed more than once because I specifically wanted to know their opinion on the classroom event. However, as this only happened on two occasions it did not mean that these pupils were missing an overly disproportionate amount of time from class.

The analysis of this thesis describes and explores the development of the concept of *heat energy*. The decision to analyse this topic from the second learning unit was based on the following reasoning. My aim was to explore the development of a concept by a group of learners. The concept of *heat transfer* was introduced to the class as a new concept (in lesson 18.03.15). Then the concept was referred to by the teacher and pupils several times throughout the lesson as the class participated in a Simulation-Role-Play, a teacher explanation and a group writing task. In the following lesson that I observed (25.03.15), the teacher introduced the concept of *insulatio*n, a concept related to the concept of *heat energy* and then carried out a problem-solving task with the class, which required them to apply their understanding of the concepts to a problem. Thus, this sequence of learning units provided me the opportunity to track the development of the

pupils' understanding of the concept across a varied range of different social groupings and different activities in the classroom.

3.9 Research methods

The case study employed a number of different research methods to allow for empirical corroboration between different data sets that were gathered from the various participants in the study. The recognition of the existence of multiple perspectives on a learning event enabled an enhancement of my description and understanding of the reality that was taking place in the classroom, which ultimately led to a more robust Text World Theory theoretical account of the processes and mechanisms involved. The case study adopted the following research methods: i) observations of the whole class, group work and one-to-one interactions; ii) semi-structured interviews with the teacher and semi-structured and unstructured interviews with the pupils; iii) stimulated recall sessions with the teacher and pupils; iv) study of documents.

3.9.1 Observations in educational research

Observation takes a central position in empirical research in the social sciences (Angrosino 2005). Observation was used in this study to capture and record how the series of events were perceived and understood by myself and the participants. As claimed previously, the knowledge construction process is not only cognitive but also social. To explore how this knowledge emerges and how it might have an impact on individuals, the social dynamics of the classroom are therefore important aspects of the learning process to focus on. By their very nature, these dynamics can be observed and documented.

The epistemological approach taken by researchers carrying out observational studies varies. Some adhere to a more positivist perspective, taking their findings as self-evident and de-emphasising the subjectivity of the researcher, so aiming to uncover the cultural facts while others adopt a more interpretivist and phenomenological approach, espoused by ethnographic researchers (Harklau 2005). The latter approach contends that the social facts cannot be separated from the researcher's own beliefs, and are in this respect interpretations. For

this reason, these researchers are guided by 'heuristic theories' to guide their research. As a consequence of this, observational researchers have defined their position as postmodernist (Creese 2010). They are generally more interested in understanding local meanings in material settings rather than understanding universal facts. As established previously in the paradigm section, this research adopts a midway position by acknowledging the subjective position of the observer but maintaining an objective focus on the phenomenon under investigation. I am seeking to understand phenomena which I believe have qualities common to all classrooms (e.g. in that in all classrooms there needs to be some convergence of mental states for learning to take place) but at the same time I am acknowledging that the approach to studying the data will be an interpretation of the events in a particular context (how this is achieved will vary).

The main means of recording my on-line observations during the data generation stage was by recording them as field notes. The lessons were also video recorded, with one camera recording the teacher and one camera recording one group of pupils. The group would change from one lesson to the next.

A distinction needs to be made here between the observations made in the classroom whilst observing the lessons and the observation made after the lesson whilst observing the events by means of a recording. The main purpose of observing the events post lesson were to prepare myself for the interviews with the teacher and pupils. These observations during the data collection stage were guided by the work of two key theoretical traditions: the sociocultural tradition (outlined in section 2.3.1) in the field of science education (e.g. Chin and Osborne 2010, Mortimer, Scott and Aguiar, 2006 and Mercer, 2008), which is largely based on a Vygotskian perspective and highlights the role of social interaction in the development of an individual's conceptual understanding and, secondly, research carried out in the field of conceptual change (e.g. Chi 1992, 2005).

To prepare myself for the interviews with the teacher and pupils, it was necessary to 'map out' the lesson according to how I interpreted the events in

the classroom. My interpretations acted as a guide to help me select video extracts from the lesson to show the participants for them to comment on. The following table shows the research questions that were used to guide this stage of the inquiry together with the theoretical bases, which underpins the question(s).

Table 3.4. Sociocultural and conceptual change framework and fieldwork questions that guided interviews

Theoretical Basis	**Fieldwork research questions that guided observations and interviews**
Sociocultural Theory	
The teacher introduces the concept/idea in an authoritative manner (i.e. transmission style) or the ideas emerge through dialogic talk (Scott, Mortimer and Aguiar 2006)	Were any new concepts and ideas introduced? What were they? How were they introduced into the discourse?
	At what stages during the lesson was this done?
	Who introduced the idea/concept?
	How did the idea/concept develop in the discourse over time?
	How was the concept represented in both verbal and non-verbal discourse?
Language as a symbolic system (Vygotsky 1986)	What aspects/features of the concept were explored?
Conceptual change theory	What aspects of the concept did the pupils appear to find challenging?
Ontological understanding of concepts (Chi, 1992, 2005)	

3.9.2 Interviews

Having 'mapped out' the data according to the questions in table two, I was able to identify sections of the lesson that appeared particularly significant when exploring how the participants construed and represented the abstract concepts under investigation. Both the teacher and pupils were asked to participate in a number of a stimulated recall interviews either on the day of the lesson, as was the case with the teacher or a week after the lesson took place, as was the case with the pupils. During these sessions I also had the opportunity to interview the

participants. With the teacher I used a semi-structured interview approach. Dörnyei and Ushioda (2013) note that semi-structured interviews are suitable for cases when the researcher has a good overview of the domain in question and is able to pre-plan some questions in advance, but does not wish to apply an overly rigid agenda which would prevent the respondent from exploring the issues in the appropriate amount of depth. The interviews were seen as additional means of generating data to the recordings and observations made during the lesson. Their main purpose was to provide an extra layer of depth to the analysis, by providing the perspectives of the teacher and a group of pupils on the learning event thus strengthening the trustworthiness of the analysis.

One of the main research methods used during the teacher and pupil interviews was stimulated recall, a technique used to aid the participants to recall a particular past event under investigation. When initially introduced as a research method, it was generally assumed that the video or audio recording would enable the participant to relive the episode and be able to provide an accurate verbal account of the original thought processes (Calderhead 1981). However, as van Manen (1990) points out, as experiences are transitory in nature; we do not understand or assign meaning at the time of the experience but through a process of reconstruction of that experience after the event has taken place. Therefore, the assumptions made throughout this research process were that the method provided a trustworthy account of the *reconstruction* of the event, instead of promising an accurate and reliable account of that original thought process.

Critics of the method go so far to say that it is impossible to reconstruct higher-order cognitive processes through introspection but only to recall *a priori* causal theories that the participant deems as relevant in explaining the outcome of their thoughts (Nesbitt and Wilson 1977). This might be the influence of the interview situation itself, which prompts the participant to account for their behaviour instead of exploring it non-judgementally. To mitigate this phenomenon, I adopted the approach suggested by Seidman (2013), namely, to ask the participants directly to reconstruct the event (e.g. Can you tell me what

happened? Can you tell me what was going through your mind?) rather than asking them to rationalise their behaviour (e.g. Why did you do that?), unless this was a genuine question (i.e. it was not clear from the video why the teacher had picked something up).

To further ensure a trustworthy reconstruction of the event I aimed to avoid leading questions but rather stated what I thought and asked directly for a response. This technique proved to be an effective one, especially with the teacher with whom a more co-participatory approach to the sessions was necessary in building up trust. Furthermore, open questions were asked to establish the territory I wished to explore, but allowed the participant to direct the interview towards what they wanted to talk about (Seidman 2013).

3.9.2.1 The teacher interviews

The teacher was interviewed to find out his perspective on the lesson, in particular with respect to what he thought the teaching purpose was. The main focus of the interview questions, that I planned prior to the interviews, was to check my understanding of the lesson I had observed in the morning of the day of the interview. During the teacher interviews, I was able to confirm whether the concept introduced into the discourse was indeed new to the pupils. I was also able to explore the teacher's assumptions about the pupils' prior knowledge, and ask whether he expected the pupils to find the concepts challenging or not and why. These questions allowed me to gain a more trustworthy understanding of the overall teaching purpose of the stages of each lesson. The questions asked were similar to the following:

- Was this idea/concept new to the pupils?
- What did you assume the pupils knew about the concept?
- How challenging did you expect the pupils to find the concept?
- How challenging did you expect the pupils to find the concept in the way it was represented in the diagram (or text)?

We met, on average, once a week. The teacher was asked to reflect on and critically evaluate selected episodes of the previous lesson. These interview

sessions were audio recorded and the interview lasted between 15 and 30 minutes. It was anticipated that as the teacher expressed some interest in my research, for his own professional development, his own particular interests might have determined the focus of these sessions. To ensure that I covered the material for my own research, I asked very focussed questions at the beginning of the session to obtain the data I needed before allowing for a more unstructured interview to explore issues as they emerged from the interview.

3.9.2.2 The pupil interviews

Each week, a small group of pupils (2-4) were chosen to participate in an interview. As the interviewed pupils missed 15 minutes of the main lesson a rota was put in place to ensure that no one pupil would miss more than 15 minutes from each learning unit. The group that was selected, was also the group which had been recorded during the lesson. The approach to interviewing the pupils was different to the teacher's in that although my main purpose was to explore their understanding of the concepts in the context of the lesson, as was in the teacher's interview, I wanted to reduce the anxiety the pupils might feel when interviewed. I therefore reduced the number of pre-planned questions, but exploited different eliciting techniques that are outlined in the following section.

During the interview, the pupils were shown an episode from a lesson that had taken place during the previous week. I had selected an episode from the lesson based on the sociocultural and conceptual change theoretical frameworks, illustrated in Table 2, that I had employed to interpret the events. This episode had in many cases been shown previously to the teacher. However, sometimes it was not always possible to show the same extract to both the teacher and pupils to obtain a multi-perspective take on the episode as the teacher was not available to be interviewed every week. As the pupils found watching themselves on a screen an amusing, possibly embarrassing experience during the pilot study, I began each session by using a technique suggested by Snell and Lefstein (2014), namely the silent viewing approach. Here, I first showed the pupils the episodes without sound and ask questions, which elicited from them their memories of

the event (*Can you remember what you were learning here? Can you remember what was said?*).

In addition to the stimulated recall sessions, I also included mini tasks which had been primarily designed to either reconstruct a learning moment in the lesson or generate a response from the pupils in relation to an aspect of the concept being taught. These included:

a) showing the pupils the same diagrams that had been shown to the whole group but allowing the pupils in the interview to give their own individual response;
b) word association tasks: pupils were provided a list of the key words and asked to say what they meant;
c) pupils were given different sentences describing a picture and asked to state which best described the picture;
d) asking pupils to draw diagrams of what was 'going through their minds' at that moment.

3.9.3 Fieldnotes

During each lesson that I observed, I wrote notes recording descriptions of the events that took place in the classroom, thoughts and comments made during informal discussions with the teacher, and occasionally with the pupils, in addition to subjective interpretations of the events as they unfolded. The notes were a useful source of information about the classroom environment, which could not be video nor audio recorded. They also provided a means to reflect on the events, thus offering an extra layer of criticality.

3.9.4 Transcribing

I video recorded 16 hours of classroom observations together with 11 video/audio recordings of group work sessions that formed part of these lessons, 5 teacher interviews and 9 pupil interviews, that were either video or audio recorded. All the recordings were listened to after the sessions and rough transcriptions were made using the software Inqscribe, that allowed me to upload the videos onto a viewing window adjacent to the transcript page. These were stored on a password protected device and anonymised, using a code system that allowed

me to identify the individual members of the class. The software enabled me to record the time on the transcription, which facilitated the process of revisiting episodes in the recording and matching them to the section in the transcript. The purpose of transcribing the recordings during the data collection stage was to develop questions that would guide the teacher and pupils' interviews (see Table 3.4.). The act of transcribing drew my attention to specific episodes, which enabled me to formulate my questions.

Once the data collection period had passed, I selected episodes to analyse in more detail. I decided to represent the spoken utterances as a written text showing as much detail as possible; thus representing on page aspects of speech related to pausing, word stress, intonation and overlapping. I used the transcription conventions used by ten Have (1999) – see Appendix A. Heath and Luff regard transcribing as an analytic tool that provides the researcher a possible means of gaining new insights into the participants' conduct, by observing their socio-interactional organisation (1993:309). Attending to details in the transcription encourages the researcher to attend to events, often quite intensely, that would have been otherwise left unnoticed (ten Have 2007). This was particularly the case during 4.2, when the teacher re-introduces the concepts of *temperature* and *heat* into the discourse from a previous lesson. Deciding to transcribe the event by paying attention to the teacher's intonation, word stress and pausing alerted me to how he was using his voice to evoke the pupils' memories of the previous lesson.

Once the recording had been transcribed, it became possible to re-read the transcripts several times to become intimately acquainted with the learning episodes. The transcripts together with the original recordings, field notes and classroom material led to the selection of the topics found in Chapters 4, 5 and 6.

3.10 Scientific trustworthiness

This section demonstrates how the research design as outlined in the previous sections secures a sufficient degree of scientific trustworthiness, following

Johnston and Smith's notions of validity within a critical realism paradigm (2010). Critical realists are concerned with whether the generative mechanisms that they have hypothesised exist, in other words do the mechanisms outlined in 2.7 and 2.8 cause the events that they observe? Translated to this particular study, a high degree of design validity was ensured by 'identifying, scoping and prioritizing' Zachariadis et al. 2013:6) the boundaries of the study. As previously mentioned in section (longitudinal study), the choice to carry out a case study with this particular school, class and teacher was made with the assumption that as this was an average performing school, with a committed, experienced teacher there would be learning, and more specifically, learning of scientific concepts taking place. Deciding to carry out the study over four months, enabled me to identify these episodes more readily, it provided me with sufficient amount of data to be able to disregard lessons or occasions when groups of pupils were away on school trips. Furthermore, as the phenomenon under investigation was conceptual development, it was necessary to collect the data regularly over an extended time period, to ensure that a development would manifest itself. By ensuring a healthy degree of design validity this way, the quality of the case study is improved in that the data generated is to a large extent not unrepresentative of a wider population.

An integral part of a study's design validity is whether the generated data is credible, which being a term closely associated with qualitative paradigms, applies to this study in that the results need to be credible to the wider audience. The credibility of a set of data can be ensured by prolonged engagement, persistent engagement and triangulation (Guba 1981). All the lessons observed were both video and audio recorded, which resulted in a high level of accuracy of the events for the transcription process. The interviews that took place soon after each lesson were an important way to check the accuracy of the observations and impressions made (Fraenkel and Wallen 2006). Within a realist paradigm which relies on multiple perspectives on a single reality, triangulation is a means by which a study may be strengthened (Barbour 1998; Healy and Perry 2000). My fieldnotes offered a further means of triangulating the results, as they unfolded during the investigation stage, in that it provided

a reflexive space for the researcher to uncover any biases and to adjust any research decisions during the data collection process.

Both the video and audio recordings, transcriptions and the fieldnotes were an important part of the Text World Theory analysis, which took place after the fieldwork. Due to the fallibility of my memory, being able to immerse myself in the events of the classroom by observing and listening to the recordings allowed for a more rigorous description and analysis of the events.

A note here needs to be made with regards to the analysis made and the largely introspective nature of the approach taken. To ensure a high level of trustworthiness and credibility, it is necessary to produce an analysis of quality. To achieve this, the analysis aims to conform to Simpsons' (2004:3) 'three Rs' of stylistics, namely it should be *rigorous, retrievable and replicable*. By a rigorous analysis, Simpson means that it should be underpinned by a framework that explains how the mind processes the various patterns in language. To ensure that the analysis is retrievable it has been organised by using terms and criteria that the community of stylisticians have agreed upon. This allows for other readers, familiar with these terms and criteria, to retrace the steps taken throughout the analysis. Finally, the analysis aims to be replicable in that its methods are made transparent so that other readers are in a position to verify them.

3.11 Conclusion

The purpose of this chapter was to outline my epistemological position, provide details of the research context and present my research design. In line with the experiential realist position that underpins the text-world approach, I outlined how the research paradigm, which guided my investigation, was a critical realist approach. I explained my rationale for adopting this position by describing how throughout my investigation, I made the assumption that independent structures (e.g. private thoughts, heat energy, atoms) exists, but are only accessible to an active subject through the person's subjective construal of them. As the purpose of my investigation was to examine these various structures and processes in a

classroom environment, and provide an account of how they interact and emerge during the learning process, a case study, with a predominately qualitative naturalistic inquiry approach was adopted to carry out the investigation. I then mapped out the chronological timeline of the research process, highlighting the considerations I made during the initial stages (sections 3.4), the ethical considerations (section 3.4.1) before providing a detailed description of the research site (3.5); the participants (section 3.5.1)), the science lessons and the wider school curriculum context (3.6) and the pilot phase (3.7). Once the preliminaries had been established, I presented an account of the main data collection phase that lasted four months. I argued that a longitudinal approach was necessary as a prolonged engagement with the classroom environment meant that the phenomenon under investigation, namely, conceptual development, was more likely to manifest itself as it afforded an in-depth understanding of the context of the classroom and the syllabus.

In section 3.9, I presented my research methods for collecting and analysing the data. I rationalised that gaining multiple perspectives on a learning event would strengthen the credibility of the investigation (Guba, 1981; Barbour 1998; Healy and Perry 2000). I explained how I undertook stimulated recall sessions and interviews with both the teacher and small groups of pupils focussing on specific learning episodes recorded in a previous lesson. Section 3.9.4 described how the recorded data was then transcribed into a written format that was suitable for a fine-grained cognitive discursive analysis. Finally, in section 3.10 I explained how I ensured scientific trustworthiness of the study, concluding that the quality of the analysis was achieved by ensuring that the analysis was rigorous, retrievable and replicable (Simpson 2004).

Chapter 4: The introduction of abstract scientific concepts into the classroom discourse

4.0 Introduction

The preceding chapters provided the background to the case study analysis that this chapter and the following two chapters will present. Chapter 2 outlined the main tenets of conceptual change research, a research agenda which is concerned with how abstract concepts emerge, develop and change in a learning situation. An overarching theoretical explanation of how this thesis positions itself in relation to this research was presented. This acts as a backdrop to the linguistic analysis carried out in this thesis. Part two of the literature review (Chapter 2), provides an account of the Text World Theory framework, the theoretical context in which this model is situated, and a rationale for using a Text World Theory approach. Chapter 3 presented my research design and details of the research context. The aims of the present chapter that are in line with the aims of the thesis, are as follows. First, it aims to provide an account of how the **abstract concepts** of *heat, temperature, heat transfer, conduction* and *an insulator* are constructed, and linguistically represented in discourse over two consecutive lessons that took place a week apart from each other on the 18.03.15 (appendix one/CD) and 25.03.15 (appendix two/CD) respectively. The second and third aims are to demonstrate the suitability of the text-world framework to investigate the development of abstract concepts in discourse. To meet these aims, a cognitive discursive analysis of the following five episodes is made.

The first episode focuses on how Mr Dalel, the teacher, at the very start of a lesson re-introduces the concepts of *heat* and *temperature* that the pupils had been working with during their previous lesson. The second episode investigates a class demonstration, during which the concepts of *heat transfer* and *conduction* emerge from the discourse-world of the immediate situation. These two concepts constitute the main learning objective of the lesson. Continuing from this, an exploration is made of how Mr Dalel and the pupils simulate the atomic structure of a solid, by means of a role-play, in order for the pupils to develop an understanding of the process of *heat transfer* using the particle

theory of matter. After the role-play, the pupils write in their jotters a definition of *conduction* to consolidate the learning that has taken place up until that point. The fourth episode analyses how the teacher 'unpacks' the term *process*, which forms part of this definition. The final episode explains how the concept of an *insulator* is linguistically represented as it is introduced into the discourse. The first four episodes take place during the same lesson (18.03.15 – see appendix one) and the final episode takes place during the second lesson (25.03.15 – see appendix two).

To gain some insight into how the pupils as individuals experienced the lesson, and understood the scientific principles behind some of the classroom activities, a two Pupils Yelena (P3) and Suzy (P6) were interviewed a week later (25.03.15 – see appendix three/CD). They were shown the role-play (without sound) and asked to comment on what was taking place. This is compared with a short exchange, which took place with a pupil and the teacher during a group activity during the lesson (18.3.15).

As established in the literature review, the meaning construction process is dependent on the wider sociocultural context it is part of. Therefore, the sociocultural context of each learning unit is presented near the start of each learning episode. This consists of (1) a *genre* analysis, based on Scott and Mortimer's framework (2003) (see section 2.3.1) and (2) the *teaching purpose* of the episode as understood by the researcher during the initial stages of the analysis and confirmed by the teacher in an interview. I drew on my own fieldnotes I had made whilst observing the class, observed recordings of the lessons, analyses of the transcripts, notes and recordings made during the teacher's interview, in addition to the literature to determine the sociocultural situation of the learning episode. This knowledge of the sociocultural context becomes part of the discourse-world at the time of the analysis. It is presented at the beginning of the main analysis to serve as an orientation point for the reader to situate the purpose of the learning context before the main text-world analysis, that then offers a more nuanced account of the conceptual architecture of the participants as the discourse unfolds.

As established in Chapter 2, part two, Text World Theory is strongly grounded in the principles of cognitive linguistics, and as a result frequently adopts

mechanisms from other cognitive linguistic theories. Similarly, this analysis integrates Conceptual Integration Theory (1998, 2005) into the Text World Theory analysis. Both these theories have 'similar traits' (Brandt 2013: 209), in that they focus on how conceptual spaces are created in the mind to represent a perceived sense of reality. Conceptual Integration Theory uses a similar construct to a text-world, namely a 'mental space' to explain how the mind is able to conceptualise a state-of-affairs. Its primary focus is on the basic mental operations that work over mental spaces to create new meaning by "blending" different scenarios. This blending process conforms to a set of constitutive principles (Fauconnier and Turner 2002): i. Counterparts from each input mental space are connected by a partial cross-space mapping. Here, the mind makes a connection between the two counterparts from the different scenarios; ii. A third mental space contains what each of the two inputs have in common, this is the generic space; iii. A new, emergent structure, the 'blend' or 'blended space' is formed through a selective projection from the inputs into the blend. The central features of conceptual integration are illustrated in Figure 4.1

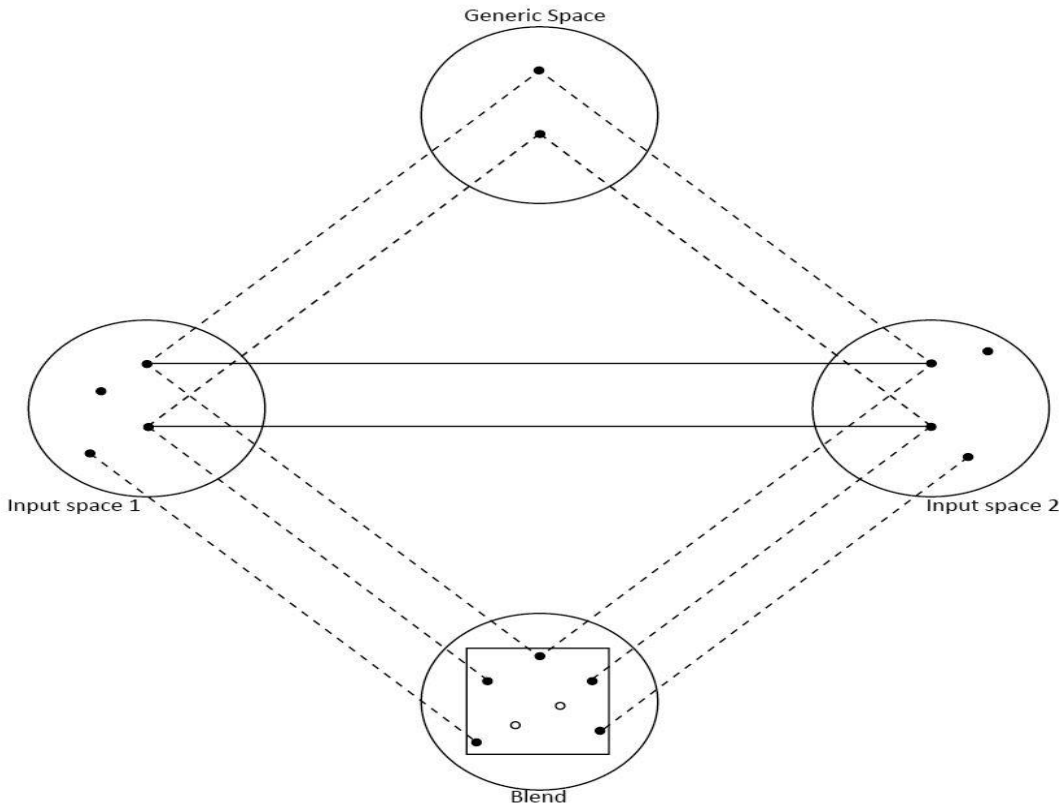


Figure 4.1. Conceptual Integration: the basic diagram (Fauconnier and Turner 2002:46)

It is important to note that the processes involved in constructing new meanings are not, as this diagram seems to suggest, static but are 'dynamic, supple, and active in the moment of thinking' (Turner 1998:133). Blended spaces were first introduced into the Text World Theory framework by Gavins (2007a) and have been adopted widely by text-world theorists since. In line with Text World Theory's notion of a 'world' the blended space in Text World Theory is referred to as a blended world.

Conceptual Integration Theory has been criticised, however, for not accounting for how the process of selective projection chooses the elements from the input space. Furthermore, it also does not explain how different metaphors (e.g. this surgeon is a butcher) can have different meanings, depending on the context they are spoken in. To address these shortcomings, Brandt and Brandt (2005) developed Fauconnier and Turner's (2002) Conceptual Integration Theory to explain how the context of the discourse can be incorporated into the analysis. Brandt and Brandt (2005) maintain that the blended space does not solely depend on the elements in the two input domains but also on the context. For this reason, they abandon Fauconnier and Turner's context-free generic space and instead, they propose a context driven construction process. A basic model of their version of blending is illustrated in Figure 4.2.

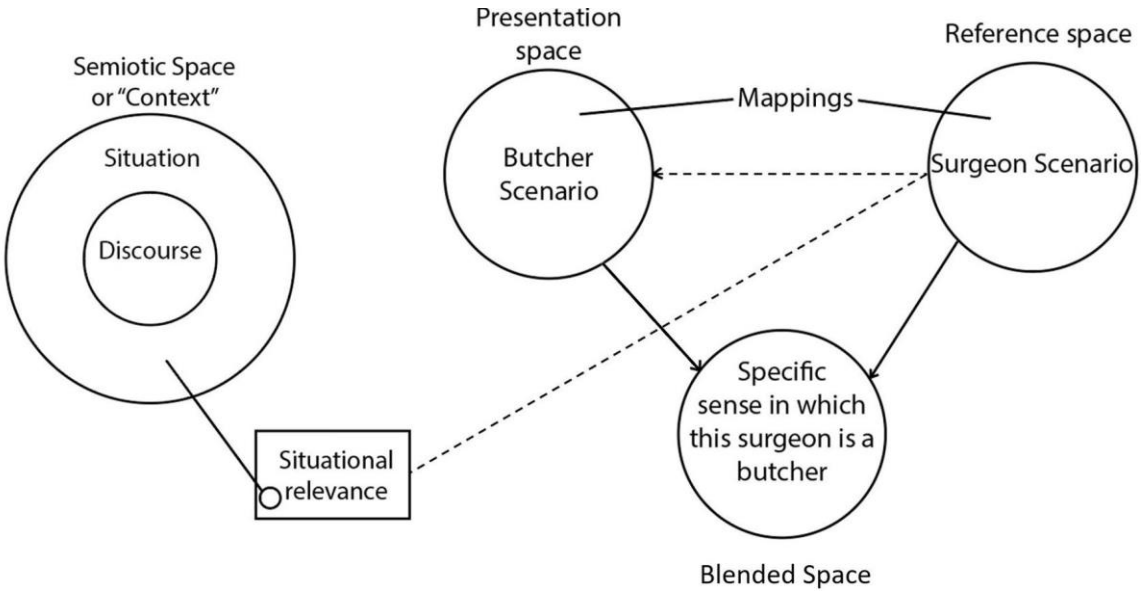


Figure 4.2 The context-dependent blending theory: 'the surgeon is a butcher'

The dotted arrow indicates that the communicative situation (i.e. context) prompts the retrieval of the two input spaces in order. First, the reference space, based in the real-world situation, and then the presentation space. For example, if we are talking about a particular surgical event, the input space of the surgeon is made available in the reference space. Based on the purpose of communication (e.g. proposing that the surgeon is heavy-handed), a presentation space that includes elements from the speaker's background knowledge (e.g. a butcher) is then retrieved and the relevant elements are mapped onto the reference space. The solid arrows represent selective projection. The goal of communication, captured through the situational relevance, determines what elements from the two spaces are projected into the blend.

Conceptual Integration Theory has been applied in this analysis to learning situations, in which the pupils are required to either make a prediction or understand a phenomenon that they cannot see using an analogy. In both cases, the analysis reveals the difficulties the pupils might encounter during the blending process, either due to constraints caused by classroom management issues, or by unforeseen gaps in the pupils' knowledge frames. To acknowledge the role that the context plays in the process, this thesis has adopted the Brandt and Brandt (2005) version, choosing to refer to the blended space as a blended world.

One further cognitive linguistic concept, which is frequently employed in this analysis, is the image schema (see section 2.6.5) (Lakoff and Johnson 1999). This chapter will demonstrate Mr Dalel's ability to construe and anticipate how the pupils might be conceptualising the *heat transfer* process during the demonstration. The underlying SOURCE-PATH-GOAL image schema appears to be one of the main motivating factors behind the language choices made by both Mr Dalel and pupils when referring to, and communicating their ideas about, the heat transfer process.

4.1 The discourse-world of the lessons

The lessons on heat transfer and insulation, that are the focus of this chapter, took place in Mr Dalel's classroom that was situated in the science block of the school building. During the lesson, the participants, who included the twenty

pupils, Mr Dalel and myself the researcher, formed part of a discourse-world (discourse-world lesson). In addition to the participants, this discourse-world consisted of the perceivable objects around us, the spoken and written texts that formed part of the lesson and all the knowledge, memories, imagination and beliefs that the participants brought to the discourse situation. As the participants are engaged in face-to-face communication their spatial and temporal position is shared, which in turn means that they occupy the same discourse-world. Throughout the lesson the participants have direct access to all the objects in the classroom, which include the five pupils' desks and chairs, the work bench situated along the wall of the classroom, Mr Dalel's desk and computer table at the front of the room, the whiteboard and the various wall displays and equipment typically found in a science classroom. It is important to mention and acknowledge these objects as their presence has a direct impact on the flow of the discourse, which becomes especially notable during the demonstration and role-play (when the pupils' bodies themselves become the objects!). One further feature of this discourse-world is the ability of the participants to be able to gauge and probe each other's cognitive states, which also impacts on the structure of the discourse.

After the lesson, this discourse-world ceases to exist in the present and is only indirectly accessible via the transcripts. The participants of the first discourse-world (lesson) cease to exist as real people and become textual entities during the analysis, known as 'enactors' (Gavins 2007a: 41) During the analysis stage, that would take place over a series of weeks often several weeks after the lessons, a new discourse-world (discourse–world analysis) was created that consisted of the office I worked in, and the body of knowledge and ideologies I had accumulated during my academic studies. As highlighted by van der Bom, who first applied a text-world approach to analysing transcripts of face-to-face interactions, I became just an eavesdropper on a separate discourse event (van der Bom 2015: 95). This has consequences on how analysts view their data and transcripts. As I was present during the lesson, and the fact that I had acquired detailed knowledge about each of the participants over the six months in the school and was able to ask for clarification from both Mr Dalel and the pupils after the event, the participants seemed ontologically more real than mere textual entities, or enactors, during the analysis. For this reason, the

participants of discourse-world (lesson) will be referred to by their names or roles e.g. Mr Dalel, Sally or teacher, unless the terms enactor or participant add clarity to the analysis.

4.2 Episode one: re-introduction of 'heat' and 'temperature' into classroom discourse

Date: 18.03.15 **Time:** Start of lesson [00:05:02.16]

Topic: Heat Transfer and Conduction

Purpose: To re-introduce temperature and heat in to discourse and to ask pupils to provide explanation for why temperature is different from heat.

Direct Observation (from researcher's field notes) *The teacher settles pupils as they come into the classroom by asking them to remember an experiment they carried out on heat and temperature. He uses a lot of long pauses to tune pupils' attention towards the focus of the lesson.*

T: okay boys and girls. thank you Zhou in you come jacket off please bags down planner out and Imran and Zarif. We,? (3.0) were,? (3.0) talking about,? (2.0) tEMperature, (4.0) ↓ weren't we, (1.0) we were ALso (1.0) talking about (.) and thinking about (.) doing experiments about (.) ((Person A distracts T by picking up keys from front desk)) er ↑ heat (((T places emphasis on t))) (3.0) weren't we. thank you ((speaks to A as she leaves room)) (.) NOW (.) we sa:id that (.) hE::t (.) in actual fact (.) is different (2.0) from temperature. (2.0) cos TWO things (.) can have (1.0) the same temperature. (.) two substances (.) like two beakers of water (.) can have the same temperature (.) like boiling water both at 100 degrees Celsius (.) right? remember? (1.0) but one has more heat energy in it than the other (.) ↑ why was that (.) that one had more heat energy than the other (.) SUMYA (5.0) go and THINK about the experiments of heat and temperature we did in pairs (.) go and think about what we found out and how temperature is different from heat from heat energy (.) go on

Extract 4.1 *from lesson one, appendix one, lines 1-15*

4.2.1 Situating the first episode: teaching purpose and socio-cultural analysis

Part of the knowledge that both the teacher, researcher and to a certain extent the pupils bring to both the discourse-world of the lesson and the analysis, is an

understanding of what the teaching purpose of the event is. This aspect of these discourse-worlds is as follows. The curriculum requires the pupils to understand the difference between *heat* and *temperature*. The teaching purpose of this episode is to ensure that the pupils can explain the difference. Mr Dalel guides his pupils to work with the scientific meanings thus supporting the internalisation process (Scott and Mortimer 2003) in three steps: he asks the pupils to recap the previous lesson by (1) reminding them that *heat* is different from *temperature* and (2) asking them to remember the results of the experiment i.e. the phenomenon of what they saw. Finally, immediately after this, he asks them to (3) provide an explanation in groups of why two beakers of different sizes with water with the same temperature have different heat energies. From the teacher's interview, a week later (date: 25.03.15), he made the point that the pupils often find it difficult to understand the difference between *heat* and *temperature*, which might explain why he decided to reinforce this point at the beginning of the lesson

51 **T:** the concept of heat they have more difficulty with yeah um because the
52 concept of heat they don't understand that because I've asked them a
53 couple of times since then if you've got boiling water at 100 degrees
54 Celsius and you've got 250 ml of that boiling water and you got 50 ml of
55 boiling water in another flask you've still got a temperature of 100
56 degrees Celsius for both flasks which one is going to have more energy
57 they often say the smaller cos the smaller volume yeah so they are
58 having difficulties with that concepts

Extract 4.2 *from teacher interview, appendix four, lines 51-58 (25.03.15)*

A striking feature of episode 4.1**,** is the shift Mr Dalel makes from generalisations to referring to a specific situation, which a genre analysis based on Mortimer and Scott's (2003) sociocultural framework establishes. Mr Dalel first provides a number of 'generalisations' (Mortimer and Scott 2003: 32), (e.g. 'now we said that heat is in actual fact different from temperature' (line 7-8), 'two things can have the same temperature' (line 8-9) and 'like two beakers of water can have the same temperature like boiling water both at 100 degrees' Celsius (lines 9-11)). He also provides a 'generalised theoretical description'**,** 'but one has more heat energy than the other' (lines 11-12) (ibid.: 31), which goes beyond the visible phenomenon as he refers to a theoretical entity (heat energy). The teacher switches from generalisations to referring to the specific experiment that the pupils carried out in the previous lesson only in lines 11, 'but one has

more heat energy than the other why was that that one had more heat energy than the other'. This pattern, moving from generalisations to a specific concrete situation is unusual in this teaching context and as will be demonstrated by the following text-world analysis, is cognitively challenging for the pupils.

As the main pedagogical purpose of this episode is to ask the pupils to provide an explanation, one might expect Mr Dalel to simply to have asked the question: "Why do two beakers of different sizes with water of the same temperature have different heat energies?" Instead, Mr Dalel chose to ask this question at the end of a long introduction over a series of utterances and turns in which the concepts of *temperature* and *heat* energy are incrementally re-introduced into the classroom discourse. As this episode proved to be a successful piece of communication (overall, the pupils demonstrated in the group activity which followed that they understood what was expected of them), it is assumed that the teacher's successful assessment of the listeners' mental cognitive states, or ability to 'mind-model' his pupils' cognitive states (Stockwell 2009), strongly determined the manner in which he chose to conduct the task. Mind-modelling is a cognitive linguistics term, coined by Stockwell (2009), that explains how we construct models of how others around us think and behave the way they do, in order to understand them. Having only direct access to our own thoughts and feelings, this model is based on a construct of ourselves. However, through our daily interaction with others our model of them can change as we interpret clues from the immediate context (e.g. the manner in which they speak). Schematic knowledge we have built up of the person over time and more generic knowledge of people related to their age, gender, cultural background and role, for example, is also used in the mind-model construction process.

As sensitivity to the audience and an ability to mind-model is a fundamental part of effective language use in the classroom, it is particularly interesting to note how Mr Dalel builds up to the main purpose of this episode. He asks the pupils why two beakers of different sizes with boiling water have different heat energies by referring to a learning unit that was physically displaced from the pupils in which the concepts *temperature* and *heat* were part of. This is arguably a more cognitively challenging task than if the pupils were to observe the phenomenon as part of their present discourse-world. And secondly, how in

order to achieve his first objective, he uses a number of communicative strategies to evoke a text-world situated in the past. Communicative strategies are defined, here, as methods of interaction that participants engage in to build knowledge together (Hendriks and Maor 2004:7). Having situated the start of the lesson in terms of its context, the following will explore the creation of the text-worlds created by the participants.

4.2.2 Evoking a text-world

Werth's definition of Common Ground (CG) is as follows:

> *(1) at any given point in the current discourse, all those propositions which have been expressed and tacitly accepted, together with:*
>
> *(2) any propositions evoked by (i) from general or mutual knowledge, though not necessarily expressed. (1999: 49)*

Mr Dalel builds up to his main purpose incrementally by using various communicative strategies, which convey his assumptions about his common ground, and also the current cognitive status of the key concepts for his pupils. To understand this phenomenon, it has been argued in the literature review section that reference to cognitive models, which place how the participants of the discourse-world experience the discourse or how the participants assume their audience experiences the discourse, should be made. Particularly suitable for this task is Werth's notion of a text-world, which he defines as 'the conceptualization of that part of the discourse-world which is 'in focus' for that part of the discourse … it is the situation depicted by the discourse' (1999: 86 – 7). Essentially, text-worlds are created by the participants as soon as the discourse commences. Despite claims that Werth's Text World Theory can be applied to any text, Werth does not refer directly to the use of communicative strategies during face-to-face interactions in his monograph. The following will explore how the various communicative strategies employed the teacher are used to create the relevant text-world and constrain both the production and reception of these text-worlds, and therefore the concepts the teacher and pupils are focusing on. In particular, references to Chafe's (1994) seminal work on intonation and consciousness have been made during the text-world analysis of this episode.

4.2.3 Establishing a common ground: building a text-world situated in the past

Before Mr Dalel moves to the key part of the episode, namely, when he asks the pupils why the heat energy levels of the two beakers were different, he uses a range of communicative strategies, including a number of intonation patterns, to activate the relevant common ground. The concepts of *temperature* and *heat,* activated at this point, need to be intersubjectively shared in the same way as when they are used in the question he will pose at the end of the episode in order for the question to be understood in the same manner as the teacher intends.

The range and purpose of communicative strategies he employs can be summarised as follows. The class together with Mr Dalel, represented by the pronoun 'we' has a prominent authorial presence. An additional use of the pronoun 'we,' used repeatedly in lines 2 – 7, is possibly to strengthen the interpersonal dimension. This deictic term used in lines 2-7 (extract 4.1), together with the use of the past tense (were, said) is used to build a text-world that is clearly situated in the past. The pupils' mutual knowledge of their past learning experience places this text-world in the time zone that the learning took place (presumably the previous lesson). Figure 4.3 shows how the reference to a past time-zone with 'were' triggered a world-switch, which created a new text-world (labelled text-world 2). Emerging from text-world 2 are a number of epistemic modal-worlds. One of these worlds is shown in Figure 4.3 as 'eps'. Furthermore, in lines 3 and 6, Mr Dalel uses twice the question tag 'weren't we,' in line 11 he says 'right?' and uses the metacognitive device and imperative verb 'remember'. Imperative verbs are classified by Werth (1999) as function advancing propositions (see section 2.7.2.1). Conceptually, they operate similarly to a deontic modal item in that they place the listener under some obligation to act. In Figure 4.3, the imperative 'remember' and 'in you come' are shown to emerge from text-world 1 as 'imp'. Not all the imperatives in lines 1-2 are shown as there too many to fit in the diagram. He uses a 'are you following me intonation', with 'right?' and 'remember?' (i.e. an intonation device, typically used to seek confirmation (Bolinger 1989). These strategies are used to provide a link between the immediate discourse-world of the participants and the evoked conceptual space or text-world situated in the past

that Mr Dalel wishes the pupils to create. Moreover, as established in section 4.3.1, Mr Dalel moves from providing generalisations to referring to the specific experiment only in line 11. Creating a text-world of a past learning experience (text-world 2 Figure 4.3), in which these generalisations are made must be cognitively quite challenging.

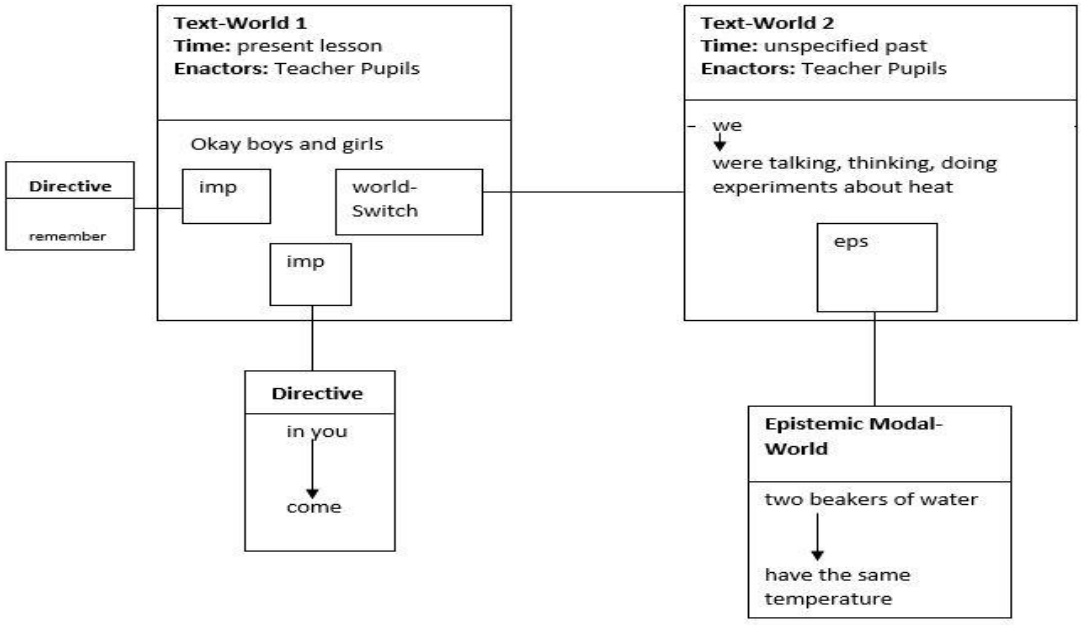


Figure 4.3 Overview of text-worlds created during lines 2-12, episode 4.1

4.2.4 Re-introduction of concepts 'temperature' and 'heat' from previous lesson

The two key concepts **temperature** (line 3) and **heat** (line 5) are introduced into the conversation separately at the start of the episode.

1 ***T:*** okay boys and girls. thank you Zhou in you come jacket off please bags
2 down planner out and Imran and Zarif. We,? (3.0) were,? (3.0) TALKing
3 about,? (2.0) TEMperature, (4.0) ↓ weren't we, (1.0) we were ALso (1.0)
4 TALKing about (.) and THINKing about (.) DOing exPERriments about (.)
5 ((Person A distracts T by picking up keys from front desk)) er ↑ heat

Extract 4.3 *from lesson one, appendix one, lines 1-5*

In lines 2 – 5, the prominence is placed on the processes *TALKing, THINKking* and *DOing* and the objects, *TEMPerature, exPERiments* and ↑*heat*. According to Chafe's (1994, 1996) model of information management, the prominent item of an utterance is reserved for information which the speaker wishes to

foreground. In this case, the prominent words belong to a text-world that is removed from the pupils' present surroundings. Evoking the text-world that these world-building elements are a part of, has a relatively high processing burden or 'activation cost' (1994:73).

Mr Dalel chunks each new piece of information into clear, distinct information units, which have long pauses between them allowing time for the preceding knowledge to be activated (Chafe 1994: 63). This is clearly a strategy Mr Dalel uses to focus the pupils' attention, as this is the beginning of the lesson when the pupils are settling in their seats and will most certainly have other thoughts going through their minds. By analysing Mr Dalel's communicative strategies in this way, it becomes possible for the observer to locate the text-world that Mr Dalel wishes the pupils to be part of.

It might be supposed that the concepts *temperature* and *heat* in this episode are 'new' pieces of information as (1) they are expressed as a full noun phrase, (2) indicated by their position in the utterance and (3) the fact they have primary accents. However, as Chafe (1994) notes, there is not a simple clear-cut distinction between new and given information as these terms might suggest. First, it is important to determine the sense these terms have in the given context. *Heat* in this context is understood to be heat energy rather than a source of energy e.g. a Bunsen burner as it is used later in the demonstration. Furthermore, the information could be either new for the speaker or listener. It is clear, that these terms cannot be new for the speaker and it is unlikely that they are entirely new for the pupils either, as they had been referred to frequently in the previous lesson and are common everyday terms too. Chafe claims that a more accurate characterisation of new is that the terms are new *in this particular conversation* and that the prominence given to the terms activates them from a 'semiactive' state to an active state in the listener. The teacher by placing a prominence on *TEMperature* and *heat* this way demonstrates that he assumes (or that he is indicating to his audience that he expects) that these concepts are part of their mutual (private) knowledge which emerged during the previous lesson, and at the point at which they are mentioned they constitute the common ground of the current discourse.

This section has looked at how the abstract concepts of *heat* and *temperature* have been re-introduced into the classroom discourse by the teacher at the start of a lesson on conduction. The challenge of evoking a conceptual space, situated in the past by creating the text-world of a past learning experience (lines 2 - 11), in which theoretical generalisations were made must be cognitively quite challenging for the pupils. In sum, Mr Dalel anticipates this challenge and uses a number of communicative strategies to facilitate the task for the pupils.

4.3 Episode two: introduction of 'new' concepts, *heat transfer* and *conduction* into classroom discourse

The discourse-world of the second episode is as follows. This learning episode takes place at the back of the classroom on the work bench that is situated under the window. Mr Dalel stands next to the apparatus and the pupils are gathered around, some sitting on chairs and others standing. I stand behind the pupils close to the camera.

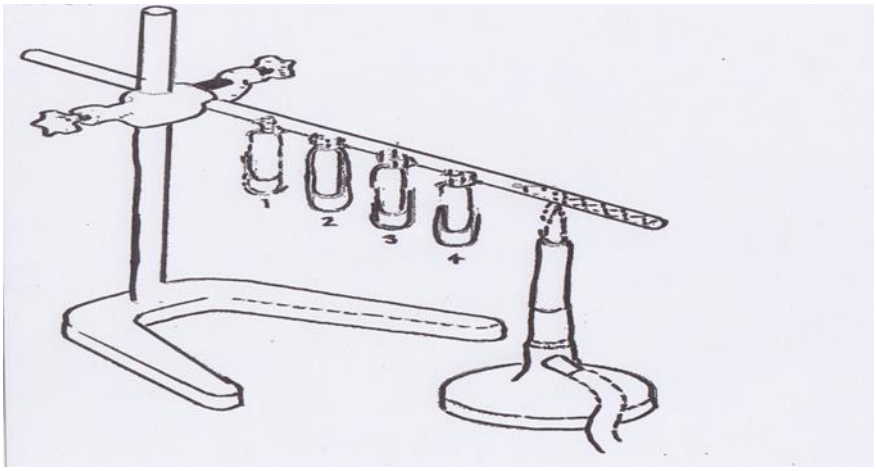


Figure 4.4. Diagram of apparatus used in demonstration

53 **T:** ↑come to the back here gu:::ys (4.0) come to the back come to the
54 back everyone stop what you are doing. (4.0) right boys and girls (.) I've
55 got ↑one ro:d rod here. what's a rod, a rod is just a straight bit of
56 something. (.) this one's made of mEtal, does anyone know what sort of metal it is

57 **P1:** copper

58 **T:** copper (.) how do you know. what colour's copper.

59 **P1:** it's browny red

60 **T:** it's browny red. (.) right that's copper. copper rod. (.) ↑ see that there?
61 (2.0) that's not a copper rod (.) it's a rod (.) it's another metal (.) does
62 anyone know what sort of metal it is?

63 **P2:** iron?

64 **T:** yes, iron (.) that's an iron rod? ok? understand? an iron rod. (1.0) and a ↑
65 copper rod, [0.5] does anyone know what ↑ this stuff is? (3.0) anyone seen
66 that before. (2.0)

67 **P3:** jelly

68 **T:** yeah petroleum jelly? has anyone ever used it before. (.) what do you use it
69 for

70 [inaudible]

71 **P3:** put it on ma lips

72 **T:** right (2.0) petroleum jelly (1.0) all I've done is, (.) transferred the
73 petroleum jelly (1.0) onto the rod. then then I'll take one of these, (3.0)
74 paper clips? you've seen these before? what do you use them for,
75 [inaudible] so (6.0) so I've got one? two? three? four, fi::ve? paper clips
76 right? (4.0) What do you think happens to the petroleum jelly? if I heat it up?

77 [inaudible]

78 **T:** TURNS INTO SOLID?! Right, let's try it (3.0) oh right? (3.0) smells, doesn't it
79 (5.0) We're doing an experiment now. (4.0) in this experiment boys and girls?
80 I'm going to heat the RODS UP that's the copper rod that's the steel rod. I'm
81 going to bring the Bunsen Burner over to this side? I'm going to hang the ↑
82 paper clips (1.0) with pieces of Vaseline (10.0) See what I'm doing? ↑ Four
83 paper clips onto the rod there? a:::::nd (2.0) clips and rods (12.0) clips the
84 clip there has gone [inaudible] the clip there has gone already hasn't it how
85 many have fallen so far?

86 **P:** [inaudible]

87 **T:** no they haven't. three. (5.0) what has happened to the Vaseline? (6.0)↑ why
88 has that not melted yet?

89 **P4:** is it because it far away from the

90 **T:** what is the heat supposed to be doing?

91 **P4:** travelling

92 **T:** travelling? very good, ok heat is tra::velling, isn't it? acro:ss the rod, (3.0)
93 heat's been trans↑ferred that one there? or that one. (3.0) what do you

94 notice? which one seems to be getting hot quicker, the ↑copper, or the
95 steel. the one at the ↑back? which one's that? the red one

96 **P4:** copper

97 **T:** copper,very good,↑what's the hottest part of the rod? this part, right, ↑
98 which one is the coldest part of the rod at the moment.

99 **P4:** this part

100 **P5:** the end

101 **T:** is it going to stay cold forever?

102 **P5:** no

103 **T:** what's going to happen to it?

104 **P4:** heat's going to travel

105 **T:** heat's going to tra:::vel? exactly? so what do you know about heat? it
106 doesn't stay in o::ne place it tra::vels along sOlidds in a straight line, (10.0)
107 we call that. (1.0) con DUCtion, you know the ↑word we wrote down.
108 conduction. (.) when heat travels from one side to the other side we call
109 that, con↑duction, heat gets transferred, ↑we you have to think about
110 things? (2.0) we are thinking about sub↑stances (2.0) we are thinking about
111 materials you have to think about particles? remember we got the water
112 ↑particles? yesterday, there were so↑lid particles? in the last topic, now
113 how were they arranged, how were they organised they were joined together
114 very very tightly, aren't they? what's starting to happen? Oh? one went there,
115 so WHAT'S THE BETTER CONDUCTOR DO YOU THINK STEEL, OR COPPER.

116 **P4:** copper

117 **T:** so copper is the better conductor you say, good stuff

Extract 4.4 from lesson one, appendix one, lines 53-117

4.3.1 Situating the second learning episode: Teaching purpose and socio-cultural analysis

By carrying out this demonstration Mr Dalel introduces the concepts of *heat transfer* and *conduction* into the classroom discourse. The syllabus requires the pupils to be able to explain the physical phenomenon of what they can see and understand during this demonstration, by using the theoretical model of the particle theory of matter which is that matter (solids, liquids and gases are made up of particles i.e. atoms and molecules. In contrast to the first episode, Mr Dalel moves from describing

a physical object situated in the pupils' immediate discourse-world to a more generalised description of a phenomenon which they cannot see. He begins this episode with a description of the apparatus, 'I've got one ro:d rod here, what's a rod, a rod is just a straight bit of something, this one's made of metal' (lines 54-56), to a description of his actions, 'all I've done is,(.) transferred the petroleum jelly onto the rod, then then I'll take one of these, paper clips?' (line 73-74).

He then refers to the cause of the phenomenon, 'What do you think happens to the petroleum jelly if I heat it up?' (line 76). Whilst waiting for the paper clips to fall he provides a generalised theoretical description, 'travelling? very good, ok heat is tra::velling, isn't it? across the rod, heat's been transferred that one there?'(line 92-93). Here, the focus is not on what the pupils can see but on understanding the concept of *heat energy* and the *transfer of heat*. However, immediately after this he refers to the apparatus and requests from the pupils a description, 'what do you notice? which one seems to be getting hot quicker, the copper or the steel' (lines 93-94).

Finally, although he does not provide an explanation during the demonstration he prepares his pupils for it by re-introducing the key words that he is going to use in the explanation e.g. particles (lines 110-114).

What is particularly interesting to note here, is the similarity in the features of the test question set at the end of the unit, the spontaneous model answer to the test question provided by Mr Dalel in the interview [18.03.15], as well as the language patterns employed by Mr Dalel during this demonstration. To see the test question, model answer and comparison see appendix D. This demonstrates his experiential knowledge frame for this explanation is very secure and well developed.

4.3.2 Developing a mental representation of the situation: from concrete to abstract

This text-world analysis focuses on the process by which the concepts of *heat*, *heat transfer* and *conduction* are introduced and maintained in the discourse. It will use Text World Theory as its basic framework as it can provide an account of how knowledge is organised in conceptual spaces. It is unlikely that the pupils

hold a clear singular thought of these concepts but that an understanding of them evolves over the duration of the demonstration. The text-world framework is particularly suitable for this task as it is a dynamic framework that tracks how speakers and listeners keep track of the discourse events. In addition, Conceptual Integration Theory (Fauconnier and Turner 1998, 2005), and the notion of image schemas (2.6.5) are employed in the analysis during specific moments as they offer a powerful explanatory account of the phenomena which appear to be taking place. These cognitive theories embed themselves well into the Text World Theory framework. They are particularly suitable for explaining how *heat, heat transfer* and *conduction* are conceptualised here as these items do not have specific clear referents in the physical world, but evolve from the interaction between the participants' perceptions of what they can perceive in the discourse-world (lesson) and their knowledge frames. Thus, these cognitive theoretical principles, that form part of my text-world analysis, provide a means of explaining how these concepts arise.

The concepts of *heat transfer* and *conduction* are introduced into the classroom discourse for the first time by means of a demonstration. The teacher, pupils, the apparatus for the demonstration and how they are referred to in the discourse by means of deictic terms such as *this, these,* and *I* are the world-building elements that are part Mr Dalel's and pupils' immediate situation. These world-building elements, as well as the knowledge frames that the teacher and pupils bring to the situation, form part of the initial conceptual level of the analysis, namely the discourse-world. The initial developing mental representation, or the text-world of the immediate discourse-world, which starts to evolve in the participants' minds is, therefore, firmly rooted in the concrete world of what the participants can perceive.

Prior to introducing the concepts of *heat, heat transfer* and *conduction* into the discourse, the teacher and pupils incrementally build up a mental representation of the key parts of the demonstration's apparatus that will feature as 'the referents that can be seen', which also feature in the final 'explanation' script that Mr Dalel has as part of his own explanation schema, that the pupils will later read when they write the test at the end of the unit. The first part of the demonstration is characterised by Mr Dalel identifying and naming the parts by

frequently employing a series of relational processes (Halliday 1994). As the term suggests, relational processes show how two elements are related to each other, either by one element being used to identify the other or one being an attribute of the other. The following examples illustrate quite clearly how the use of these relational processes 'serve to characterize and identify' the parts of the apparatus which the teacher wishes to foreground (Halliday and Matthieson 2004: 210).

I've got a rod; paper clips	possessive identifying
It's browny red	intensive attributive
That's copper	intensive identifying
It's another metal	intensive identifying

4.3.3 Propelling the discourse forward: preparing for the experiment

Once Mr Dalel has set the scene and has foregrounded the parts of the apparatus which are considered by him to be important elements of the mutual (private) knowledge to be held by all participants of the classroom, he starts to propel the discourse forward by commenting on what he does to the apparatus in order to prepare it for the experiment. These function-advancing propositions are in this case material intention processes (Werth 1999: 238; Gavins 2007a: 56), e.g. 'right all I've done is transferred the petroleum jelly' (line 72-73). Talking through the steps he took to set up the experiment may serve an additional function, namely, to add more detail to the pupils' demonstration frames and therefore their understanding of the apparatus. In line 80, he uses *heat* as a material process, 'I'm going to heat the rods up'. Interestingly, this description of the cause of the phenomenon later transpires to form part of his 'model' explanation in an interview held three months after this experiment took place. Again, this is evidence that Mr Dalel's knowledge frame of this explanation is very secure.

4.3.4 Adding levels of complexity: modal-worlds

Alongside this main text-world that the teacher and pupils create by engaging with their immediate discourse-world, are instances when Mr Dalel and the pupils create new text-worlds. The first instance of this occurs at the start of

the demonstration in line 55. By using an intensive identifying relational process, 'a rod is a straight bit of something'. Here, Mr Dalel demonstrates his knowledge of the world (general knowledge Werth 1999:94), over and above his perceptual knowledge of the immediate surroundings by establishing an epistemic modal-world. This modal-world also potentially reasserts his identity as a figure of authority who has access to a richer knowledge base about science than his pupils.

The participants, the teacher and pupils, are, in principle, all able to ask each other questions and seek clarification. In other words, the participants are all able to verify each other's claims. In text-world terms the text-worlds that the participants construct, are all 'participant-accessible' (Gavins 2007a: 76). The extent to which this text-world is participant accessible, will depend on how credible the pupils find this statement. It is likely that the majority of pupils would find it credible for two reasons. First, the objects of the text-world, 'a rod and a straight bit of something', are participant-accessible in that although Mr Dalel refers to any unspecified *rod* and any *unspecified bit of something* by using the indefinite article *a*, the pupils are able to verify this statement against their perceptual knowledge of what a rod looks like in the discourse-world (Mr Dalel points to one on the bench). Secondly, as claimed by Grice (1975) our preferred model of communication is one of co-operation and not of deception which implies that participants generally expect that the other is telling the truth (Gavins 2007a: 76). This is especially true of what Mr Dalel, a person with a perceived position of authority, says in the classroom.

For pupils whose first language is not English, however, accessing this text-world could prove more of a challenge as they might not have the specific linguistic knowledge to recognise items such as rod /rɒd/ and straight bit of something /əstreɪbɪʔʌv'svmθɪŋ/ in spoken discourse, even when they are part of their immediate surroundings. In contrast, pupils who have a semantic frame for the English of *rod* and *a straight bit of something* will have more developed language and cultural frames associated with these terms that they have used in their past, when processing the discourse of the demonstration.

The second instance of an epistemic modal-world takes place when Mr Dalel chooses to involve and include the pupils in his narrative by directing his question

to the class, ‘does anyone know what sort of metal this is?’ (line 60-1). He achieves this by first requesting with an interrogative that a member of the class answers. This initial epistemic modal-world is made up of the mental process ‘know’, the Senser ‘anyone’ and the projected clause ‘what sort of metal it is’. The slight rising tone on the nucleus ‘metal’ of the projected clause is notable as it is somewhat unexpected (default tone for wh- interrogatives is a fall tone). One possible interpretation of this is that the teacher wishes to soften or make a more tentative request (Halliday 1994) to encourage a response from the pupils.

The illocutionary force of the teacher’s question (i.e. the intention behind the question) places a kind of obligation on the listener, who is required to actualise Mr Dalel’s intention of establishing the type of metal that the rod is made of. The questions posed does not seek information unknown by Mr Dalel, nor is it unlikely that many of the pupils do not know the answers. As shown by the socio-cultural analysis of this episode, the purpose of this section of the episode is to describe and foreground the parts of the apparatus which Mr Dalel deems to be relevant. When posing the question to the class, it seems likely, therefore, that Mr Dalel assumed that at least one of the pupils would ‘play the game’ and respond appropriately, i.e. he anticipated a correct or near correct response. This is indicated by the attitude expressed by the falling tone of his intonation on his response to the pupils’ answer ‘copper’, indicating that he expected the answer that the pupil gave. This three-part exchange structure, initiated by Mr Dalel, constitutes an epistemic modal-world that is fully realised in Mr Dalel’s final turn, when he utters ‘copper’ with a falling tone. Initiated by Mr Dalel’s question, whose illocutionary effect is a request, the epistemic modal-world has been created jointly by both participants.

4.3.5 Introduction of ‘heat’ into discourse: creating a hypothetical

The material process *heat* (line 80) is introduced for the first time into the episode’s discourse when Mr Dalel requests the pupils to predict what will occur when he applies heat to the Vaseline. ‘Heat’ in this context refers to the heat energy supplied to the end of the rod that moves towards the petroleum jelly: it is the cause of the phenomenon. Mr Dalel and the pupils create an unrealised, remote hypothetical of a scene in which the Vaseline is heated. Mr Dalel initiates

this construction by requesting the pupils to create a mental representation of the Vaseline, with the metacognitive device, 'what do you think happens' (line 76). In Systemic Functional Linguistic terms, the teacher uses the mental process 'think', which in this context functions as an epistemic modal lexical device, prompting the pupils to visualise a scene. Using their perceptual, experiential and cultural knowledge frames, the pupils create the epistemic modal-world.

Werth claims that discourse triggers the appropriate areas of memory, or relevant knowledge frames required to interpret the text, and in this case imagine a hypothetical scene (1999:148). In this particular instance, it is unlikely that any of the pupils have actually seen Vaseline being heated, as this is not the everyday association most pupils have with it (see: put in on ma lips - line 71). Although the response of one pupil is very faint, the teacher's response 'TURNS INTO A SOLID?' strongly indicates that the pupil responded in the previous turn with 'turns into a solid'.

Fauconnier and Turner's (1998, 2005) Conceptual Integration Theory offers a plausible account of how the pupil arrived at his answer. Here, Brandt and Brandt's (2005) adaptation of Fauconnier and Turner's Theory will be used. The discourse evokes a blended world, which is created by a merger of two input spaces, the reference space, which is part of the real-world, and the presentation space, evoked from the pupil's memory. In Text World Theory, a blended world can carry the same ontological status to text-worlds or the input spaces from which they originate (Gavins 2007a). The reference space, the actual perceptual world of the Vaseline visible to the pupils acts as an "anchor" to the blended world (Hutchins 2005). In this anchored blend, the pupils are able to verify their predictions with what happens during the experiment. The presentation space is a conceptual model of a similar looking substance to the Vaseline being heated that the pupil has seen previously. One obvious example that springs to mind is egg white which turns into a solid when heated. However, it is uncertain whether the pupil had this in mind when responding to Mr Dalel's question. Nevertheless, it is likely that the conceptual model is one of possible-outcomes-of-substances-being-heated (e.g. turns into a solid, melts, disappears). This is intersubjectively shared by members of the class and wider

population because if it were not, the response would not make any sense to the other members of the class.

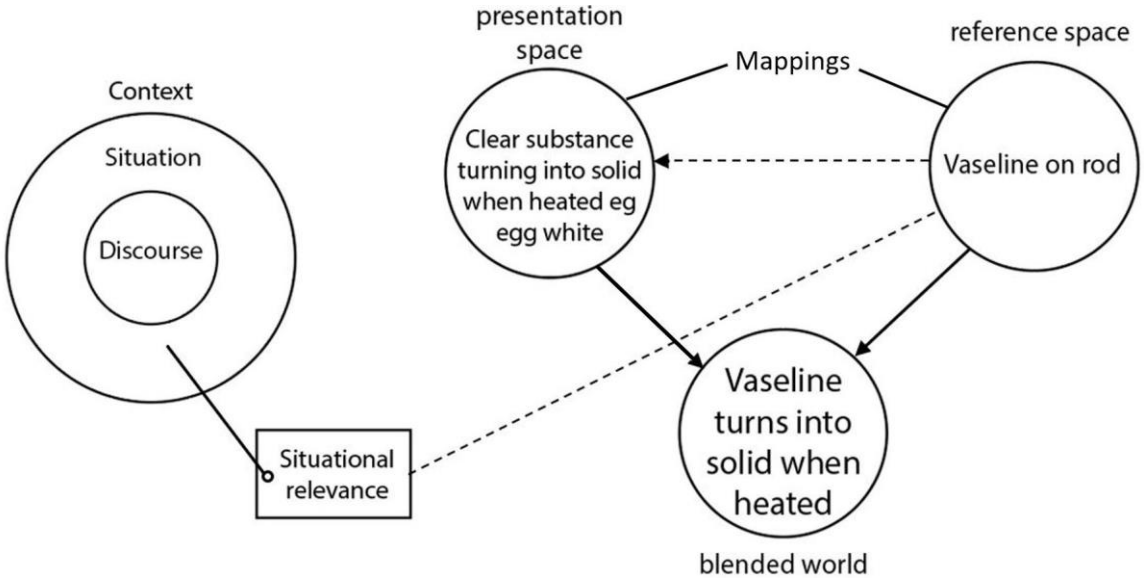


Figure 4.5. Possible blended world created in mind of pupil, episode 4.4, lines 76: What do you think happens to the petroleum jelly if I heat it up?

It is quite possible that the other pupils would have responded differently due to Mr Dalel's question evoking different images of the Vaseline melting (or perhaps glowing?) but these remain as public knowledges (Werth 1999: 94) of the individual pupils rather than a mutual (private) knowledge shared by the class members. The credibility of the pupil's response would to some extent depend on the pupil's status in the class. It seems likely that if the pupil is normally considered to be a reliable participant of the discourse-world i.e. a pupil who often responds 'correctly', it is more likely that the other pupils would regard the text-world created by the pupil as reliable and trustworthy. Mr Dalel's turn 'TURNS INTO A SOLID?' indicates with its raised intonation Mr Dalel was surprised at the pupil's response. However, Mr Dalel does not sanction the pupil's response completely but continues with the function advancing imperative, 'Right let's try it'. This creates a certain amount of suspense in Mr Dalel's narrative in that the pupils need to wait and watch the experiment to find out what happens to the Vaseline when heated.

4.3.6 'Capturing' pupils' mental SOURCE-PATH-GOAL schemas

Mr Dalel continues by describing the actions he undertakes during the initial phase of the experiment to the class. Lines (80-82) are characterised by function

advancing propositions: *I'm going to heat the rods up, I'm going to bring the Bunsen burner to this side, I'm going to hang the paper clips with pieces of Vaseline*. In SFL terms these are material processes, which with the 'going to' intension future form gives the impression to the addressee that the teacher had pre-planned the actions he undertook. The nucleus tone of the intonation unit falls on the processes *heat, bring* and *hang*, whose prominence is emphasised further by the effect of parallelism.

The process *heat* is used in line 80 to describe an action and in this particular instance the action that caused the melting of the Vaseline. Shortly after Mr Dalel had applied the heat, he asked the pupils to consider why the Vaseline furthest from the source of the heat had not melted, 'why has that not melted yet' (line 88). A pupil responds appropriately with, 'is it because it's far away from the[' (line 89). Mr Dalel interrupts the pupil, not I think because the pupil supplied an incorrect answer but because he wanted to 'capture' the mental images that motivated the pupil's response at that moment.

87 ***T:*** no they haven't. three. (5.0) what has happened to the Vaseline? (6.0)↑
88 why has that not melted yet?

89 **P4:** is it because it far away from the[

90 **T:**]what is the heat supposed to be doing?

91 **P4:** travelling

92 **T:** travelling? very good, ok heat is tra::velling, isn't it? acro:ss the rod,
93 (3.0) heat's been trans↑ferred

Extract 4.5 *from lesson one, appendix one, lines 87-93.*

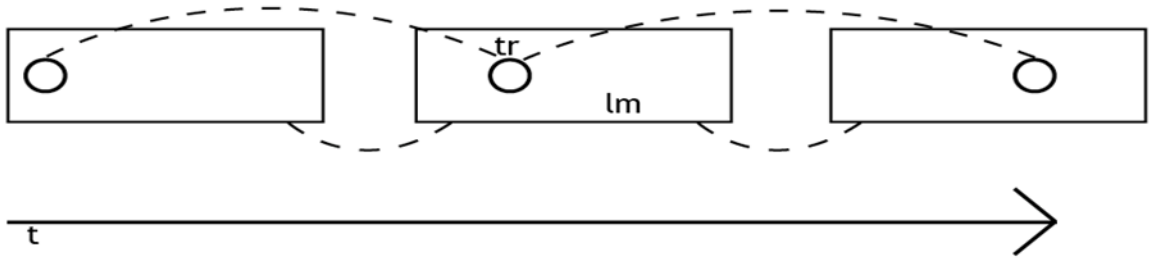
In order for the pupils and Mr Dalel to conceptualise and therefore understand the heat transfer process, an image schema is evoked. As mentioned in the literature review, an image schema is 'a recurring dynamic pattern of our perceptual interactions and motor programs that gives coherence and structure to our experience' (Johnson 1987, xiv).

During this short episode, the SOURCE-PATH-GOAL image schema is evoked by the participants when the teacher asks, 'why has it not melted yet?' (line 88). This is the negative counterpart to *why has it melted*? builds an image of the Vaseline melting in the immediate future, through the use of the time adverbial *yet*. The

Vaseline is the end point, or the GOAL of the schema, which motivates the response, 'is it because it's far away from the' (line 89) from the pupil. As the desired SOURCE-PATH-GOAL schema is at this moment intersubjectively shared between the participants, Mr Dalel harnesses this mental image to develop his description of the heat transfer process. This is a good example of how Mr Dalel is successfully able to anticipate what his pupils are thinking. In other words, although he is not able to step into their heads and gain direct access to their thoughts, he is able to construct an accurate model of what they might be thinking. This ability of Mr Dalel to mind-model (Stockwell 2009) is especially prevalent throughout this episode.

Thus, the teacher focuses the pupils' attention towards the PATH element of the SOURCE-PATH-GOAL image by asking the pupils, 'what is the heat supposed to be doing?' Mr Dalel uses *is supposed to,* to construct an epistemic modal-world. According to Carter and McCarthy (2006) 'is supposed to' refers to what is expected to happen and in this case in accordance with the SOURCE-PATH-GOAL schema. Furthermore, the pupils' attention is drawn to the PATH element of the schema with the textual trigger 'is doing', a material process verb in its continuous form. The use of the continuous form is motivated by the PATH image that the heat is undergoing some kind of process over a time period. Utilising the SOURCE-PATH-GOAL mental image the pupil in line 91 supplies the PATH element to the image by responding to Mr Dalel's question with 'travelling'. Mr Dalel acknowledges this immediately and in his turn repeats and develops the pupil's response with, 'travelling? very good, ok heat is tra::velling, isn't it? across the rod'. The PATH image is reinforced by Mr Dalel elongating *tra::velling,* when he uses his voice to place prominence on the word. This serves as an onomatopoetic device to signal to the listener that the heat is moving. This again, is further emphasised with the use of the preposition across, in 'across the rod' (line 92). This analysis draws on Langacker's (1991a) cognitive grammar system which offers a linguistic description that accounts for the profiling effects the language structures have on the mind. Furthermore, as features of Langacker's grammar system are very visual, it is possible to represent this language diagrammatically.

The sense that *across* takes in this instance can be represented in the diagram below:



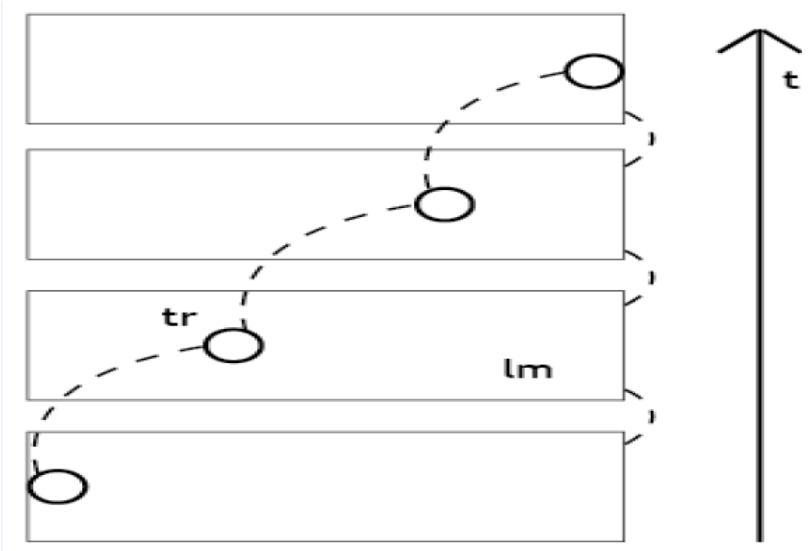
KEY: t = time, tr = trajector (heat) and lm = landmark (rod)

Figure 4.6. 'across the rod' based on Langacker's diagrammatic representation (1991a:22)

The trajector (heat) occupies all the points on the path leading from one side of the landmark (the rod) to the other and does so successively through time as further indicated by the use of the morpheme –ing on the process *travelling*.

4.3.7 Profiling the GOAL part of the schema

At this point, Mr Dalel rephrases what he has just said by naming this process with the scientific term, 'heat's been transferred' (line 93). Here, the use of the passive voice profiles 'heat' and the process by which the energy reaches the Vaseline, in a similar way to 'heat is travelling' However, the past participle 'transferred' profiles the end result of a process, the goal, which is illustrated in Figure 4.7.



KEY: t = time, tr = trajector (heat) and lm = landmark (rod)

Figure 4.7. 'heat's been transferred' based on Langacker's diagrammatic representation (1999:22)

What is particularly interesting to note here is the discrepancy between Mr Dalel's language (e.g. *heat is travelling* and *heat's been transferred*) and what the participants might note if they touched the rod at this point. The mental image or situation model constructed by the pupils during lines 87-93 might resemble one in which the entity *heat* is a self-contained unit, rather like a car moving along a road. However, when one pupil later touches the rod, he notes that the heat spreads (like butter on toast) and by the end of the experiment the whole rod is hot. When comparing the two constructions *heat is travelling* and *heat's been transferred,* the passive construction *heat's been transferred* profiles the end result of the process and downplays the process by which it arrived at its end point. It could, therefore, be argued that the mental image supported by the scientific term (as opposed to heat is travelling) conflicts less with the notion of 'spread' could, therefore, accommodate the experiential, kinaesthetic world of the participants.

The question arises at this point as to whether the introduction of the passive construction in fact triggers a change in the way the pupils construe the situation. Mr Dalel directly substitutes *heat is travelling* with *heat's been transferred* as if the two terms are equivalent. There is no change to the context prior to this point, which would support any change in profiling. However, in the following section Mr Dalel asks one pupil to touch the paper clip end of both the copper and the steel rod and note the difference in temperature:

92 **T:** travelling? very good, ok heat is tra::velling, isn't it? acro:ss the rod,
93 (3.0) heat's been trans↑ferred that one there? or that one. (3.0) what
94 do you notice? which one seems to be getting hot quicker, the ↑copper,
95 or the steel. the one at the ↑back? which one's that? the red one

96 **P4:** copper

97 **T:** copper,very good,↑what's the hottest part of the rod? this part, right,
98 ↑ which one is the coldest part of the rod at the moment.

99 **P4:** this part (pupil touches rod)

100 **P5:** the end

101 **T:** is it going to stay cold forever*?*

Extract 4.6 *from lesson one, appendix one, lines 92-101*

In lines (92-101), Mr Dalel draws the pupils' attention to the GOAL element of the SOURCE-PATH-GOAL schema with, 'which is the coldest part of the rod at the moment' *and* 'is it going to stay cold forever?'. This is profiled in the passive construction, *heat's been transferred* that Mr Dalel introduced in line 93. This would support the claim that for Mr Dalel, the introduction of the scientific term *heat's been transferred* was motivated by a different mental image in the mind of the teacher; one which emphasises the GOAL aspect of the schema. To evoke this image in the minds of the pupils, he asks them to focus on the destination point of the energy by asking one pupil to touch the rod.

The above shows how image schemas underlie many of the clausal structures used to construe the target abstract concept of heat (energy) and heat transfer of the lesson. In the above examples, it is profiled as the trajector with the predicate as the landmark: e.g. *heat is travelling along the rod*. Some expressions used by the teacher give heat (or heat transfer) the main attentional focus and some do not. The analysis demonstrates the construal operation of profiling. In other words, it shows how the propositional content of this language can be construed by the pupils in a manner of different ways, depending on how the teacher presents it.

4.3.8 Introduction of the concept conduction.

The concept 'conduction' is introduced into the discourse of the demonstration for the first time in line 107:

105 **T:** heat's going to tra:::vel? exactly? so what do you know about heat? it
106 doesn't stay in o::ne place it tra::vels along sOlidds in a straight line,
107 (10.0) we call that. (1.0) con DUCtion, you know the ↑word we wrote
108 down. conduction. (.) when heat travels from one side to the other side
109 we call that, con↑duction, heat gets transferred, ↑we you have to
110 think about things?

Extract 4.7 *from lesson one, appendix one, lines 105-110.*

The concept is introduced at the end of the demonstration after Mr Dalel and the pupils have established a common ground for the heat transfer process taking place during the demonstration. Mr Dalel asks the question 'so what do you know about heat?' setting up an epistemic modal-world, in which Mr Dalel requests that they think about the ontology of heat energy. He does not give them time

to respond but provides instead his own answer, ‘it doesn’t stay in o::ne place it travels along sOlids in a straight line’ (line 106). These features or properties of heat constitute mutually shared definition of conduction.

Mr Dalel signals the scientific register and importance of the item *conduction* first by the deictic pronoun ‘we’, in ‘we call that’ (line 107), to signify the scientific community thus indicating to the pupils that the mutual (private) knowledge established is also part of the more general knowledge of the scientific community. The importance of the item is further emphasised by reminding the pupils that they had written it down at the start of the lesson, as one of the ‘key’ words to be memorised.

In summary, this section has provided a Text World Theory account of how Mr Dalel introduced the terms *heat* as the cause of a phenomenon and *heat transfer* and *conduction* into the discourse during a demonstration. The analysis has shown how Mr Dalel and pupils have jointly established an understanding of the concepts as a result of incrementation during this on-line discourse event, thus creating a mutual (private) knowledge base. The analysis illustrates that it is the ‘text’ and the situation in which the text finds itself that determines which knowledge frames are evoked, in order for the pupils to be able to interpret the event and therefore develop an understanding of the abstract concepts being taught.

4.4 Episode three: simulation-role-play: heat transfer at a microlevel

At the end of the demonstration, while the participants are waiting for the clips to fall, Mr Dalel reminds the pupils of the work they did in a previous lesson on the atomic structure of solids. This functions as a lead into the next section of the lesson, in which the pupils ‘act out’ the heat transfer process: their bodies represent the atoms during this process.

4.4.1 Teaching purpose and rationale

The curriculum requires the pupils to provide an explanation of the heat transfer process that took place during the demonstration by referring to the particle theory of matter. This episode offers the pupils the opportunity to understand this process, in micro terms, by using a technique frequently used in science

classrooms and referred to in the literature as Simulation-Role-Play (Aubusson et al. 1997). The basic premise of this technique is that the body or parts of the body stand for entities in either a description or explanation of a phenomenon (Scherr et al. 2010). As in this case, the phenomenon is one that the pupils are unable to directly experience. The technique can either allow for the participants to externalise the mental representation into concrete entities (their bodies) that they have of the phenomenon or as in this case, as it is teacher-led, it enables the pupils to create a mental representation of an otherwise unobservable process.

T: Zarif come here you move down Sanja as I said to you before I don't want you in actual fact I don't want you you are packed more tightly than that (.) if you are actually real atoms you'll be VERY VERY tightly packed I'm not actually going to get you to to (2.0) link together so I don't want you to actually make contact with any other pupils ok that's fine because (.) particles in a solid are tightly packed together just the way you are just now particles in a solid vibrate just ever so slightly from left to right so just move your shoulders very slightly that's too much THAT'S IT just bobbing from right to left now I'm going to start applying a bit of HEAT to my copper rod 2 atoms at the start of my copper rod are vibrating ever so gently just now I'm going to go shhhh and fire a Bunsen burner at them so what's going to happen to the vibration

P: [go faster?]

T: they're going to go faster go on guys go faster AH AH I didn't ask ↑YOU I said the first two atoms now the first two atoms that receive the heat now they are going to bump very gently into the next two atoms behind them represented by George and Haaqiz now going on ever so slightly ↑NOT YOU LOT just these four bump bump bump all of you vibrating now these two here are going to bump into the two behind them bump into them touch into them ever so slightly they start bumping keep repeating that pattern right bump go on get bumping that's it and as soon as you start bumping bump the ones behind you not too much BOYS YOU'RE OUT WRITING keep going keep going keep going keep going keep going keep going keep going that's the WAY ↑everyone vibrating go that's it that's called the TRANSFER OF HEAT ENERGY and heat energy in terms of particles is basically just movement of particles (.) the faster they are moving (.) the higher the temperature (.) the more ENERGY they've got right guys you've lost all your energy it's alright you've cooled down *again taken the heat away right boys and girls over you go back*

Extract 4.7 *from lesson one, appendix one, lines 121-151*

4.4.2 Blended world: bodies as atoms

At the end of the demonstration, the teacher asks the pupils to recall what they know about the atomic structure of solids. The class had covered this topic during a six-week unit in the previous term, so the subject was not new to them. It can therefore be assumed that some of the pupils would approach the Simulation-Role-Play with some kind of mental image or schema of a typical structure of the atomic structure of a solid. As this had been represented several times in the previous unit by drawings, it could also be assumed that some of the mental images or schemata might have elements of the following:

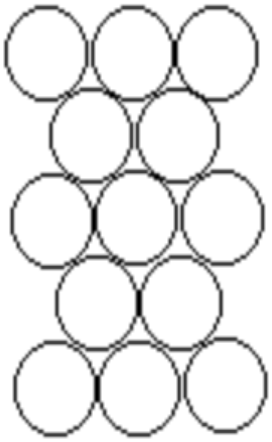


Figure 4.8. Atomic structure of a solid: Example of a diagram found in pupil's handout.

4.4.3 Applying conceptual blending theory to simulation-role-play

The main purpose of the simulation-role-play is to help pupils gain a deeper understanding of what happens to the atomic structure of a solid when heated. The pupils are expected, therefore, to build a text-world or mental image of the atomic structure of a solid when heated. According to Brandt and Brandt's (2005) context dependent blending theory this image of the atomic structure is represented by the 'presentation space'. In this case, it will be the atomic structure of a solid. This will be made up of a schema of the atomic structure of a solid, similar to the one depicted in the above illustration, that will to some extent, have been stored in the pupils' episodic memories. The bodies of the pupils belong to the discourse-world and form part of the 'reference space', the second input space that is required for the intended blended world, in figure 4.8. The goal of the communication, which is here to understand what happens

to the particles in the solid when heated in a science lesson, is captured through its situational relevance that determines which elements from the spaces are projected into the blend.

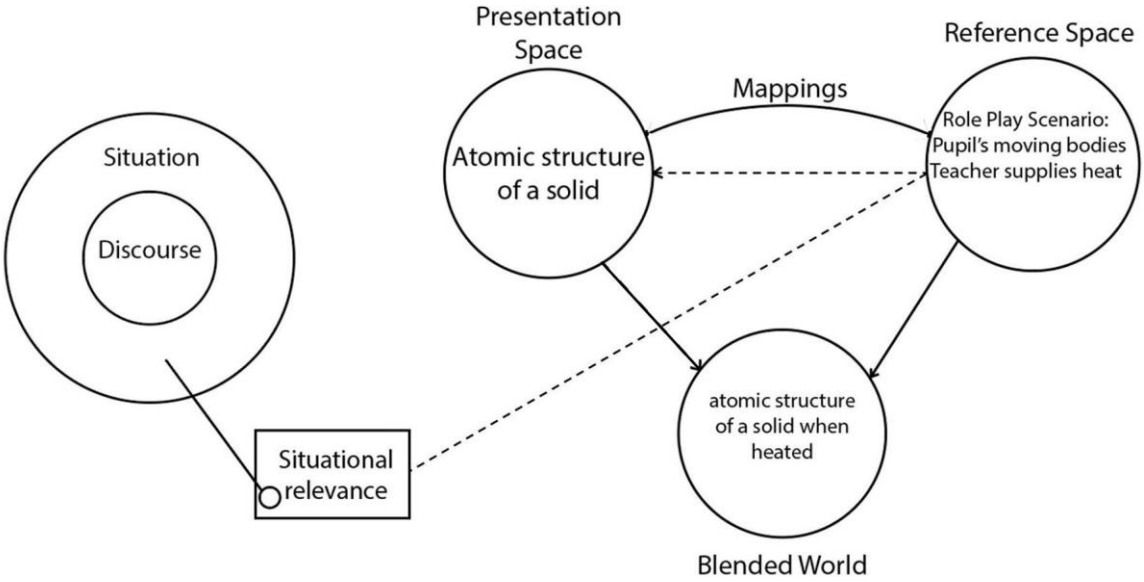


Figure 4.9. Context-dependent blend: Atomic structure of solid when heated during a simulation- role-play

4.4.4. Guidance by the teacher

During the Simulation-Role-Play, Mr Dalel refers to both input domains simultaneously. For example, in lines 122-123 he says, 'you are packed more tightly than that if you are actually real atoms you'll be very very tightly packed'. This ability both on the part of Mr Dalel and the pupils to simultaneously communicate and reason about the presentation space and reference space, is a very predominant feature of pretend play amongst children (Li et al. 2012). It has been argued that this phenomenon of being able to communicate about both spaces simultaneously assists the blending process (see section 4.0) the participants undergo when creating a mental image of what is happening, which in this case is to the atomic structure of a solid when heated. As established in section 4.4.3, the goal of communication is captured through its situational relevance, which determines which elements from the two spaces are projected onto the blend. The key feature of the image, that the pupils need to utilise during the role-play, is one in which the atoms are *discrete items* that are *packed tightly together* and that they *vibrate*. Without this the role-play wouldn't make any sense. The fact that the atoms are often represented as being round is not

significant and could be a potential source of confusion for some pupils (as most pupils are not round!), if they believe it is.

Here, we can note that it is Mr Dalel who not only set up the activity by deciding that it is the pupils who should represent the atoms (rather than using balls, for example), but also how they should behave. Mr Dalel is in a seemingly privileged position here, as his knowledge and understanding of an atom's structure and behaviour will be greater than that of the pupils. To understand what might have been the unconscious motivation behind Mr Dalel's decision to select the pupils to represent the atoms, we can draw on prototype theory (Rosch 1978). A prototypical representation of an atom in a classroom is usually a ball or a uniform round object. However, as Rosch notes, we often classify other objects belonging to this group, even if they have just some of the attributes. Sawyers and Carrick (2003) classify these objects as 'low level prototypical substitution' in role-play situations. This ability to use these low-level substitutes requires the participants to understand the constraints imposed by the substitute and by the imagined object it is substituting. In other words, if the pupils do not focus on, or understand the reason why they are packed tightly together and can vibrate (rather than move around on their legs), then the essential elements, or 'iconic attributes' won't be projected into the intended blend, and the role play will not make sense.

At the start of the role-play the pupils are not left to do this unaided, and the teacher provides several directives focusing the pupils' attention towards by foregrounding the salient features of the two input spaces he wishes them to focus on. For example, in lines 122-123, he says, 'you are packed more tightly than that if you are actually real atoms you'll be very very tightly packed'.

Throughout the role-play it is the teacher who directs the actions of the pupils with, 'they're going to go faster go on guys go faster I didn't ask you I said the first two atoms now the first two atoms that receive the heat now they are going to bump very gently into the next two atoms behind them' (lines 135-8). In text-world terms, Mr Dalel is controlling and directing the pupils in the discourse-world. The success of this activity in terms of classroom management depends on the pupils being physically active and complying with the commands of the teacher. To signal to the pupils which behaviours are permitted and which are

not, he uses several imperatives: *come here*, *you move down*, *just move your shoulders very slightly that's too much*, to express deontic attitude. This sets up a separate text-world, which should form the reference space, in which the pupils' permitted movements are taking place. However, as stated previously, in order for the pupils to create the required blend from the two input spaces they need to understand the significance of the constraints on their movements in this reference space. There are possibly two reasons why this might not take place. Potentially, the high number of imperatives could result in the pupils operating solely within the deontic modal-world, rather like puppets, simply complying with the teacher's directives without making the connection between their actions and the salient feature of the presentation space. Secondly, the presentation space, which should include salient features from the image-schema of the atomic structure of a solid may not exist or be different to the teacher's image-schema. In both cases, there exists the possibility that the intended blend did not take place. The activity might appear to have been a success in terms of classroom management but conceptually, some of the pupils might not have made the necessary links between their movements, and the movements of atoms in a solid when heated. In order to find out how successful this activity was, the researcher interviewed a group of pupils a week after the lesson.

4.4.5 Interview with pupils

One week after this lesson took place two of the pupils were asked to take part in a stimulated recall session. The following will provide a concise text-world analysis of the interview (see section 5.12 for a full interpretation of the text-world layers during a stimulated recall). The pupils observed the role-play session without sound. The objective was to elicit language from the pupils to describe the Simulation-Role-Play. I decided to play the video without sound as I did not want the recorded commentary of the teacher during the lesson to directly influence how the pupils construed the situation during the interview.

63 **T:** oh dear hang on…then how would you explain [what is happening in the
64 video] [R shows recording: Mr Dalel is waving his arm close to the pupils]

65 **P3**: the Bunsen burner

66 **P6:** heats the particles and the particles bump into each other and make
67 them vibrate and the heat passes through the particles

Extract 4.8 *from pupil interview 25.03, appendix Three, lines 63-67*

Here, we can note how Suzy (P6) has understood the intension of the teacher to represent the particles with the pupils' bodies by how she refers to the pupils' bodies in the video as 'particles'. She successfully provides a descriptive account of the process by using objects (the pupils' bodies) that she can see in the discourse-world to represent the objects (particles) of her mental image. If the context of the pupil's response is disregarded, however, the description is quite striking in that in her description the teacher intends to heat up atoms (not a metal rod) and the heat is construed as a substance which passes through or between the atoms. If this is interpreted according to a prominent line of research in conceptual change theory (that physical concepts such as heat are conceptualised by experts correctly as a process of molecular excitation and novices conceptualise it incorrectly as a substance) then this would be a clear illustration of the pupil's incorrect ontological categorisation of the concept of heat (Slotta et al. 1995).

In the context of stimulated recall session, however, Suzy's response gave the impression to the researcher that the pupil had understood the concept of heat transfer *well enough*. The metaphorical expression *passes through the particles* could be construed in this context either as a substance or as a process or a conceptual blend of both (Dreyfus et al. 2014). Despite the ambiguous nature of the expression, it is tolerated at the time of the interview as it conveys sufficient amount of the process image to the researcher to give the impression that the pupil understands. Interestingly, only after the interview the researcher began to question the security of Suzy's understanding, which becomes a focal point of the interview with the teacher later that afternoon (see Chapter 6). The issue of ambiguity in pupils' language is explored in Chapter 6.

By comparing this short episode with what Zarif (P7) said a week earlier in the lesson 18.3.15, when the pupil is asked by Mr Dalel during a group activity to explain heat transfer using the following diagrams as a prompt, we can note further evidence of understanding.

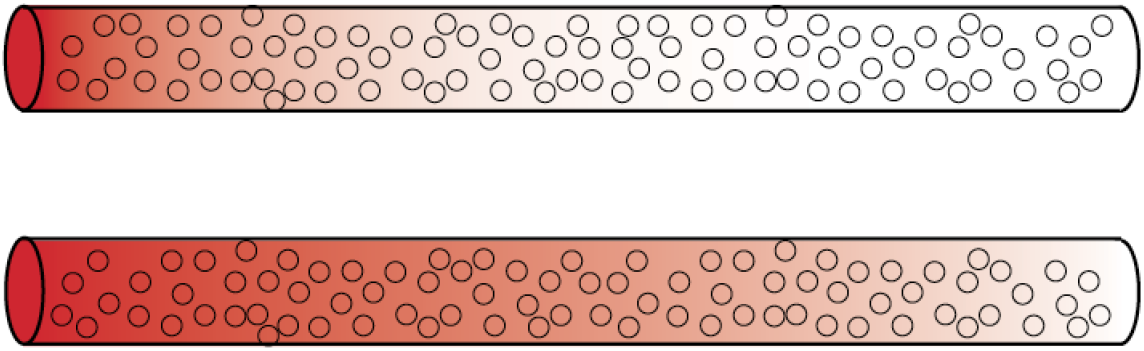


Figure 4.10. Diagrams used in pupil teacher exchange to illustrate heat transfer

T: What's heat transfer then .. [points to diagram on board]

P7: that one is when it starts to heat up and the particles vibrate (pause) and that one is when all the particles vibrate and heat flo.. transferred through the rod

T: U..huh

Exchange reconstructed from own field notes

In this task, the pupil has in front of him two diagrams of the internal atomic structure of a metal but in the shape of a rod. The rod and the atoms have become part of the pupil's discourse-world, and are foregrounded by the diagrams. In this instance, the pupil choses to construe heat again as a process: *it starts to heat up and the particles vibrate (process),* and as a blend of a substance and a process *heat flo.. transferred through the rod*. Despite the seemingly ambiguous nature of the expression, it gives the impression to the researcher that the pupil has understood.

In conclusion, section (4.4) has provided a cognitive discursive account of a Simulation-Role-Play set up by Mr Dalel to develop the pupils' understanding of heat transfer. The success of the activity relies on the pupils' being able to blend two input spaces. One input space, a mental image of the atomic structure of a solid may for some of the pupils be ill formed, incomplete or different to the standard model. This could lead to pupils wondering what the pupils' bodies are supposed to be representing. Constraints due to Mr Dalel's role as classroom

manager may also prevent pupils from projecting the relevant elements of each input space into the blend. Despite the seemingly high-risk nature of the activity, the pupil interview indicated that the activity had been a success in that one pupil showed that he had understood that the pupils' bodies represented atoms.

4.5 Episode four: conduction is a process: from talking to writing

Mid Lesson: consolidation of concepts of conduction and heat transfer

Date: 18.03.15 **Time:** [00:37:42.05]

Topic: Heat Transfer and Conduction

Purpose: To consolidate the learning that has taken place up to this point by requesting that the pupils write down the definition of conduction. Mr Dalel 'unpacks' the term *process*.

Direct Observation: Teacher writes on whiteboard 'conduction is the process where heat is transferred through a solid.'

195 **T:** ↑conduction (.) is (.) the (.) process (.) where heat is trans(.)ferred
196 through a SOLID write that down into your jotters write that down into
197 your jotters conduction is (.) the process where heat is transferred
198 through a solid that is what conduction is 1.0) what's a ↑process (1.0) a
199 process has steps in it (.) for example (1.0) say for example (.) you want
200 to make a bowl of cereals for your breakfast (.) what's the ↑process
201 ↑ROSE (.) say you wanted to have some cornflakes for breakfast (.)
202 what would the process be? What would the first thing you do?

203 **P15:** get a bowl

204 **T:** get a bowel ↑good

205 **P15:** put cornflakes in it

206 **T:** put cornflakes in it, yeah?

207 **P15:** pour milk in it

208 **T:** pour milk in it, yeah

209 **T:** ↑that's it yeah. That's your PROCESS so a process has steps in it

***Extract 4.8** from lesson one, appendix one, lines 195-209*

4.5.1 Situating the learning episode

In this episode, Mr Dalel consolidates the main 'learning point' of the demonstration and role-play namely that 'conduction is the process where heat is transferred through a solid'. He signifies the importance of this by telling the pupils to write this statement down in their jotters. This proposition is packed in high semantic density language (Martin 2013), some of which was unpacked with the pupils during the previous two activities. With the aid of an analogy he demonstrates and checks the pupils' understanding of the term 'process', which is introduced here for the first time. At the start of this episode, the teacher provides a theoretical account of what conduction is. To unpack the meaning behind the term 'process', one pupil and the teacher use the analogy of making a bowl of cereal to provide an empirical descriptive account of a process.

4.5.2 Text World Theory analysis of 'conduction is the process'

At the start of this episode Mr Dalel tells the pupils to write 'conduction is the process where heat is transferred through a solid' in their jotters. It is not the first time that Mr Dalel has asked the pupils to write down any key information that either he, or the curriculum, has specified as being important. Therefore, this act of writing signals to the pupils that this information is important and that it should be memorised and understood. The language of the proposition is highly abstract. In other words, it is comprised of signs, which do not have direct referents in the current discourse-world.

Both the temporal and spatial world-builders are unspecified. There are no named participants and two of the objects have no direct referent in the pupils' discourse-world. The first function-advancing proposition is an intensive relational process consisting of an identifier (the process where heat is transferred through a solid), which identifies 'conduction' (the identified). Although the term *heat* can be directly experienced by touch, it has no visual referent in the pupils' discourse-world. And finally, the term *solid* is a superordinate term for all objects and not a specific object, which the pupils saw during the demonstration. The

proposition also contains a relative clause with the relative pronoun *where*, an ellipsis of whereby.

4.5.3 Critical progression in language development

The language of the proposition, *conduction is the process where heat is transferred through a solid* is the theoretical expression of what the pupils experienced during the demonstration and role-play. It illustrates clearly what Halliday calls the 'critical progression', in both a child's development and in the learning process in the classroom (1998). First, it uses more general language i.e. 'common' terms e.g. *solid*, instead of 'proper' terms e.g. *rod*. Second, it uses abstract terms e.g. *conduction*, which do not have direct visible referents in the discourse-world, rather than concrete terms, which have. And finally, the language uses more metaphorical construals e.g. *conduction is the process*, instead of congruent ones. However, despite the language being more removed from the pupils' more familiar discourse-worlds, the clause 'heat is transferred through the solid', had been introduced to the pupils during the demonstration and role-play. Furthermore, this proposition is understood metaphorically via the SOURCE-PATH-GOAL schema, in other words in terms of more concrete concepts that the pupils are more familiar with.

4.5.4 Using an analogy to 'unpack' the term 'process'

However, the term process in this context is new to the pupils. To unpack the term, Mr Dalel uses an analogy to illustrate what he wants to signify by the term in this context.

198 ***T*** what's a ↑process (1.0) a
199 process has steps in it (.) for example (1.0) say for example (.) you want
200 to make a bowl of cereals for your breakfast (.) what's the ↑process
201 ↑ROSE (.) say you wanted to have some cornflakes for breakfast (.) what
202 would the process be? What would the first thing you do

Episode 4.9 *from lesson one, appendix one, lines 198-202*

Here, the pupils are required to create a text-world in their minds in which they make themselves a bowl of cereal for breakfast. In the interview with Mr Dalel, which took place a week later, he described his rationale behind using the analogy

of making a bowl of cereals. It is evident from the interview, that he anticipated that the pupils would find the term difficult.

26 **T:** becoming red and more atoms becoming red and so there is a process
27 taking place and so I was thinking what do they understand by a process
28 because a process is something which involves steps

29 **R:** steps so how

30 **T:** one thing leads to another to another

31 **R:** m-mm

32 **R**: so you had an analogy of the

33 **T:** so I used the analogy of the cereals that just popped into my head
34 because it was breakfast they just had their breakfast

35 **R:** no no it's good it's good

36 **T:** m-mm

Extract 4.10 from teacher interview 25.03.15 appendix four (lines 26-36)

Whilst Mr Dalel and Rose describe the process of making a bowl of cereals, Rose uses the imperative form to describe each separate stage or 'step' of the process:

202 **T:** What would the first thing you do?

203 ***P15:*** *get a bowl*

204 ***T:*** *get a bowel ↑good*

205 ***P15:*** *put cornflakes in it*

206 ***T:*** *put cornflakes in it, yeah?*

207 ***P15:*** *pour milk in it*

208 ***T:*** *pour milk in it, yeah*

209 ***T:*** *↑that's it yeah. That's your PROCESS so a process has steps in it (.) so if*
210 *the process of conduction has steps in it (.) conduction is the process*

Extract 4.11 from lesson one, appendix one (lines 202-210)

In order for the analogy to be successful, the pupils will need to project the essential elements from the input spaces into a blend. These input spaces are

made up of the reference space and the presentation space (see section 4.0 and figure 4.11). The reference space is the input space of the steps involved when making a bowl of cereal. Here, the steps are discrete and clearly distinct actions 'get a bowl', 'put cornflakes in it', and 'pour milk in it'. The different actions are foregrounded through the repetition of the different material processes. However, the goal of the communication is to understand the concept 'process' in the context of understanding the concept 'conduction'. This should determine which elements are projected from the presentation input space (the pupils' mental representation of heat transfer) into the blend. In the analogy, the foregrounded material processes are the most salient features in the cereal reference space, furthermore these processes are discrete and different (get, put and pour). From just observing the lesson it is difficult to ascertain what Mr Dalel intended by the word 'process' in this instance. In other words, what salient aspects from the conduction presentation space the teacher wished the pupils to project into the final blend. In Mr Dalel's interview, that took place after the lesson (25.03.15), the teacher explained the notion of process that he wished his pupils to understand.

15 **R:** so question is in your own words what did you want to get across to the
16 pupils

17 **T:** yeah ok well

18 **R:** cos I have an idea but

19 **T:** we were looking at the atoms we were looking at the metal and how the
20 first step was how the metal heats up and then transfers energy to well
21 the atoms on the outside become heated therefore they become more
22 energetic and transfer energy through vibrations to the atoms next to
23 them which then transfers energy to the atoms next to them and so the
24 energy of vibration that is kinetic energy gets transferred from the
25 bottom to the top and that was illustrated by the atoms becoming red and
26 more atoms becoming red and so there is a process taking place and so I
27 was thinking what do they understand by a process because a process is
28 something which involves steps

Extract 4.12 from teacher interview 25.03.15 appendix four (lines 15-28)

Here, it becomes clear that by 'process' in this context the teacher means a transfer of kinetic energy from one set of atoms to the next and then to the next

'atoms… transfer energy through vibrations'. The material process is 'transfer', which is on-going but unlike the material processes of the reference space it is the same ('transfer' not 'get,' 'put' and 'pour'). The salient feature of the presentation input space is the continuous on-going material process over time, which is situationally relevant in this instance. The pupils may, however, create a blend different to the intended blend and wonder at the end of the analogy what the discrete and different actions involved in the process of conduction are (when there aren't any).

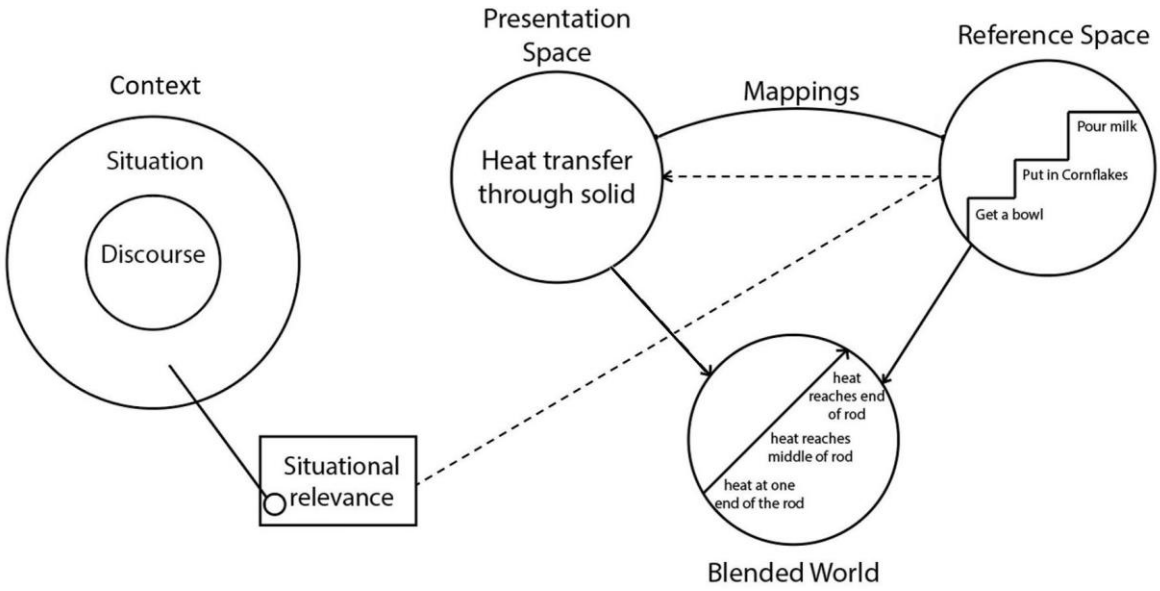


Figure 4.11. Context-dependent blend: a blended world of 'conduction is a process'

Section 4.5 analyses how Mr Dalel both consolidates and develops the pupils' understanding of the concept conduction by writing a definition of the term that is shown by the analysis that is highly abstract in nature. Mr Dalel is aware that the pupils might not understand the item process so uses the analogy of making a bowl of breakfast cereal to clarify it to the pupils. However, the analysis of the analogy shows that the concept *process* in the context of making a bowl of cereals and in the context of conduction are not the same, in that the steps in the cereal making process are discrete. This crucial difference might therefore result in the pupils not understanding the analogy as the teacher intended.

4.6.1 Situating episode five

Date: 25.03.15 Time: Start of lesson [[00:03:04.23]]

Topic: Heat transfer and Insulation

Purpose: To introduce the concept of an insulator and to be able to name some good insulators

Direct Observation (from researcher's field notes) After teacher has taken the register and the pupils settle the teacher begins by telling them the aim of the lesson by writing the heading and success criteria on the board.

T: Ok boys and girls (.) jotters open please thank you what we are learning about today guys is ↑insulators (10.0) and I want you to put a heading down into your and that's your learning intentions and that's your success criteria. You want the name of the things that are insulators

[pupils write]

is that down ↓right pen and pencils down (5.0) once you get that done guys (.) so all an insulator is guys (1.0) is (1.0) an insulator is ↑actually the opposite (4.0) of a conductor [picks up some glass rods] come up to the back. Remember the ↑experiment with conductors? give me some examples of ↓conductors

P1: copper

T: ↑copper's a good conductor

P2: iron

T: iron's a good conductor (.) so what have all these things got in common copper(.) iron steel

P3: metals

T: they're all ↓metals (.) the best conductor was what

Ps: copper rods

T: do all things allow ↑heat to go through?

Ps: no

T: well that's the thing (.) things that are opposite of conductors are called ↑insulators and we're going to discover out of this lot which ones are the insulators (.) what d'ya reckon? do think the glass is an insulator or a conductor (.) will it allow heat to go through it? What kind of experiment could you do again what would you do

P: [inaudible]

T: how would you ↑know that heat was travelling through?

P: [inaudible]

T: that's exactly what you do (.) right go and write that down [points to board]

right guys did you get that Mahta (.) what did you say (.) nice and clearly and load

N: "insulators are materials which do not allow heat energy to travel through them easily they are the opposite to a conductor"

T: did you get ↑that? (.) right come up (1.0) what we're going to do next guys open up your sheets to activity (.) it's after conductivity (.) right activity 4 (.)have you filled up activity 3 properly yeah

Ps: yeah

T: we'll do activity 4 boys and girls (.) all you're simply going to do is you're going to put in hot water and then you're going to put these things in and then you're going to see by testing with your fingers which ones are the conductors and which ones are the insulators right ok so I want one person from each group so you're working in pairs right (.) you can work on your own

T: right (.) I want the other person in the group to collect 4 of these one of each

T: right put them into the beakers now guys all of them all together then see how heat travels through them (1.0) ok you can do your diagram you've got four things in there

Pupils in group [drawing diagram]

T: guys guys you can take the bits out and touch it not the water has the heat come through or not (2.0) touch each one in turn

Ps: this one has

T: take it out for a wee bit but don't touch the bit that touched the water obviously put it back in quickly though (1.0) is heat travelling through any of them?

57 **T:** [To pupils on table 2]: yeah the metals ones

58 **T:** which one allows the heat to go through the best y'a reckon?

59 **Ps:** plastic

60 **T:** plastic ↑ y'a think so? not bad plastic [Teacher touches the metal rod]
61 that's hot the heat's there (1.0) not bad warming up a little bit plastic not
62 that much the glass not that much right what was the best you reckon

63 **P:** plastic

64 **T:** shouldn't be should be the steel (1.0) plastic's not bad

65 **T:** ok boys and girls let's look at your sheets then it says can I have your
66 attention now thank you stop talking and pay attention to me

67 Which material becomes hot to touch (reading from sheet) I would say
68 steel right becomes quite hot to touch right write that down

69 Which materials remain cool? Would you say the glass remained cool

70 **Ps:** yeah

71 **T:** Right write that down then did the plastic remain quite cool yeah write
72 that down would you say that the wood remained quite cool yeah write
73 that down

74 **T:** ok boys and girls can I have your attention again please thank you
75 [switches lights off

Extract 4.13 *from lesson two 25.03.15 appendix two (lines 01-75)*

The aim of this episode is to introduce the concept of *an insulator* and to be able to name some good insulators. At the start of the lesson (25.03.15), the pupils' attention is drawn to the learning objectives and success criteria of the lesson. They are then told, in everyday language how an insulator might be thought about in relation to a conductor, namely, that it is 'the opposite of a conductor'. In other words, the teacher starts the lesson with a generalisation (Scott and Mortimer 2003). Then, Mr Dalel asks the pupils to cast their minds back to an experiment they carried out measuring the conductivity of four different metals in the previous lesson (I was not present). The pupils name examples of good conductors. At this point, Mr Dalel asks: 'do all things allow heat through?' (line 19), thus conceptualising an object as being something that either *permits* heat

to travel through it or not. Mr Dalel establishes the common ground that not all materials are conductors and that substances, which do not allow heat to travel through are known as insulators.

The pupils carry out an experiment to determine which of the four rods (wood, plastic, glass and steel) are good insulators by placing them in a beaker of hot water and waiting to see which rod(s) do not become hot.

4.6.1 Insulator is the opposite of conductor

In this episode, the concept of insulation is introduced to the pupils as being 'the opposite' of conduction. The teacher has harnessed the apparent ease at which even very young children grasp the notion of oppositeness (Croft and Cruse 2004: 2342). At the start of the lesson, the teacher states: 'So all an insulator is guys is (1) an insulator is actually the opposite (4) of a conductor' *(*lines 7-8*)*. In the previous lesson the pupils learnt that conductivity is the process where heat is transferred through a solid. They also learnt that there are 'good' conductors e.g. copper and 'less good' or 'bad' conductors e.g. steel.

Therefore, at this point some pupils might either conceptualise an insulator as:

Scenario one: an object in which heat is **NOT** transferred through a solid or

Scenario two: a **bad** conductor

In both instances, there exists a binarity component. That is, opposite meanings are construed as mutually excluding some domain and within this domain there are only two possibilities (1. is transferred and is not transferred and 2. good and bad).

However, scenario one and scenario two illustrate two different construals of oppositeness. In the first instance, the relationship between the two construals of 'is transferred' and 'is not transferred', is mutually exclusive. It is a complementarity relationship. In other words, if the object is a conductor it is not an insulator; it can either transfer heat or it can't. In the second scenario, the relationship is one of antonymy (Croft and Cruse 2004). Here, the image schema

of SCALE is evoked, in which the property of conductivity is construed as being more or less i.e. a ‘good’ conductor or a ‘less good’ conductor.

It is difficult to determine how the pupils might construe an insulator and conductor in both a binary division and a scale, as there are no additional situational clues, which would favour one form of construal over another. In this instance, the pupils have only their knowledge frames at their disposal to interpret the propositional content of the teacher’s statement.

In line 9, Mr Dalel asks the pupils to cast their minds back to a specific event that took place in the previous lesson, namely, to when they measured the conductivities of different metals. The metacognitive device ‘remember’ triggers a world-switch to the time and place of the previous lesson. The objects in this text-world include copper, iron and steel metal rods, whose mental images become part of the participants’ assumed common ground. On responding to the pupils’ answers (line 11 and 13) providing the metal names of the different conductors, the teacher adds ‘[metal name] is a good conductor’.

Here Mr Dalel, by asking the pupils to recall examples of conductors, sets up a CONTAINER schema. The metals named by the pupils belong to this container. The teacher repeats the pupil’s response with a fall tone indicating agreement and adds ‘a good conductor’, thus shifting the intersubjectively shared CONTAINER schema to a SCALE schema.

Mr Dalel then asks: ‘do all things allow heat to go through?’. This is the first time that the teacher has conceptualised conductors in the classroom discourse as objects which *permit* heat energy to flow through them. The image of a barrier that prevents heat energy to flow in this context appears useful as it is one that the pupils might be already familiar with from playing with water.

To sum, this section (4.6) has analysed how Mr Dalel has introduced the concept of an insulator by structuring the discourse around the notion of oppositeness, which draws on two image schemas, namely the CONTAINER and SCALE schema.

4.7 Conclusion, reflection and further comments

This chapter has provided a cognitive discursive account of how the scientific abstract concepts of *heat, temperature, heat transfer, conduction* and *an insulator* are linguistically represented in discourse. It examined the conceptual development of these abstract concepts by a group of first year secondary pupils and their teacher in the physical and social setting of a classroom during five episodes, in which the concepts were either introduced, or re-introduced into the discourse. The framework for the analysis was the Text World Theory model. Two aspects of the model were foregrounded in this chapter, namely, blending and image schemas. The following will reflect on some of the affordances and constraints of the framework to examine the effectiveness of the Text World Theory framework for exploring the development of abstract concepts in a school environment.

The Text World Theory framework provided me the means to track the events as they took place over time and space. It was well suited to the task of analysing the interdependent relationship between the physical and social aspects of the immediate surroundings of the participants' discourse-world and the evolving conceptual spaces or text-worlds that constituted the participants' common ground. One particular strength of the framework was that it uncovered the close interdependent relationship of the formation of the abstract concepts with the concrete conceptual world of here and now. For example, section 4.3 demonstrated how the teacher and pupils first built text-worlds depicting parts of the apparatus of the demonstration, that was situated in the discourse-world, that the teacher wished to foreground, using the deictic and referential elements supplied by the discourse. The language used to refer to the concept of *heat energy* and *heat transfer* in this context, in addition to the shape of the apparatus evoked the SOURCE-PATH-GOAL image schema that was shown to play a key role in the concepts' dynamic construction, and metaphorical representation of the participants' ideas to each other within the group.

By applying Brandt and Brandt's (2005) adaptation of Fauconnier and Turner's (2002) Conceptual Integration Theory to the analysis (e.g. predictions, Simulation-

Role-Play and analogies), a cognitive explanation of the linguistic phenomena observed during the creation of hypothetical worlds by the blending of the pupils' input spaces was provided. One possible weakness of the analysis is that it gives the impression that the participants started with a structure with clear inputs to begin with, which after a series of discrete operations, resulted in a blend. It is, however, the constraints of the analysis itself i.e. the manner, in which it is represented that gives the reader this impression. Fauconnier and Turner (2002) are however clear that the actual blend-construction is 'an on-going, emergent, network based process, it is also, by necessity, one which involves revision and changes to the construction during the process (Alexander 2011: 129). Furthermore, these network-building processes happen at the same time. Nevertheless, for pedagogical purposes, mapping out this construction using the conventions provides the researcher with the means to identify potential sources of confusion for the pupils.

One constraint of the original Conceptual Integration Theory is that it has been applied more frequently to written texts and not to naturalistic settings such as the classroom. It became quickly apparent from my initial analysis that the situation and the discourse played an important part in determining which elements of the input spaces would be projected into the blend. Brandt and Brandt's (2005) context dependent blending theory provided me with the possibility to show how the situation (i.e. intended purpose of the interaction) could influence the blend-construction process.

Finally, much of the discourse appeared to be structured by underlying image schemas (or p-prims in conceptual change theory), for instance the SOURCE-PATH-GOAL schema during the demonstration and the CONTAINER schema during the lesson on insulation. This qualitative analysis demonstrated the fluid nature of these schemas, which evolved and shifted over time depending on the purpose of the exchange. The interview with the pupil provided a striking example of how within the context of the interview, the form of schemas evoked were heavily influenced by the task set and how the interpretation by the researcher of the responses was influenced by the social structure of the interview. This poses a serious challenge

for dominant conceptual change theorists who work with the assumption that pupils move from naïve misconceptions to expert conceptions in a linear manner.

As this chapter has looked at how these concepts were introduced into the discourse space by the teacher, they are as expected very teacher focused. The teacher takes the dominant position throughout, rather like the narrator of a story. Despite this, the analysis reveals that the exchanges made by the teacher are based on his ability to construct accurate mind-models of his pupils. That is, his selection and choice of language have been shown to be based on his situated assumptions of the knowledge frames of his present audience (e.g. see section 4.3.6 when Mr Dalel seems to 'capture' the pupil's emerging SOURCE-PATH-GOAL schema to move the narrative forward).

Despite the apparent 'success' of the exchanges, passages were identified in the analysis which might have resulted in the pupils not understanding the event in the same way as the teacher intended due to 1) a misalignment between the teacher's and the EAL's pupils' linguistic and cultural knowledges (e.g. see section 4.4.4). Further sources of confusion may have resulted from 2) the teacher's overestimation of the pupils' background knowledge (e.g. see section 4.5.4) and 3) issues surrounding classroom management (e.g. see section 4.4.4). The cognitive linguistic frameworks proved to be very effective tools to tease out and isolate potential problem areas.

This chapter has focused on how abstract concepts are introduced into the discourse space by the teacher. It has demonstrated the suitability of a text-world framework to tracking the development of abstract concepts in a naturalistic setting. The next chapter will focus on how these concepts become part of a more negotiated discourse space taking place between pupils in discussions or between the teacher and/or researcher in more open ended pedagogical tasks.

Chapter 5: Application of the concept of *insulation* to a problem-solving task

5.0 Introduction

The first analysis chapter looked at how the abstract concepts of *heat, temperature, heat transfer*, *conduction* and *insulation* are either re-introduced or introduced for the first time by Mr Dalel into the classroom discourse. In contrast, this chapter focuses on how the pupils apply their understanding of *insulation* to an everyday problem in a negotiated discourse space, in which the teacher plays less of a central role and the pupils have more opportunities to steer the discourse. Interestingly, the word *insulation* does not feature in the discourse until quite late (the word *insulator* appears for the first time in the transcript only in line 264: see appendix two), and not by Mr Dalel but by a pupil. Despite this, an understanding of the concept is necessary, if the pupils are to solve the problem that Mr Dalel sets at the start of the lesson. It is the development of this understanding by a collective group, 'the class' and two individual pupils Rose and Sanja which is explored in this chapter. The specific aims of the chapter are as follows. First, in line with the main aims of the thesis, it aims to provide an account of how the abstract concept of *insulation* is applied to a problem-solving task and linguistically represented in discourse during the task. The second aim is to investigate the suitability of the text-world framework to explore the development of the abstract concept of insulation during whole class, small group interactions and an interview situation. To meet these aims, a cognitive discursive analysis of the following two situations is made.

The analysis of the lesson 'the snowman and his coat' (25.03.15) is organised into eight episodes, each with its distinctive analytical focus. In the first episode (5.3), the teacher, Mr Dalel, presents the problem by showing the pupils a cartoon visual (see Figure 5.2), in which three children are building a snowman. The three children in the visual each have a different opinion about whether the coat, which one of the children is holding, would cause the snowman to melt or not. The three episodes (5.4-5.6), examine how the pupils decide which of the three opinions of

the children in the visual they agreed with. The analysis of episodes (5.5.2-5.5.3) focuses on the epistemic stance, pupil participation and participant identity, in terms of their roles (see 5.1.4 for a fuller explanation of what is meant by this term), from a cognitive discursive perspective. Pupils draw from their own episodic memories to make sense of the new situation. During the following episode 5.6, in which the pupils take a more prominent role in the knowledge building process, the language becomes more ambiguous. The role this plays in the knowledge building process is explored. Once the pupils have committed to one of the three outcomes, Mr Dalel makes two small snowmen out of ice in order for the pupils to see the outcome for themselves. One snowman has a coat made out of cardboard. The class take the snowmen outside and the two snowmen are placed in a shady place next to the science block (episode 6). Once the pupils are back in the classroom, they reform again into their small groups, and discuss together which of the snowmen would melt first. The epistemic stance of the pupils working in small groups, is analysed in section 5.9. Particular attention is paid to the epistemic marker 'I think'. Shortly before the bell goes, the pupils are taken again outside to see which of the snowmen has melted first (5.10).

The stimulated recall interview took place during the first fifteen minutes of the lesson on 01.04.15. Two pupils, Sanja and Rose, were extracted from the class and were interviewed in a nearby room. The reason behind choosing these two pupils was that during the class discussion their responses to the teacher's question were inaudible but from Mr Dalel's responses, it appeared that Rose and Sanja had contrasting viewpoints. The interview provided me with the opportunity to ask the pupils if they could remember what they had said and I thought the resulting data would be more interesting if I interviewed pupils who did not hold the same view. The main purpose of the stimulated recall session was to explore the two pupils' reasoning in more depth. During the interview, I listened to what Rose and Sanja had remembered about their original ideas before they had seen the result of the experiment, to find out how their ideas had changed after seeing the result.

The text-world approach to analysing the data allowed me to map out and explore the different conceptual levels of the discourse which played a key role in the knowledge building process. Furthermore, the cognitive discursive approach allowed for a fine-grained linguistic analysis of the pupils' reasoning of their memories which for most linguistic analyses (e.g. conversation analysis, discursive psychology) would not be possible, as these approaches do not recognise the mental states and faculties that lie beyond the discourse (New 2003). The stimulated recall session acted as a type of meta commentary on the analysis of the lesson. Despite this, I have decided to keep the analysis of the lesson and interview separate in this chapter as each has its own distinct narrative. However, where there are clear links and when the result of one analysis sheds light on the result of the other, this will be made explicit in the text.

The main topics that emerge from the analyses of the lesson and interview in this chapter are as follows:

1. Discourse-worlds and context
2. Use of cartoon visuals for pedagogical purposes
3. Epistemic modality: I think, 'would'
4. Pupil participation and identity
5. The role of ambiguous language in the incrementation and accommodation process

The following will provide a brief overview of these topics and how they are covered in this chapter.

5.1.1 Discourse-worlds and context

Although Werth recognises that the surrounding context plays an important role in the interpretation of the discourse (1999: 150), he places a particular emphasis on the text-driven nature of the interpretation of a piece of given discourse; 'the retrieval and selection knowledge relevant to a piece of discourse must be text-driven' (1999: 149). However, as exemplified in this chapter, in a classroom

environment attention to the participants' discourse-worlds is just as important, if a truly contextual interpretation is to be made.

Therefore, an additional difference to the previous chapter is that this chapter pays more attention to the discourse-world, or immediate context of the participants. This is in line with more recent contributions by text-world theorists who have applied a text-world approach to discourses other than the reading of texts by a single individual reader e.g. classroom discourse (Giovanelli 2016; interviews (van der Bom 2015); reading groups (Whiteley 2011, Peplow et al. 2016). Therefore, the relationship between the physical and social contexts which constitute the participants' discourse-worlds, and the knowledge frames of the participants during the interpretation process, will be a key feature of this chapter.

5.1.2 Use of cartoon visuals for pedagogical purposes

Mr Dalel introduces the problem of the melting snowman, at the start of the lesson, by means of a visual that shows three children building a snowman. Each of the children's opinions is written in a speech bubble. This cartoon like depiction of an everyday situation is clearly a different genre to the prototypical academic genre. However, in the lesson it has a pedagogical purpose in an academic setting. In section 5.3.2, the use of this cartoon visual in an academic setting is explored from a text-world perspective.

5.1.3 Epistemic modality: 'I think', 'would'

One prominent feature of the discourse in both the lesson and the interview is the language used by the participants to express their confidence towards their claims. This chapter will provide a short overview of epistemic modality from a cognitive discursive perspective (see sections 5.5.2, 5.5.3 and 5.9.1) before applying and combining this theoretical model with a text-world approach to the data.

5.1.4 Pupil participation and identity

In the first analysis chapter, the role of the participants was part of a teacher centred context in which the teacher positions himself as the central narrator,

introducing or re-introducing the key concepts into the discourse space. In contrast, this chapter analyses how the pupils adopt a more active role in the learning process, and how Mr Dalel moves between more than one identity i.e. being the 'orchestrator' and 'the knower'. The shifting identities of the participants is analysed from a text-world perspective. Importantly, the emergence of the various identities of the participants is viewed in this chapter as being central to the knowledge building process.

5.1.5 The role of ambiguous language in the incrementation and accommodation process

The knowledge building process is understood here, in text-world terms, as a process of incrementation and accommodation. Briefly put, incrementation is the text-world term for the process by which knowledge of an individual participant becomes shared amongst those present. Central to this, is the process of accommodation that accounts for how participants react and assimilate new information in 'a background way' (Werth 1999: 280). These concepts are defined more fully in section 5.7. In this chapter, the cognitive discursive analysis of the class discussion and group work demonstrates how the ambiguous nature of the language used does not only provide new and interesting possibilities (Littleton and Mercer 2013:9), but also is an essential feature of the incrementation and accommodation process.

5.2 Some preliminaries: the discourse-world of the participants: split worlds, knowledge frames and identities

5.2.1 Split worlds

This chapter, like the first analysis chapter, is mainly based on the analysis of a transcript (see appendix two) of the lesson, which took place on 25.03.15. References to the original recording and field notes, written during the observations were also made, as part of the final analysis.

The section of the lesson which is analysed in this chapter, starts with Mr Dalel showing a visual of a group of children building a snowman. This visual forms part of the participants' discourse-world. As previously established, Werth defines the

discourse-world as the situational context surrounding the production and interpretation of any given discourse (1995a:51). The scene the visual depicts and the text-world it generates, however, is of another time (winter) and place (a park or a garden). In most reading situations, the text represents a split between the spatiotemporal world of the reader and the author (Gavins 2007a). In this example, this split is between the pupils in the classroom and the material designer, the author of the visual. In other words, the pupils and author occupy separate temporal and spatial locations. The teacher occupies the same discourse-world as the pupils but occupies separate temporal and spatial locations to the author. As the teacher chose to use this visual, however, his knowledge and belief systems are assumed to be closely aligned with the original author, as they are the same science teaching community. For this reason, the teacher and author could be seen to occupy the same person. The participants have the choice therefore to construe the teacher and author as one person or two. This explains how the teacher is able to shift his position from being a voice of authority, to one who assumes a more co-participatory stance during the class discussion. It will be demonstrated in the analysis of this chapter (see section 5.6) how the interplay and at times tension between these two positions is a necessary catalyst which propels the discussion forward.

5.2.2. Knowledge frames

Both Mr Dalel and the pupils all make their own inferences of the scene depicted by the visual of the snowman, by using whatever available knowledge frames and other mental faculties such as their beliefs, imagination, memories, that they judge as relevant. The discourse-worlds of the participants (teacher (author), and pupils) consist of several mental faculties, which Werth (1995) represented as follows:

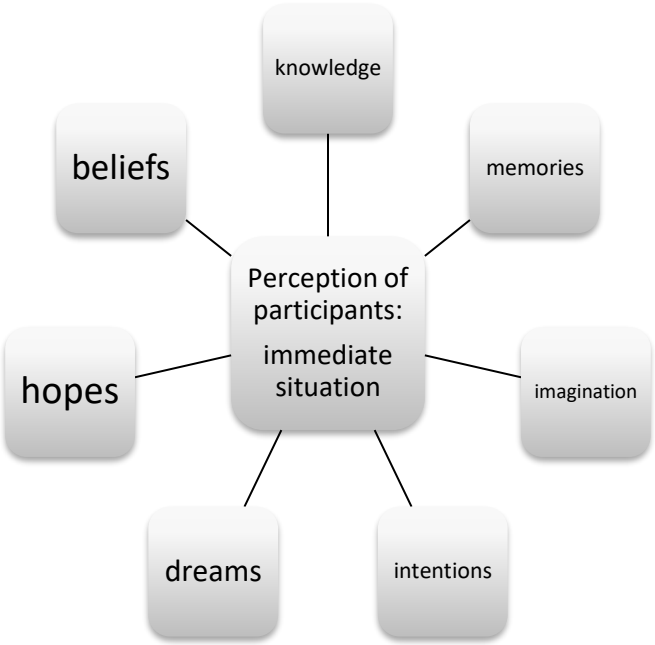


Figure 5.1. The discourse-world (adapted from Werth 1995: 52)

The pupils' inferences are shown to be influenced by memories of building a snowman and the ability to imagine a winter's scene. This is illustrated by the following exchange, in which Rory, P17, in line 129 draws on his past experience of building a snowman with a friend to inform his reasoning during the class discussion:

128 **T:** so you think it won't make a different right this group

129 **P17:** one of my ↑friends put a jacket on and it never melted

130 **T:** it never ↑melted when you put the jacket on the snowman do you think it
131 would melt more quickly if it HADN'T been put on the snowman (4.0) it
132 might it might not well that the experiment we're going to do next yup

Extract 5.1 *from lesson two, appendix two, lines 128-132*

In contrast, the teacher's choice and delivery of the task must be influenced by his knowledge of teaching in general, and more specifically of teaching *heat transfer* and *insulation*. It will be influenced by what he hopes to achieve in terms of intended outcomes of the lesson and specific task, how he believes his pupils learn and how able he is to imagine what the pupils might be thinking, in other

words his ability to mind-model (Stockwell 2009) (see section 4.2 for an explanation of mind-modelling). Rather than seeing this knowledge as being fixed, it seems more appropriate to view it as one which changes and evolves according to the physical and sociocultural context it is in. The type of knowledge that he has to guide him through this process will consist of both a knowledge of the subject matter (e.g. heat transfer), and knowledge of how to represent this knowledge (i.e. through visuals, demonstrations, analogies and examples) to a particular group of learners, within the context of a learning programme. Shulman (1987) refers to this blend of content and pedagogical knowledge as *pedagogical content knowledge* which he describes as 'that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding' (1987: 8). He maintains that pedagogical content knowledge forms a knowledge base for teaching that is concerned with how ideas in the classroom are managed (Shulman 1987:1).

Although this model is a description of a teacher's knowledge base, I would argue that the distinction between content knowledge and a knowledge about how to represent this knowledge applies to learners and indeed to anyone engaged with understanding how knowledge in the classroom can be conceptualised. Indeed, Shulman's model is not incompatible with Werth's conceptualisation of knowledge (1999). In Werth's model, the speaker- and hearer-knowledge required to interpret an ongoing discourse consists either of propositional (i.e. factual knowledge expressed as a proposition) or functional knowledge (i.e. largely unconscious physical actions or conceptual processes). The distinction Werth makes between propositional and functional knowledge resembles the distinction Shulman made between content knowledge and how to represent that knowledge. For example, typical propositional knowledge about heat transfer would be 'insulators are bad conductors of heat'. The corresponding functional knowledge, or how this knowledge could be demonstrated or represented would be setting up an experiment to show insulators are bad conductors. In other words, functional knowledge 'may consist of a set of *acts*, directed towards some specific goal, or undirected' (Werth 1999: 102). Werth's model is more detailed, however, than

Shulman's in that he subdivides his propositional and functional knowledge into four categories; cultural, linguistic, perceptual and experiential.

Particularly relevant to this cognitive discursive analysis of the development of abstract thinking is the notion of functional experiential knowledge which constitutes not only extended activities such as setting up the problem-solving task, but also cognitive *acts*, which structure the participants' thinking. Drawing on work by Lakoff and Langacker, Werth maintains that image schemas constitute functional knowledge (1999:110). Werth's position is in line with recent findings from the field of cognitive science which has provided a substantial amount of evidence that abstract concepts, such as those evoked during this episode, consist of both language and images, that can be in the form of image schemas (Barsalou, 2010). This chapter, especially the pupil interview, will build on the first analysis chapter by acknowledging the role that image schemas play in structuring abstract thought and additionally it will contribute to existing knowledge on image schemas by demonstrating how they structure thought in a social setting.

5.2.3. Identities of participants and enactors

If a fully contextual, sociocognitive account of the incrementation process is to be made, which Werth proposes (1999), that it is important to focus on the interpersonal aspects of the discourse-world of the participants as well as the ideational (i.e. the conceptual and logical). However, as pointed out by Peplow et al. (2016:176) the interpersonal dimension in the accumulation of shared knowledge during communication tends to be overlooked by text-world theorist. This might be because Text World Theory has until only recently been applied to situations which involve multiple participants as opposed to a single reader and writer.

Peplow et al. remind us that information regarding the participants' identities forms part of the mutual shared knowledge which is both developed and orientated towards during the incrementation process (2016: 176-7). This chapter examines how the learner and teacher identities are both represented and constructed in discourse. Whereas traditional essentialist notions of identity have characterised it as discrete and static, more recent discursive views acknowledge

the negotiable, complex and fluid nature of identity construction (Bucholtz and Hall 2005). The approach taken here, when conceptualising the identities of a specific learning community, goes beyond thinking about identity as purely a discursive phenomenon. It examines what lies 'beyond the discourse' (van der Bom 2015: 56). In other words, it acknowledges the participants' memories, and cultural knowledge frames that they bring with them and use in the classroom which, it will be argued, form an essential part of the knowledge and identity building process.

By applying a cognitive-discursive approach to analysing pedagogical discourse, it will be shown how the often subtle shifts in identity-taking by the participants during learning episodes can either privilege, sanction or evoke certain knowledge frames.

5.3 The lesson: 'the snowman and his coat'

5.3.1. Situating episode one

The teaching purpose of the following episode is to introduce an everyday situation to the pupils whose outcome is not known, but is to be predicted by the pupils during the consecutive class discussion and group work. According to Mr Dalel, with whom I spoke to just prior to the lesson, the pupils should be able to correctly predict the outcome of the situation if they apply their knowledge of insulation which had been introduced in the previous lesson (25.03.15), and at the beginning of this lesson (01.04.15). Mr Dalel starts this episode by depicting and describing a scene, which is illustrated by means of a visual diagram (Figure 5.2) shown on the whiteboard at the front of the classroom.

77 **T:** ok look at this picture here (.) you know what that is don't you

78 **P:** snowman

79 **P:** it's a snowman

80 **T:** it's a snowman right you usually put stuff on a snowman (.) I want you to
81 pay attention to the ↑scree:::n I want you to pay attention to the board
82 (.) everyone look at the board and look at what I'm telling you (2.0) right
83 there's a snowman (.) he's got a scarf he's got a hat ↑a:nd the 3 children
84 are saying don't put the coat it will melt him (.) and the boys is saying no
85 it won't it will keep him cold and ↑stop him from melting the other friend

here is saying I don't think the coat will make any difference (.) so there's ↑three different points of view there. One is saying the coat will MELT the snowman if we put it on (.) the other is saying it will stop him from melting it will keep him ↑cold and the third one is saying it won't make any difference (.) at all (.) so what do you think? ok what I want you to do is I want you to have a discussion (.) about what you think all your ideas and ↑why you think what you think ok ↑what I also want you to do is one person from the group to take away all the water and the plastic bits one person to do that ↑one person to actually ↑scribe one person to actually make sure everybody actually contributes(.) GET BUSY for the next two or three minutes

Extract 5.1 *from lesson two, appendix two, lines 77-96*

The start of this activity is characterised by language that is institutional classroom language (Seedhouse 2004), 'I want you to pay attention to the screen I want you to pay attention to the board everyone look at the board and look at what I'm telling you' (line 80-82). The directives used by Mr Dalel are aimed at drawing the pupils' attention to the visual displayed on the whiteboard which constitutes part of the pupils' discourse-world. Mr Dalel provides a brief description of the scene, 'right there's a snowman (.) he's got a scarf he's got a hat ↑a:nd the 3 children are saying' (line 82-3). The scene takes place in a park or garden during the winter. The ground is covered with snow. The conversation between the enactors is an example of casual conversation between three children building a snowman. It is used in the classroom for a particular pedagogical purpose, namely to introduce an everyday situation whose outcome the pupils are to predict. The use of non-institutionalised talk in a classroom situation has consequences for the manner in which the visual is interpreted. This will be outlined further in the following section.

5.3.2. Employing a cartoon visual for pedagogical purposes

In the visual, the enactors of the scene, the '*three children*' (line 83), have built a snowman. They have dressed him with a scarf and a hat and are discussing whether to put a coat on him.

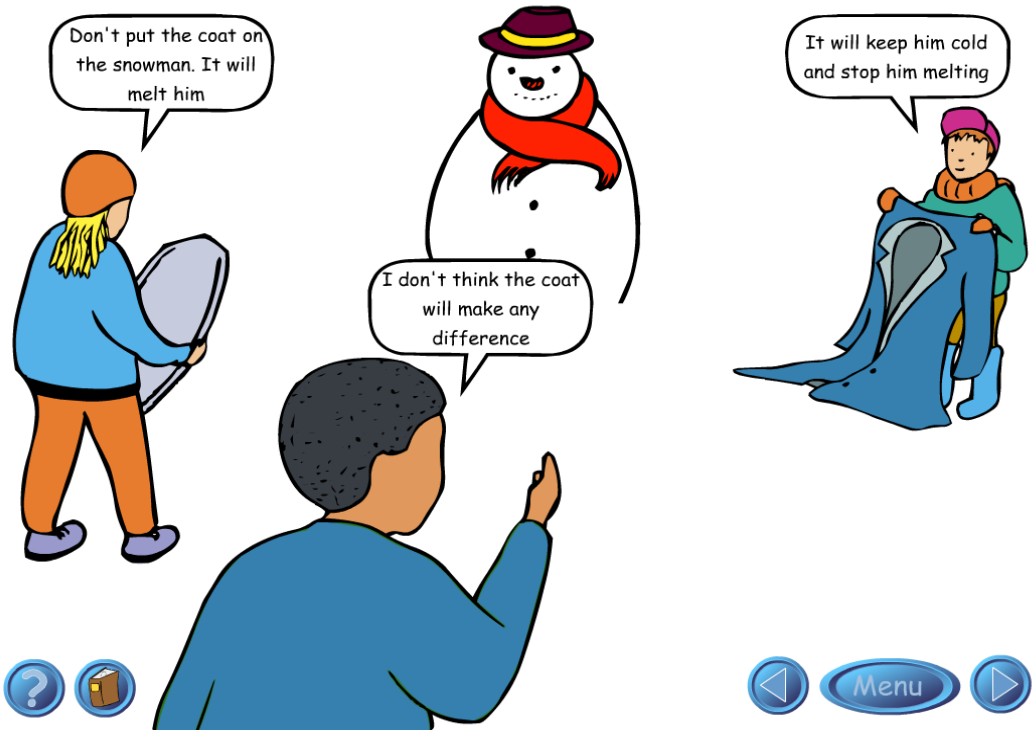


Figure 5.2. Visual used to present the problem: Science concept cartoons, Milgate House Education Ltd.

The illustration on the whiteboard that the participants see invites them to identify more or less equally with any of the three children, as none of the enactors is portrayed or foregrounded in the visual as being necessarily more knowledgeable than another. The conversation between the enactors takes place outside the classroom and therefore represents a casual conversation. The direct speech of the enactors is written in speech bubbles in the diagram, and is brought to life by Mr Dalel in lines 84-86, when he animates the scene by re-enacting what the children say. Through the visual and Mr Dalel's animation, pupils might initially experience this as a piece of casual conversation. By changing the pitch of his voice into a more childlike voice, Mr Dalel further supports the creation of a text-world in which the participants are able to experience more closely as if they were actually present. The participants are transferred momentarily to a time (winter as there is snow) and place (outside) other than that of the discourse-world of the classroom.

The use of direct quotes, albeit in literary texts to achieve the effect of transporting the participants into the world of the enactors has been well

documented (Gavins 2007a; Clark and Gerrig 1990). What is relevant to this analysis from this coverage in the literature is Clark and Gerrig's claim that the participants interpret the scene 'in part through direct perceptual experience' (1990:767), which is achieved with a familiar winter's scene, the teacher's animated voice and the use of direct speech. Through this experience of the scene and the Mr Dalel's animation, the text-worlds created may be felt to move closer and become *more* participant-accessible. This exemplifies and supports the notion made by van der Bom (2015), that text-worlds are participant accessible *by degree* and not either only participant accessible or not participant accessible, as has been the case with text-world studies until recently.

As already established, the illustration on the whiteboard that the participants see, invites them to identify more or less equally with the three children. However, on closer inspection of the language, there appears to be a qualitative difference between the three turns which may, as I argue, influence the way they are interpreted.

Each enactor's (or more precisely the writer's) choice of the modal verb 'will' in the epistemic modal-worlds one and three, indicate their equally strong commitment to the state of the world and their prediction of the outcome of putting the coat on the snowman.

Epistemic modal-world 3 has a slightly different quality in that it is the negation of a difference the coat will make as represented in modal-worlds 1 and 3. The use of the negative, in this particular instance, has a subtle foregrounding property in that it makes the statement stand out as different from the other two statements (Givón 1979, 1993).

Enactor 3 chooses to position himself as not agreeing with enactors 1 and 2's claim which is that the coat will have an effect. He does not put forward his own positive statement possibly because linguistically, it would be much more complex than simply saying: *I don't think it will make any difference*. In academic discourse,

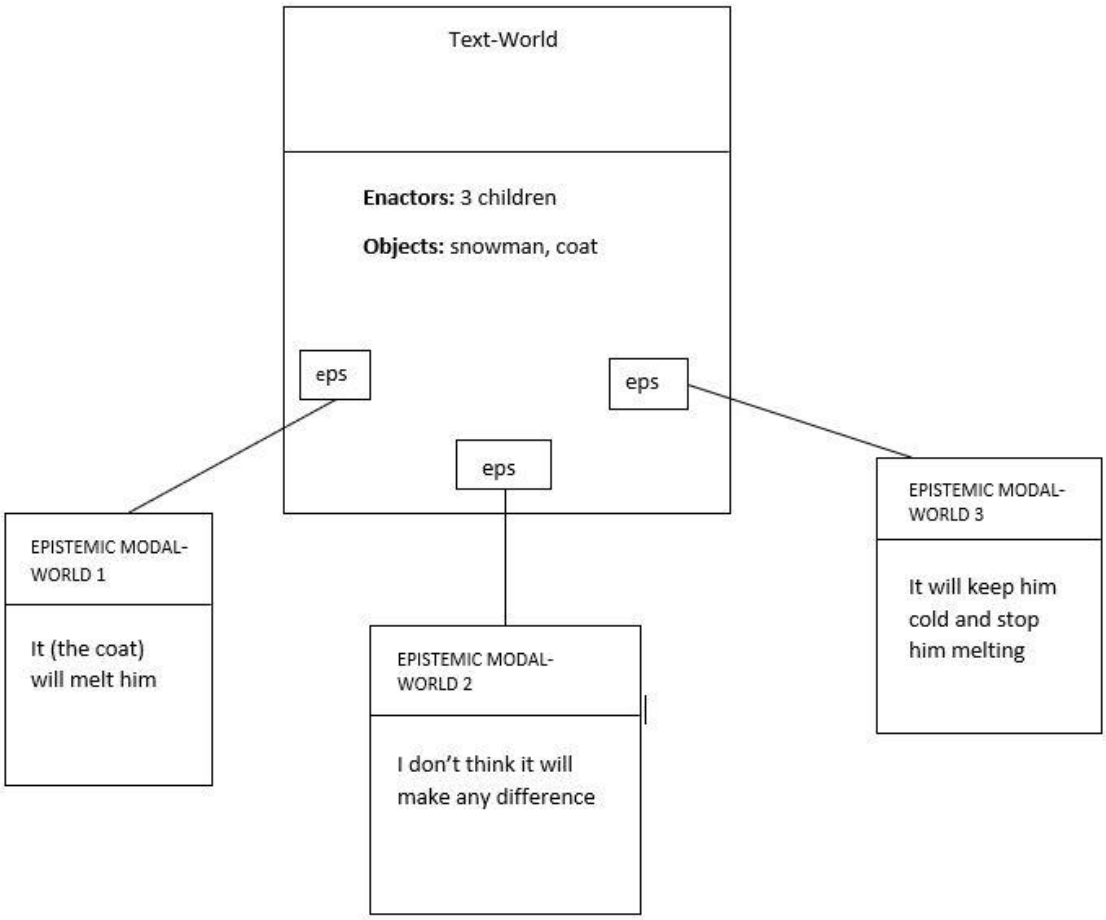


Figure 5.3. Text-world of visual 'children building a snowman'

this might result in his statement being interpreted as being less convincing if such a turn were perceived to be motivated more by a negative stance towards speakers 1 and 2, rather than an evaluation of the evidence. However, in this particular context, the pedagogical purpose of the visual is simply to present three alternative, equally weighted viewpoints about the state of the snowman after a coat has been put on him. Mr Dalel reinforces the pedagogical purpose in his description of the scene in lines 80-90. Here, Mr Dalel reports what the children say but does not foreground or show a preference for any of the children's opinions. He presents them to the pupils in a matter of fact manner as simply: 'three different points of view' (line 87). The resulting interpretation of the

participants will depend on their sensitivity to the above-mentioned foregrounding elements, their understanding of the pedagogical purpose of the task, and of course, the interplay between these and their own background knowledge frames.

5.4. Episode two: initial positioning of pupils

After introducing the visual, Mr Dalel organises the pupils into groups and asks them, 'so and what do you think' (line 90). According to Mr Dalel, the main pedagogical purpose of the group sessions is, 'to get them to think about things a bit more' (interview: 18.2.15). From observing the groups, the main conceptual focus of the exchanges was for some of the members to simply state their position. The group work served an interpersonal purpose too. Working in small groups enabled the pupils to reveal their inner thoughts in a less face threatening manner, than if they had to do this for the first time in front of the whole class. This group session, therefore, served as a preparatory session for the class discussion which follows.

By asking the pupils what they think, Mr Dalel requires the pupils to create an epistemic modal-world, in which they decide which of the three points of view they consider to be correct. In the next three minutes of the lesson, the pupils exchange views on what they think. The following is an example of one of the conversations held:

98 **Grp:** this pen's not working
99 **T:** just get another pen
100 **P1:** Suzy what do you think?
101 **P6:** what?
102 **P1:** so one person's saying don't put the coat on it'll make him melt
103 **P6:** doesn't (.) make (.) it (.) melt
104 **P1:** er
105 **T:** ok boys and girls

Extract 5.2 *from lesson two, appendix two, lines 98-105*

The exchanges in lines 98-105 between Mahta and Suzy are characterised by the pupils stating what they think without expressing any reasons for their choice. According to Mercer and Littleton (2013), this type of talk in which pupils simply state their opinion rather than explore reasons is classified as *cumulative talk* and is generally viewed as being less effective in getting pupils to think together, or 'interthink'. As pointed out by Peplow et al. (2016), the focus taken by Mercer and Littleton in their analysis is a sociocultural one. They are interested in how language is used in joint intellectual activity and how shared understanding is developed in a social context over time (2013: 13). They distance themselves from 'linguistic' discourse analysis in that they are less interested in how talk is organised and structured. However, by not paying enough attention to how the linguistic forms reflect the cognitive states of the participants, there exists a tendency to classify talk only in terms of how it responds to the social circumstance of the classroom. Peplow et al. (2016) rightly maintain that by applying a Text World Theory analysis to interactive discourse allows for a clearer understanding of how text-worlds are evoked, maintained and developed. This additional layer of analysis allows for a reassessment of the talk from a cognitive perspective and leads to a more nuanced account of how talk is used to build knowledge together.

Interestingly, Mahta in line 102, does not state directly what she thinks but uses the opinion of one of the enactors in the illustration to move the conversation forward to build a participant accessible text-world, 'so one person's saying don't put the coat on it'll make him melt'. In line 103, Mahta responds very directly to Suzy's turn by establishing an epistemic modal-world which negates Mahta's text-world, 'doesn't (.) make (.) it (.) melt'. The intonation is monotone and the words have short pauses between them giving a staccato like quality to the utterance. Mahta responds with the filler, 'er', which could either indicate surprise at the manner at which Suzy expressed her opinion, or at the propositional content of what is said. Suzy moved from Hong Kong four years previously and retains features in her speech typical of Cantonese speakers. However, as the two pupils had worked together before, including during the previous activity, Mahta should be accustomed to Suzy's pronunciation. Therefore, the surprise that Mahta shows

is probably more likely to be towards the ideational meaning. This is further supported by the fact that Mahta chose to state, 'one person's saying don't put the coat on it'll make him melt' (line 102), and not the other two opinions, indicating that Mahta probably favours this opinion over the others, and therefore she disagrees with Suzy. The ambiguity of the language and the range of possible meanings poses a challenge for the text-world analytical approach in that it is difficult to pinpoint exactly the nature of the text-worlds that result from this dialogue. Referring to the wider social context provides evidence for the different possible interpretations.

Regardless of whether Mahta's reaction was directed to the manner or the propositional content of Suzy's utterance, what is clear from analysing this brief episode from a cognitive discursive perspective is the speakers have the opportunity to co-construct and establish to each other their stance and the degree of confidence they have towards their position through the creation of epistemic modal-worlds. Furthermore, this brief exchange illustrates how they are able to reassert their own identities as learners with different cultural and linguistic knowledge frames.

5.5. Episode three: initial response of class

5.5.1. Situating episode three

In the episode which follows, the pupils are required to state in turn which of the three positions they agree with. The aim of Mr Dalel is to encourage the pupils to commit to one of the positions. The pupils move over to Mr Dalel at the side of the room with their show-me boards. Two groups out of five of the groups of the pupils have written their decisions on the boards, and Mr Dalel invites each group to state their predictions:

105 **T:** bring your show me boards here (.) right guys over here(.) that table
106 over here (3.0) right ok can everyone see (1.0) what was the group's
107 decisions what ideas came up

108 **P15:** I think [inaudible] warm up [inaudible]

109 **T:** so what you reckon would happen if the coat were put on would it melt
110 ↑more quickly or ↓less quickly

111 **P15:** wouldn't make a difference

112 **T:** it wouldn't make a difference right (1.0) Sanja what did you think what
113 did you do

114 **P10:** [inaudible]

115 **T:** so you thought the coat would actually make the snowman melt more
116 quickly ↑is that correct? Okay that's what you thought OK Zarif

117 **P6:** It would melt the snowman because coats are supposed to keep you
118 warm

119 **T:** okay coats are supposed to keep you WARM and the snowman should
120 melt (1.0) and

Extract 5.3. *from lesson two, appendix two, lines 105-120*

Here, Mr Dalel does not indicate what the correct answer is but instead requests each group to state their decision for the other members of the group to hear. Mr Dalel's apparent desire for the pupils to make some degree of commitment towards their statements is reinforced by the use of the show me boards, which form part of the discourse-world the pupils find themselves in. The arrangement of the pupils is significant here, as it appears to have a direct impact on the manner in which Mr Dalel interacts with the pupils. A non-threatening and possibly more intimate, thought-sharing discourse-world is created, by having the pupils gather in a group by the side of the classroom.

The common ground shared between the discourse members at the start is made up of the three possible alternative viewpoints, which were initially presented as the beliefs of the enactors in the visual, but are used as starting points to develop the viewpoints of the pupils. That is, the epistemic modal-worlds depicted in the direct quotes in the visual become pending epistemic modal-worlds accessible to the pupils. The strength of the commitments towards the viewpoints held by the pupils is somewhat unclear, as they are not challenged to defend their views but simply state them. However, there are some clues that indicate the degree of commitment the pupils hold towards their statements. First, only two of the five show me boards have the group's decision on them, indicating that many of the pupils may not have reached a decision. Further indication that the epistemic modal-worlds of the participants might be pending and therefore less certain is

indicated by the participants (both teacher and pupils) use of 'would', the psychologically remote form of 'will' (Werth 1997, 1999) to make most of their predictions with.

5.5.2. Epistemic modality

The main pedagogical purpose of this episode is for the pupils to predict the future outcome of an action. To do this, Mr Dalel and pupils set up epistemic modal-worlds, to express their degrees of confidence in the truth of their claims. Before embarking with the analysis, a brief coverage of modality from a cognitive discursive perspective is made.

According to Werth, modality is 'the situating of the information with respect to the current context' (1999: 183). He goes on to say that this information can be situated in context on three levels, namely, i) social interaction ii) location (either physical or abstract), and finally iii) probability. The epistemic-modal worlds set up here define the situation of the scene depicted in the visual from the viewpoints of the pupils, which are removed from the immediate discourse-world of the classroom and are therefore more remote. They are stipulating the probability of an event that cannot yet be confirmed. Epistemic modality is frequently categorised as being an expression of either a subjective or objective evaluation of the state of affairs. According to Lyons (1977), epistemic modality can be defined as either subjective modality, (i.e. according to the speaker who is just uncertain of the hypothetical fact), or as objective modality (i.e. the speaker computes the mathematical likelihood of an event to take place). However, as pointed out by Nuyts (2001: 33) there are a number of issues with Lyon's definition. Firstly, the distinction between these two categories is difficult to distinguish, when analysing empirical examples, as there is no clear indication of which formal properties of the language mark them as either subjective or objective (therefore, for purposes of this research, it would be difficult to categorise the examples found in the transcript as either subjective or objective). Secondly, he questions what it means to be uncertain about a state of affairs (do we really compute a mathematical probability when speaking). He points out that

the distinction may lie more with the quality and reliability of the evidence i.e. the 'evidentiality'.

In contrast, Nuyts' (2001) model proposes that epistemic modality comprises of two dimensions, namely, one which involves i) an evaluation by the speaker of the probability of the situation and ii) an evaluation of the evidence. He proposes that subjectivity is part of the evidential domain but also an evaluation based on that evidence from the perspective of the participants. Rather than a strict dichotomy between subjectivity and objectivity, Nuyts replaces these terms with subjectivity and intersubjectivity, placed on a cline. Evaluations which are spontaneous and are based on the speaker's own personal knowledge are classified as subjective, whereas if the speaker knows that the information is shared by other members of the group or wider community, they are intersubjective. In text-world terms, subjective evaluations are only accessible to the speaker and intersubjective evaluations are accessible to the group.

Table 5.1. Nuyts' model of epistemic modality

subjectivity	**intersubjectivity**
speaker alone knows or has access to evidence (and thinks only they know this)	evidence is known by larger group of people (and speaker thinks this).

Nuyts' model of epistemic modality is more socially interactive than Lyon's version, which focuses primarily on the evaluations made by the individual. For this reason, Nuyts' version sits well with Werth's context view of modality, which he claimed to be, 'the interaction between the participants and what is said' (1999: 176), and is therefore better suited to the study of interaction patterns taking place in the classroom. Thus, the text-world analysis of epistemic modality in this thesis incorporates Nuyts' version of epistemic modality into its framework.

5.5.3. Epistemic modality: would

One prominent feature of the participants' discourse is that the pupils frequently use the modal verb 'would' to communicate epistemic distance to each other. It has been claimed that the proximal-distal metaphor NOW IS HERE - THEN IS THERE is involved in the speakers' choice to use the modal 'would', (the past form of the modal 'will'), indicating still a strong but slightly lessened commitment than 'will' (Tyler 2012). However, as pointed out by Werth, it is 'will have', which expresses certainty about a past-time zone e.g. John will have been home for at least an hour (1999:177). Instead, 'would' designates psychological distance, which although it has a 'parasitical relationship' to time (ibid.) it is used in cases when there is a need for social distance (e.g. politeness), withdrawn personality (e.g. shyness), positive face (the need for respect) and negative face (the need for self-determination) (1997: 87).

In line 109, *what you reckon* and *if* set up an epistemic modal-world. The hypothetical is then taken to a further point by both the teacher and the pupils using 'would' function advancers.

109 **T:** so what you reckon would happen if the coat were put on would it melt
110 ↑more quickly or ↓less quickly

111 **P15:** wouldn't make a difference

112 **T:** it wouldn't make a difference right (1.0) Sanja what did you think what did
113 you do

Extract 5.4 *from lesson two, appendix two, lines 109-113*

The use of 'would' in this episode are part of a hypothetical construction, which is removed from the self in the present discourse-world of the classroom. Hypotheticals are one way we are able to communicate epistemic distance in discourse (Gavins 2007a: 118) and are used to create imaginary worlds situated beyond our present discourse-world.

The choice of ‘would’ over ‘will’, can be explained by referring to the context. First, the scene is removed from the classroom in both time and space and, therefore, is deictically removed from the pupils’ immediate surroundings. The pupils do not need to make a decision to act in the world as do the enactors, who interestingly all use ‘will’, which carries more force (Talmy 1988, Sweetser 1990). Second, the pupils in the classroom are required to put forward opinions which might turn out to be wrong in front of their peers. Therefore, the establishment of a more tentative, remote text-world to express their evaluations offers the participants a safe haven during the discussion. Third, as each viewpoint has been presented to the pupils as equally viable, neither of the viewpoints is particularly foregrounded by the teacher. This means that the pupils have not been persuaded to favour any one of the viewpoints but instead have to use their *own* experiential knowledge to decide which of the three views they agree with.

5.6 Episode four: evoked knowledge frames and pupil participation

During lines 115-118, Mr Dalel acts as a co-constructor in this knowledge-building process by either repeating what the pupil says to reinforce the point and possibly encourage the pupil to take ownership of the idea, ‘so you thought the coat would actually make the snowman melt more quickly is that correct? Okay that's what you thought’ and/or making it available for all to hear, by repeating what the pupils said more loudly. Evidence that some of the pupils are starting to use their experimental knowledge to make sense of the situation is evident in lines (117):

115 **T:** so you thought the coat would actually make the snowman melt more
116 quickly ↑is that correct? Okay that's what you thought OK Zarif

117 **P7:** It would melt the snowman because coats are supposed to keep you warm

118 **T:** okay coats are supposed to keep you WARM and the snowman should melt

Extract 5.5 *from lesson two, appendix two, lines 115-118*

Here, pupil Zarif (P7) introduces new information by referring to his everyday or experiential knowledge of the function of coats, ‘it would melt the snowman because coats are supposed to keep you warm’. In other words, Zarif is expressing

a subjective viewpoint rather than a viewpoint which has already been intersubjectively established by the group. The ontology of this remote epistemic modal-world, which is set up with 'would' in this context, seems well suited to the highly subjective nature of the pupils' opinions.

What is interesting about Zarif's contribution is that it is not prompted by the teacher explicitly asking the pupils to supply a reason. Zarif is motivated at this point to provide a reason based on his own knowledge frames and episodic memories. To explain this phenomenon, it is useful to remind ourselves of what Werth meant by a frame. As established in section 2.6.3, the notion of a possible situation or an outcome, a 'frame' was developed by Werth (1984) in his earlier work on 'scenes', which he defined as a 'schematic outcome of a situation-type' (1984: 42). Over time, a speaker builds up a collection of these scenes, which are then used to help the speaker predict the outcome of a new situation. In text-world terms, each time a situation is expressed by a proposition and accompanied by knowledge frames of the speaker, a text-world is created (Werth 1999: 112). Frames are abstracted generalisations of text-worlds; they are the 'distillation from a pattern of text-worlds (1999:112). Werth does not state how these different frames interact, other than 'it is a relationship between cognition and language' (1999:111). Furthermore, Werth does not elaborate on how the mind extracts the salient features of the situation. To understand this further, and to see how these frames play a role in this particular learning episode I will now refer to some recent work from the field of cognitive science.

Barsalou (2009) points out that concrete concepts such as bicycle, or in this case a jacket, are not normally processed in isolation but are represented in the mind in relevant situations (e.g. someone wearing a jacket or the jacket hanging on a clothes peg). He goes on to say that the reason for this is that when someone tries to simulate or recreate a representation of a concept that they have perceived in the past, it should recreate the whole situation the concept was part of because situations are an inherent part of perception: 'At any given moment in perception, people perceive the immediate space around them, including agents, objects and events present' (Barsalou 2009: 1283). In Text World Theory terms, this

constitutes the participants' discourse-world. Over time, these situations become entrenched in memory and are triggered into an active state when the participant encounters a similar situation. Initially, however, only part of the situation is perceived, and in order to fill the gaps inferences are drawn which go beyond the given information. Theorists of the mind are showing us that paradoxically our understanding and interpretation of narratives and situations as coherent wholes require these gaps in information in order for meanings to be made (Bernaerts et al. 2013).

The above illustration suggests that concepts such as a jacket are both understood and represented as part of a situation. A jacket is an example of a concrete concept. However, Schwanenflugel (1991) maintains that it is not only concrete objects which require a situational context to make sense of them but also abstract concepts, such as *heat transfer* and *insulation;* the abstract concepts being learnt in this lesson. She claims that abstract concepts depend even more on the surrounding situation to be understood. This analysis supports Schwannenflugel's claim, but it also highlights that the situational context consists not only of the physical here-and-now world of the immediate situation but also the knowledge frames that the participants bring to the situation. In line 117, Zarif goes beyond the given information of the visual by supplying information from his own experiential knowledge (that jackets keep you warm) frame to fill the information gap, thus giving the situation meaning.

To conclude, there appears to be a combination of factors which could trigger a response from a pupil which is based on their own knowledge frames. This opportunity for pupils to initiate their own responses and take ownership of their thinking as opposed to being told what to think is an important step in the learning cycle. The factors in this learning cycle are as follows. The first major factor is the reconfiguration of the usual discourse-world: moving the pupils to the side of the classroom in a more intimate seating arrangement has led to a change in context. In addition to this, the roles of participants have shifted from a teacher-led arrangement to one in which the participants assume a more co-participatory position. It appears then that a change in the social and physical environment

reconfigures the participants' mental faculty frames: although the teacher is in a more privileged position, with regards to knowing about the subject, he adopts a neutral stance whilst encouraging the pupils to commit to their own position. The dual role that Mr Dalel plays, and the choices he makes, when deciding what information to introduce, acts as a catalyst to propel the discussion forward (this will be exemplified in section 5.7).

The second key factor involved in triggering responses from the pupils is related to the text-driven nature of the knowledge building process. The language which emerges from the discussion reflects the participants' conceptual understanding of the situation, it also changes them. The information gaps in the text result in pupils trying to find coherence so they fill the gap by drawing from their own subjective experiential knowledge frames.

5.7 Episode five: incrementation and accommodation and the role of ambiguous language

Zarif's explanation and the teacher's response about the coat appears to prompt other pupils to contribute their own reasoning:

117 **P6:** It would melt the snowman because coats are supposed to keep you warm

118 **T:** okay coats are supposed to keep you WARM and the snowman should melt
119 (1.0) and

120 **P1:** it would melt the snowman if the jacket is warm

121 **T**: again you think it would melt the snowman no-one thinks it won't melt the
122 snowman

123 **P15:** would it what like wouldn't it depend on what sort of jacket it is

124 **T:** WELL let's say it's a sort of warm jacket

125 **P15:** hasn't it been heated

126 **T:** no no no it's not been heated it's been out in the cold

127 **P15:** right so it won't make a difference

Extract 5.6 *from lesson two, appendix two, lines 117-127*

Mr Dalel acknowledges what Zarif (P7) says by repeating his contribution word for word. By emphasising and foregrounding the word WARM in, ‘coats are supposed to keep you WARM’ (line 118), he reinforces Zarif’s contribution further. The idea that is being developed here, is the notion that coats have the everyday function of keeping us warm.

Mahta (P1) in line 120, notes the foregrounded item WARM but also establishes a hypothetical, ‘if the coat is warm’. Hypotheticals communicate epistemic distance by setting up a situation that is not yet actualised by our own reality (Gavins 2007a: 118). For this reason the hypothetical ‘if the coat is warm’ sets up an epistemic modal-world. Here, warm could be interpreted either as an attribute of the jacket, i.e. it is hot to touch, or as a metonymy of ‘keep you warm’, i.e. this is a warm jacket, it will keep you warm. This is an interesting example of how language can act as a tool in providing new and interesting possibilities because it is not always reliable in causing the listener to have the exact same meaning as the speaker (Nerlich and Clarke 2001, Littleton and Mercer 2013:9). Irrespective of which of the two meanings is intended, Mahta introduces the idea that the coat (or jacket) needs to have a certain quality, if it is to cause the snowman to melt. Mr Dalel, in line 121, does not query the pupil’s reasoning but returns to his original objective, namely, to get the pupils to commit to which of the outcomes they agree with. However, Haaqiz (P15) in line 123 pursues Mahta’s idea that the jacket needs to be of a certain type, ‘would it what like wouldn't it depend on what sort of jacket it is?’ Mr Dalel then responds with, ‘WELL let’s say it’s a sort of warm jacket’. The use of warm here is again ambiguous – but possibly intentionally so, as the purpose of this episode is not for Mr Dalel to provide an authoritative answer but for the pupils to develop their own ideas. There appear to be two key forces driving the exchanges forward. On the one hand, Mr Dalel aims to establish how many of the pupils agree with each of the positions depicted in the visual. On the other, the pupils are trying to fill the gaps in the information given to give coherence to the situation.

Haaqiz in line 125 asks Mr Dalel for clarification by setting up a pending world switch ‘hasn’t it been heated?’. The use of the negative here has a confrontational

and challenging quality (Givón 1993: 188), which triggers a corresponding reaction from Mr Dalel, 'no no no it's not been heated it's been out in the cold'. Mr Dalel's use of the negative here acts as a foregrounding principle whereby the pending expectation that the coat has been heated is focused on and challenged (Werth 1999: 250). This feature of negation as having a pre-suppositional nature in that it 'has the capacity to evoke the corresponding positive proposition in order to negate it' (Hildago-Downing 2014: 265). It denies a certain expectation that has been set up within the dynamic common knowledge created in this episode and is, therefore, 'intrinsically dialogic and intertextual' as in order to deny something an explicit reference needs to be made to what is being denied (Hildago-Downing 2014:265). The text-world set up by the teacher establishes an alternative deictic structure that potentially defeats the pending expectations held. The change appears to be a permanent one, as one of the pending world-parameters from the original world has been deleted: the negation used here can be seen as a type of incrementation. In other words, it appears to 'modify the world-building parameters which have already been set up' (Hildago-Downing 2014:250). Haaqiz has established that the coat itself does not generate heat and cause the snowman to melt and therefore decides that it does not make a difference.

What is interesting here is that it is the *pupil (*Haaqiz*)* who actively retrieves information from Mr Dalel to 'fill the gap', thus creating a stronger sense of coherence. He adopts a more active role and in so doing creates his identity as an assertive learner. The teacher, in contrast, has to toggle between two identities. On the one hand, he acts as an 'orchestrator', moving the interaction along so that he is able to achieve his purpose of getting the pupils to commit. On the other, he is perceived by the pupils as the 'expert', who has access to knowledge that the pupils themselves do not have.

As established, there appear to be two key almost opposing forces that create a degree of tension that drives the exchanges forward. Although Mr Dalel aims to establish how many pupils agree with each of the positions depicted in the visual, the pupils seem aware that the information that they have available is incomplete,

and that in order to come to a decision they need more information. In order to achieve this, they use Mr Dalel and each other as a resource.

One further interesting feature of this exchange is how the pupils react to new information that is presented as Werth describes it 'in a background way' (1999: 280). Werth calls this phenomenon **accommodation** and claims that it is one of the most central processes of world building. In the example he gives, Werth demonstrates how Speaker B introduces the new information, that s/he has a brother, not as the most important information in the utterance but with reduced emphasis due to its reduced grammatical form:

A: How's life with you?

B: Great! I realized last night that my brother wasn't dead.

A: I didn't know you had a brother!

Example used by Werth 1999:267

However, Hearer A will pick up the information that Speaker B has a brother as new and as though this information were part of their common ground because Speaker A assumes that Speaker B is being coherent and co-operative. Werth states this process is text-driven in that the Hearer will monitor the incoming text against the current text-world and common ground. He places particular emphasis on the grammatical form of the text when noting whether this information is secondary or not:

Where a dependent grammatical form contains new information, take it as coherent, but secondary, information. Increment it.

(1999: 281)

In lines 120-123 and 127-128, the speakers introduce new information in forms that arguably are less emphatic than if this information had been introduced in an upfront way at the start of the episode:

120 **P:** it would melt the snowman if the jacket is **warm**

121 **T**: again you think it would melt the snowman no-one thinks it won't melt the
122 snowman

123 **P15:** would it what like wouldn't it depend on what sort of jacket it

Here, 'if the jacket is warm,' is a dependent clause, which sets up a hypothetical.

127 **T:** no no no it's not been heated it's been out in the cold

128 **P15:** right so it won't make a difference

Although 'it's been out in the cold' is an independent clause, it is not foregrounded in the teacher's utterance as a primary source of information. It acts as a recast of 'it's not been heated'. The teacher's intended purpose, namely, to establish which of the viewpoints the pupils agree with might render the information 'if the jacket is warm' as irrelevant (as he does not respond to it in his response which indicates he does not think it important), whereas for the pupils who are actively seeking new information 'to fill the gaps' this information might appear to be highly relevant. In fact, in line 123 Haaqiz asks the teacher, would it what like wouldn't it depend on what sort of jacket it is?' indicating that for Haaqiz the type of jacket is important.

127 **T:** no no no it's not been heated it's been out in the cold

128 **P15:** right so it won't make a difference

……

179 **T:** we'll leave it there (.) most of you seem to think that that one's going to
180 melt first (.) most of you think that this is going to melt right. ↑ WHO
181 THINKS THIS IS GOING TO MELT FIRST HANDS UP (4.0) yeah and who thinks
182 this is going to melt first ↑PUT YOUR HANDS UP (under his breath yeah
183 (slightly more) well let's leave it

184 **P1:** was heat in here

185 **T:** beg your pardon

186 **P1:** was heat in here (.) in winter time there wouldn't be heat (.) in winter time
187 there wouldn't be heat

Extract 5.7 *from lesson two, appendix two, lines 127-128 and 179 - 187*

Indeed, Mahta responds to the new information supplied by the teacher later in line 184 by asking, 'was heat in here?', bringing the focus now to the temperature of the surrounding air. The use of 'in here' foregrounds the discourse-world of the classroom in which the surrounding air of the experiment becomes the focal point.

The use of both the past and present tenses in lines 179-187 is curious in that the mixing of these tenses indicates that the speakers are toggling between two text-worlds, one situated in the 'now' depicted by the visual (in the winter) and one in the present (now in the classroom as this snowman is being built).

184 **P1:** was heat in here

185 **T:** beg your pardon

186 **P1:** was heat in here (.) in winter time there wouldn't be heat (.) in winter
187 time there wouldn't be heat

188 **P2**: yes they would turn the ↑radiator on

189 **T:** so there's heat in here so you think if we take it ↑outside we would get a
190 better idea (.) cos it's quite cold

191 **P2:** but it wouldn't really affect it because it's not like there's one ↑outside
192 and there's one ↓inside it's just that it's even still it's not like

Extract 5.8 *from lesson two, appendix two, lines 184-192*

The mixing of tenses is a common feature of speech. Traditional cognitive models of language processing have accounted for this phenomenon as general features of online processing, and cognitive overload (Skehan 1998). According to an innate rule governed approach the speaker makes, therefore, syntactical 'errors'. An alternative interpretation is that, Mahta's, 'was heat in here' is a blend of the past (in the winter, the conditions they are trying to recreate) and the present activity (making a snowman in the classroom) and the speaker is blending the two conceptualisations of the scenarios into one. In line 186, Mahta continues with, 'in winter time there wouldn't be heat (.) in winter time there wouldn't be heat'. As Mahta has not indicated a deictic spatial shift in, 'in winter time there wouldn't be heat', the listener might interpret this as being: *there wouldn't be heat in the classroom*. The effect of this is that the listener, Aariv (P2), appears to think Mahta wants to know if the classroom was warm, which is indicated by her response, 'yes

they would turn the radiator on'. However, Mr Dalel in line 189 appears to have interpreted Mahta's 'in winter there wouldn't be heat' as *there wouldn't be heat outside*. Due to Mr Dalel's privileged position and well-established narrative schema of the situation he has used Mahta's response as an opportunity to take the pupils outside and conduct the rest of the experiment there.

5.8 Episode six: outside one

Mr Dalel takes the pupils outside to the side of the science block. The pedagogical purpose of the next episode, which takes place outside the school building, is to set up an experiment by placing the two snowmen in a position that Mr Dalel suggested as a result of the class discussion. For the pupils to understand the significance of why the snowmen were placed next to the building, Mr Dalel spends a moment foregrounding various features of the pupils' discourse-world which may have an impact on the outcome of the experiment.

The sun is shining and it is relatively cool. The two snowmen are placed in the shade next to the wall of the building. The pupils stand round the teacher and snowmen in a semi-circle. Mr Dalel foregrounds features of the snowmen and their surroundings by drawing the pupils' attention towards them with relational processes which as illustrated in Chapter 4 in 4.3.2 'serve to characterise and identify' the parts of the experiment which the teacher wishes to foreground (Halliday and Matthieson 2013: 210). Interestingly, Mr Dalel mentions for the first time a crucial piece of information, namely, that *one is exposed to sunlight*.

213 **T:** (outside) right guys we've got about 15 minutes left temperature here is
214 about the same both aren't exposed to any kind of sunlight one's in the
215 box with a jacket and the other's exposed to heat here okay we'll come
216 back down in about ten fifteen minutes before the bell goes

Extract 5.9 *from lesson two, appendix two, lines 213-216*

5.9 Episode seven: group work two

Back inside the classroom the pupils work in their groups and are told by Mr Dalel

to discuss their ideas with each other and decide together which of the snowmen will melt first. This time the pupils refer to the actual snowmen that were made rather than the snowmen depicted in the visual. The pupils' utterances are more detailed than the utterance made during the first group work session. Furthermore, the participants start to provide reasons for their opinions with 'because' and 'so'.

220 **Suzy:** the one with no cardboard melt first

221 **P1:** I don't know (.) I think I think the one ↑with cardboard would melt first
222 because I don't know why because

223 **S:** what

224 **P1:** I actually think the CARDboard one would melt first

225 **S:** no the one without the (.) cardboard (.) would melt first

226 **P2**: I think the one ↑without the cardboard would melt first (.) because the
227 cardboard one is actually protected from the heat (sounds quite assertive)
228 which will make it last a bit longer (.) than the one without the cardboard

229 **S:** yes yes

230 **P2:** it wouldn't have protection from the heat

231 **S:** the one with cardboard protect (.) itself so it will last longer so the one
232 no cardboard melt first

233 (15 mins) the one ok the one without cardboard (writing) heat (Chinese
234 students chatting)

235 **P2:** right ok (.) so the one ↑without the cardboard would melt ↑first because
236 there's NO protection from the heat and then the one with the coat will
237 melt a close ↓second

Extract 5.9 *from lesson two, appendix two, lines 220-237*

5.9.1. Mental state predicate: I think

A striking feature in this short episode is the frequent occurrences of the mental state predicate, 'I think'. This predicate has both challenged and been a source of interest for many pragmatists and semanticists due to its unusual linguistic behaviour (see Nuyts 2001, Kärkkäinen 2003, Aijmer 1997). According to Aijmer (1997), *I think* is not a pure pragmatic expression such as *you see* or *you know* due to its structural flexibility in that it can be used in different tense, aspect and

modal forms (e.g. I thought, I'm thinking that, I would have thought). Furthermore, it can be negated and used in a question form. This flexibility allows it to 'straddle grammar and discourse' (1997:7).

In the above extract, it has a performative use, in that the speakers demonstrate their current epistemic evaluations of a co-constructed text-world of the event that is taking place outside the classroom. One phenomenon that is important to consider when analysing this data is that the participants have not had time to think through all the consequences, nor evaluate the evidence, or they might even believe in contradictory things. Although at this stage in the lesson the pupils have had the opportunity to develop their ideas through class discussions, they remain tentative as the pupils' text-worlds remain hypothetical in nature. They have not yet seen the result of the experiment and are, therefore, drawing on their own experiential knowledge, as well as the shared mutual knowledge created during the incrementation process. The quality of the evidence that the pupils are basing their judgments on can therefore be considered as possibly less reliable than when they see the result of the experiment. Therefore, the function here of the cognitive verb *think* is that it may indicate to the listener that subjectively qualified information is being made explicit (Fetzer 2014: 71).

For this reason, 'the subjectivity and epistemic vagueness' of the predicate is well suited to the dynamics of spoken interaction (Nuyts 2001: 123), including classroom discussions.

The predicate is also used in small group work as in episode 5.10. The effect of its use in this face-to-face interaction, or indeed non-use by Suzy, is worthy of note here:

224 **P6:** the one with no cardboard melt first

225 **P1:** I don't know (.) I think I think the one ↑with cardboard would melt first
226 because I don't know why because

227 **S:** what

228 **P6:** I actually think the CARDboard one would melt first

Episode 5.10 *from lesson two, appendix two, lines 224-228*

Suzy's (P6) statement in line 224, 'the one with no cardboard melt first' is unusual, in that it does not use a mental state predicate to set up the epistemic modal-world, as might be expected in a face-to-face discussion. Furthermore, as there are no locational or clear temporal markers to place the modal-world in a particular time and place, Mahta needs to draw instead from their shared knowledge to locate this text-world.

Suzy arrived in Scotland from Hong Kong three years ago and her verb forms are rarely marked with tense or aspect. She uses the verb form 'melt' here, which could place the text-world in the discourse-world of the here and now. The effect of Suzy's statement is that Mahta in line 225 responds by using *I think* twice in a clause initial position together with the marker *I don't know*.

The function of the predicate and the marker are multiple. First, Suzy's statement might cause Mahta to need some thinking time to place Suzy's text-world in a specific time and location. Mahta may also have expected Suzy to have expressed a subjective viewpoint in this context. For these reasons, *I think and I don't know* appear to serve a textual function, in that they are acting here as fillers, to provide Mahta some extra thinking time.

Secondly, in this face-to-face interaction, the use of, *I think, I don't know* and *would* have an intersubjective function by setting up an epistemic modal-world to show Suzy how her standpoint expressed in the proposition, 'the one ↑with cardboard would melt first' (line 225) should be understood. In the context of a classroom discussion, the intention is not that the propositions should be taken categorically but that the speaker opens up a dialogic space for further alternatives to be discussed. This is referred to in the literature as 'intersubjective positioning' (cf. Defrancq and De Clerck 2011; Downing and Perucha 2013).

As her opinion contradicts Suzy's, the mental predicate could also act as a face saving device to protect her from a potential rebuttal from Suzy. In fact, Suzy responds with '*what*', which could be interpreted as Suzy either requesting Mahta to repeat what she said or showing surprise or disbelief.

Interestingly, in line 228 the predicate, *I think* serves a very different function than in line 225, in that it is used to assert Mahta's opinion. This is reinforced with the adverb *actually*. Mahta uses *I think* both as an intensifier and mitigator of the illocutionary force of her proposition.

Irrespective of the multifunctional uses of the mental predicate in this episode, they all indicate that what is said is the speaker's own opinion. The speaker takes responsibility of the content of what is said and acknowledges that it might not be shared by the other group members.

The predicate situates, therefore, the discourse into the interpersonal frame of the discussion. From a text-world perspective, *I think* 'pegs' the discussion into the discourse-world of the here-and-now. Biber (1999) classifies the process *think* in 'I think' as a mental verb, which reflects its original non-qualificational meaning of think as reasoning with knowledge thus locating the mental activity in the minds of the subject (Nuyts 2001: 127), or in text-world terms, in the minds of the participants who are part of the discourse-world. As this process is hidden from view and does not form part of what the co-participants' can directly see, it remains a subjective process. Despite this, the communicative purpose of the utterance is made clear to the other co-participants through the use of the predicate, namely to set up an epistemic modal-world that shares the same temporal and spatial parametres of the discourse-world.

5.10 Episode eight: outside two

At the end of the lesson, Mr Dalel takes the class outside to look at the two snowmen and note which one has melted the most. The snowmen had been left outside for twenty minutes.

270 **T:** so you can see (1.0) there's a fair amount of melting going on (.) ↑now
271 it's unfortunate (.) that we haven't had enough time to allow for the
272 whole thing (.) to give it a chance to actually melt (.) but you are in again
273 tomorrow

274 **Ps:** yes

275 **T:** so we can (2.0) which one has melted the ↑most?

276 **Ps:** that one

277 **T:** that one (.) and the one in the cardboard has actually melted LESS (.) who
278 was right?

279 **Ps:** ME

280 **T:** question is (.) once you've seen that happen (.) you have to ask yourself
281 why (.) right so what ideas you had before you've got to review them

Extract 5.11 *from lesson two, appendix two, lines 270-281*

Mr Dalel draws the pupils' attention towards the snowmen by asking them to note which of the two snowmen has melted the most. He sets up a deontic modal-world with 'you have to', which is then developed further with the function advancer 'ask yourself why'. This tendency of the teacher to encourage the pupils to think about the reasons for their observations is observed and analysed more fully in section 6.2.1. I was not present at the following lesson that took place the next day but according to Mr Dalel, who I spoke to briefly, the pupils had discussed and reviewed the evidence. The following section will analyse how two individual pupils, namely Rose and Sanja, reconstructed and made sense of the lesson. Moreover, it will analyse how the two pupils draw on their own memories, i.e. remote text-worlds, as well as their own knowledge base to talk about their understanding of the snowman task.

5.11 Interview and stimulated recall interview with pupils

1 **P8 P10?** [inaudible]

2 **R:** right (1.0) great (.) now if I put that there (2.0) ↑Do you remember the
3 little experiment we did with the snowman (.) well not (.) he asked you to
4 predict something did[

5 **Rose:**]yeah

6 **R:** he had on the board a picture of a snowman (.) and then there were like
7 ↑three possible scenarios (.) like you put a jacket on ↑do you remember
8 what the scenarios were

9 **Rose:** the one person said I wanna put this coat on him (.) one person said that
10 don't put the coat on cos the snowman would melt and the other person
11 said (.) it won't make a difference

12 **R:** and the other one?

13 **Rose:** that was it

R: oh ↑yes so it was (.) those three (coughs) mm (1.0) excuse me (.) what I want to do is just play you that bit where he was asking you what you predicted (.) cos I think you two mentioned something and I can't hear what you say (.) so maybe if I play it back to you it will trigger your memory and it you might remember what you actually said (.) is that all right? Uh right [from audio: T: that table here ok can everyone see what was the groups' decisions what sort of ideas P1: I think it's the middle one because [inaudible] T: so what d'ya reckon would happen]

R: do you do you remember what you said

Rose: yeah

R: you do? ok can I write it down (.) yeah brilliant go on

Rose: it wouldn't make a difference

R: u-huh?

Rose: because the jacket wouldn't be heated up (.) and it wouldn't be cold (.) so it wouldn't make a difference

R: okay so it wouldn't make a difference because (.) because the jacket ↑wouldn't be heated up you said

Rose: yup

R: u-huh and?

Rose: and it wouldn't be cold outside

R: very good (.) okay and then

[lesson's recording} – Sanja what did you think? Sanja: [inaudible] T: so you thought that the coat would actually make the snowman melt more quickly is that it? Is that correct? Is that what you thought? okay]

R: is that what you said do you remember what you actually said?

Sanja: a little bit (.) I think so (1.0) I think I said um if you put the jacket on the snowman (.) the snowman would get heated up

R: okay yeah that sounds right (.) cos he kind of said what you said so that would make sense okay so I'll just play you the rest of that [Zarif… listen

Extract 5.*12* *from pupil interview 01.04.15, appendix five, lines 1-42*

The episode starts by the interviewer asking the two pupils Sanja and Rose to cast their minds back to the lesson in which the class carried out an experiment with a snowman. As the discourse-world of the lesson is now positioned in the past, it is no longer directly accessible. In the pupil interview, it comes into existence by

observing the video recording. The participants of the discourse-world of the lesson (the teacher, the pupils and myself the researcher), become the enactors of the text-worlds created in the interview as they are no longer 'real people', who share the same spatio-temporal position and therefore have a different ontological status to the participants in the interview (van der Bom 2014: 156). A similar shift takes place when I, the analyst, listen to the recording and read the transcript of the interview. The discourse-world of the interview becomes only accessible via the transcripts and recordings. The final analysis is made up of three past discourse-worlds which feed into the final analysis matrix. This layering of discourse-worlds can be represented as illustrated in Figure 5.4.

In order to arrive at a full interpretation of the pupil interview (01.04.15), it was necessary to listen to the original recording of the lesson and refer back to the visual that had been used during that lesson. All the discourse-worlds, apart from discourse-world four of an imaginary winter's scene, have a high degree of accessibility as I was present during both the lesson and interview. The final analysis was carried out by me interpreting the data from alternating perspectives, either as an enactor of the interview or as an enactor of the lesson. The various paths of influence of the different discourse-worlds on the final analysis are represented in the above diagram (figure 5.4).

It is also important to mention at this point, the effect the different mediums (the video, the transcript) have on myself the analyst. The choice to show the pupils the video recording of the lesson as a means of simulating the original experience of the lesson, as opposed to engaging them with, for example, a transcript was based on the recognition that film, with its visual and auditory properties, provides a very direct immersive experience of the event (Gallese and Guerra 2012). This understanding is based on the notion that immersive consciousness is constructed through the embodied experience formed by the relationships between the body, mind and the environment (Marleau-Ponty 1962). Therefore, accessing a past discourse-world by means of a video is a very different experience

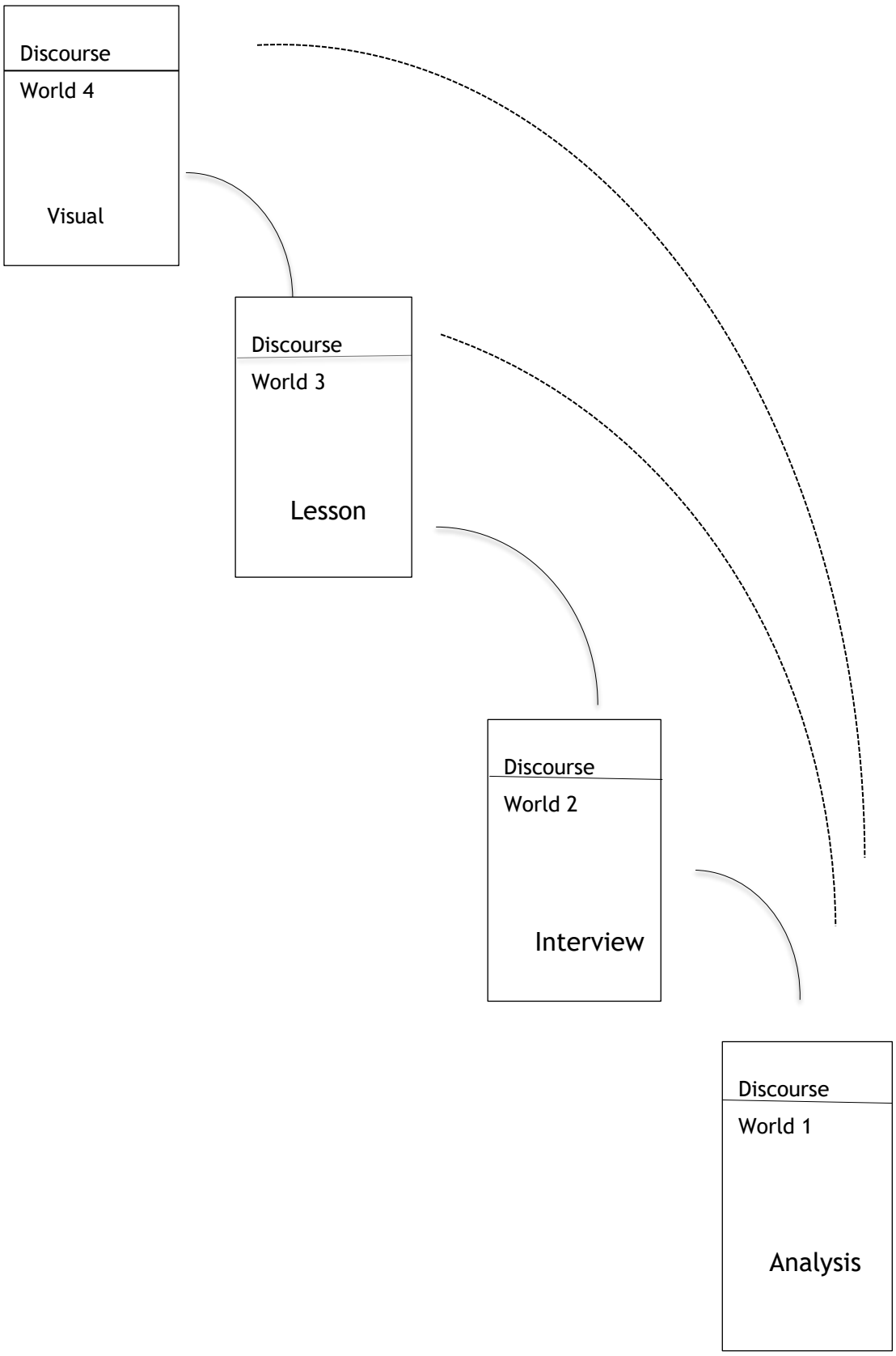


Figure 5.4. Text-worlds of stimulated recall interview

than accessing it via a transcript.

5.12.1. Pupils cast their minds back

The purpose of the initial part of the interview is twofold. First, by showing the video of the previous lesson to Sanja and Rose (P11 and P16) they are given the opportunity to recall the main elements of the lesson, and thus provide individual accounts of the events recorded. Secondly, the pupils had been selected for the interview because during the discussion in the lesson (lines 105-206) they had been asked by the teacher to state their opinion to the rest of the group. However, from the recording it was not possible to determine what the two pupils had said as they spoke quietly. Therefore, the interview offered me the possibility to emphasise the importance of all contributions to a process by asking the two pupils if they remembered what their responses were and by inviting them to provide more details about their thoughts at the time of the lesson.

The episode starts with me asking the pupils in line 2 to cast their minds back to the lesson in which they carried out an experiment with a snowman, '↑do you remember the little experiment we did with the snowman'. The utterance with the mental process 'remember' (i.e. do you remember), triggers an epistemic modal-world. The situation constructed cannot be realised at the discourse-world level (Werth 1999: 246-7; Gavins 2007a: 110). The time and location of the epistemic modal-world become established and a world-switch occurs when I, Sally, continue with, 'the little experiment with the snowman' (line 2-3). Although the time and place are not specified, the Sanja and Rose's common ground enables them to infer that I will be asking questions about prior learning experiences in the classroom. The text-world is developed further with I report what Mr Dalel said, 'he asked you to predict something (lines 3-4). Rose indicates with 'yeah' (line 5) that she remembers, which encourages me to continue building the text-world with function-advancing propositions, 'he had on the board a picture of a snowman (.) and then there were like three possible scenarios like you put a jacket on' (line 6-8). The purpose of these function-advancing propositions is to foreground the elements of the visual that I want the pupils to remember and pay attention to.

From this text-world, a new epistemic modal-world is created when Sally asks, 'do you remember what the scenarios were?'. Rose's response, 'the one person said I wanna put this coat on him (.) one person said that don't put the coat on cos the snowman would melt and the other person said (.) it won't make a difference (line 9-11)' is not only immediate but also contains vivid and detailed elements of a text-world of the scene she experienced. Her use of indirect speech, to report what the three characters in the visual said, accurately reflect what the cartoon characters say in the visual. Despite the fact that the interview takes place a week after the lesson, Rose's accurate response indicates that she remembers the events of the lesson well.

The purpose of the second task was to establish Rose's and Sanja's positions towards the statements made by Mr Dalel and the other pupils during the discussion. As I had only ten minutes available to interview the pupils, I decided to present the statements made during the class discussion by the pupils and teacher on a list (see Table 5.2) as this would take less time than listening to the recording. Although the statements were not embedded in a co-text the context of the discussion would have been familiar to both pupils. Sanja and Rose were asked to decide which of the statements on the list they agreed with. Writing the statements down as a list had the advantage that the pupils were required to focus on the content of what was said without being influenced by who said it.

44 **R:** okay brill so you remember that don't you I just I wrote out some of the
45 phrases do you remember which ones you would have you did agree with
46 at the time

47 **Sanja:** uh

48 **R:** so if you read those which one of those

49 **Sanja:** [reading from list] lot more quickly (4.0)

50 **R:** so if I put um which one again

51 **Sanja:** it would melt the snowman

52 **R:** and the another one

53 **Sanja:** that one

54 **R:** ok and ↑Rose which would you agree with

55 **Rose:** this one (2.0) and this one

56 **R:** u-huh ok (3.0) can you explain your reasoning? Why did you (0) choose
57 those why did you think those[

Extract 5.*13* *from pupil interview 01.04.15, appendix five, lines 44-57*

Table 5.2. Sanja and Rose select which responses they agree with

Pupils responses made during classroom discussion	**Sanja agrees**	**Rose agrees**
1. The coat wouldn't warm up this snowman		✓
2. It wouldn't make a difference		✓
3. The coat would make the snowman melt more quickly	✓	
4. It would melt the snowman cos coats are supposed to keep you warm	✓	
5. It would melt the snowman cos the jacket's on		
6. Doesn't it depend on what jacket it is		
7. Sir my cousin's put a jacket on and it never melted		

8. I think the coat itself would warm the snowman		

Sanja agreed with the statements 3. *the coat would make the snowman melt more quickly* and 4. *it would melt the snowman cos coats are supposed to keep you warm*, whereas Rose agreed with the statements 1. *the coat wouldn't warm up this snowman* and 2. *it wouldn't make a difference*. Neither of the pupils deliberated when giving their answers, indicating that they were confident about their memories of their thoughts at the time of the class discussion. The task provided me with the opportunity to probe their thinking further by asking them to explain their reasoning:

R: u-huh ok (3.0) can you explain your reasoning? Why did you (0) choose those why did you think those[

Sanja:] at the time?

R: at the ↓time (.) exactly because you've seen the experiment so you might think something different (.) but can you remember (.) back to that time (.) ↑why did you think the way that you did at the time?

Sanja: because I thought (.) like the jacket would ↑melt the snowman because it would bring a lot of heat to the snow (.) which would make it melt

R: yeah and Rose and you thought something slightly different didn't ↑you so can you remember what you thought at the ↑time?

Rose: like if you put on a ↑jacket it's not like (.) instantly warm (1.0) the body heat needs to heat up the jacket.

R: u- haah

Rose: so the jacket hadn't been on a radiator (.) or near any ↑heat so if you put it on the snowman it wouldn't make any difference (.) and there's no like source of well there's the cold of the snow but it wouldn't keep him cold like

During line 57, Sally establishes an epistemic modal-world with the question, 'can you explain your reasoning?' This is situated in the discourse-world of the interview in that the spatial and temporal parameters of the epistemic modal-world are aligned with those of the discourse-world of the interview. The question refers to the pupils' current task of completing the grid. To evoke and foreground the text-world of their inner thoughts during the lesson, I asked, 'why did you choose those (.) why did you think those[' (line 57-58). Sanja co-operates by intercepting and completing what I was about to say indicating that she understands what I want her to do with the response, 'at the time' (line 59). Past evoked episodic memories might be difficult to discuss in public especially if we now think differently. We might feel embarrassed in front of others of our former thoughts. In lines 60-61, I rationalise these fears by addressing directly the fact that thoughts often change when we have new evidence, 'at the ↓time (.) exactly because you've seen the experiment so you might think something different (.) but can you remember (.) back to that time why did you think the way that you did at the time?'

Despite this, the pupils' responses (lines 62-71) describing their inner thoughts during the discussion, are detailed and indicate a strong willingness to talk about their initial ideas. Sanja indicates through the use of *I thought* that she shares the text-world situated in the past that I established in the previous turn. This co-constructed text-world becomes a shared conceptual space for Sanja and then Rose to describe their inner thoughts of the learning situation to the other participants present. What can be gleaned from Sanja and Rose's responses, is that they draw from their own 'clothes' schema. They apply this knowledge to the everyday situation depicted in the task. This application of an embodied knowledge to solve practical, everyday problems has been found to occur frequently in both pupils' and professional scientists' reasoning (Kolari and Savander-Ranne 2000; Başer 2006).

In Sanja's response in lines (62-63), 'the jacket would ↑melt the snow because it would bring a lot of heat to the snow', the agency of the jacket is instantiated by its subject position. In this context, this implies that it *causes* the snow to

melt and is the source of heat; *it would bring heat*. If this is interpreted literally, it might imply that the jacket generates heat energy. During her response, it appears that two image schemas are employed to structure her reasoning. First, the SOURCE-PATH-GOAL image schema realised in *it would bring heat* (i.e. heat *comes from* the jacket and *goes to* the snowman), and secondly the CONTAINER image schema: 'at first I thought like (.) the cardboard would melt the ice the snow **it's trapped** (.) and it has no way of like cold air to keep it to keep it to keep it a solid'. Here, the jacket is conceptualised as a CONTAINER. Although there is no clear referent for *it* in *it's trapped*, from the co-text it might be assumed to be the warm air *inside* the jacket.

When Rose is asked to describe her inner thoughts, the SOURCE-PATH-GOAL image schema that Sanja initiated with her implication that the jacket was a source of heat, appears to structure her reasoning too. Rose, however, contributes to the dialogue her knowledge that it is the human body which is a source of heat and not the jacket. In other words, Rose's schema of putting on clothes and understanding why they make you warm has a different and possibly more elaborate structure to Sanja's as it acknowledges the role that body heat plays. Furthermore, Rose demonstrates a willingness to consider factors that either she had stored in her own schema before the lesson, or that she had accreted into her existing schema during the classroom discussion (see lines 69-71). For example, she mentions alternative sources of heat (e.g. *radiator*), that are not shown in the picture. In line 70, she establishes a hypothetical with an external source of heat, 'so the jacket hadn't been on a radiator or near any heat'.

In both cases, however, neither of the pupils considers the surrounding temperature or the sun as being a source of heat energy, which might be seen as a little surprising as usually the surrounding temperature is what determines whether we feel warm or not, and hence could cause the snowman to melt in the experiment. To understand why the two pupils might not have factored the sun and the surrounding temperature into their initial reasoning, it is important to analyse the visual that the pupils initially saw and how it was introduced into the classroom. In the visual, there is no sun and the sun is not mentioned and

therefore not foregrounded by the teacher until the pupils are outside (line 218 appendix two), 'right guys we've got about 15 minutes left temperature here is about the same both aren't exposed to any kind of sunlight one's in the box with a jacket and the other's exposed to heat'. Therefore, the sun and the surrounding temperature do not constitute part of a discourse- or text-world of the initial class discussion, which the pupils at this point in the interview are immersed in.

The point is, the pupils were given specific information by the teacher during the first part of the discussion, on which to base their reasoning on. Their knowledge at this stage of their learning is largely made up of separate isolated text-worlds that although related have not yet been abstracted out to form a secure frame of the situation (see section 5.2 on relationship between text-world and frame). Although Rose does not consider the sun, she does display stronger reasoning skills than Sanja. She displays the metacognitive strategy to think outside the discourse in-focus, in other words the text-world she is immersed in and to draw relevant information from other sources, namely, her knowledge frames, other text-worlds and from people and objects in the discourse-world. In the following episode Sanja discusses with the researcher how her opinions changed after she saw the results of the experiment:

74 **R:** yeah that's reasonable ↑isn't it so both of you it's quite reasonable
75 how have your ideas changed cos you've seen it now crikey how does
76 that work can you could you say something about (.) how do you
77 explain what you saw now

78 **Sanja:** at first I saw like (.) the cardboard would melt the ice (.) the snow it's
79 trapped (.) and it has no way of like cold air to keep it (.) to keep it to
80 keep it a ↑solid so I thought the heat would go to the snow

81 **R:** m-mh have you changed your view?

82 **Sanja:** yeah

83 **R**: and how have you (.) how do you think differently how would you
84 explain that now?

85 **Sanja:** I think (.) I thought like the cardboard would melt the ice first (.) but
86 when I saw the experiment I was actually quite ↑surprised

87 **R:** ↑U-huh?

88 **Sanja:** that the heat from the ↑sun would melt it first

89 **R:** ok

90 **Sanja:** not the one without the cardboard

91 **R:** so (.) the cardboard (.) what is it doing what would you say its function
92 is?

93 **Sanja:** I think it's trying to keep the cold (.) inside the space it's in

94 **R:** and how does it manage that?

95 **Sanja:** not really sure

Extract 5.*14* *from pupil interview 01.04.15, appendix five, lines 74-95*

In line 85, Sanja describes the surprise she felt when observing the result of the experiment that the snowman without a jacket had melted first. On comparing the responses of Sanja, when she describes her initial ideas with those she had after observing the outcome of the experiment (lines 85), she clearly demonstrates the need for an alternative explanation for what she has seen. In line 93, she provides a revised explanation for the phenomenon that she saw. Still using the CONTAINER image schema to structure her thoughts she describes how the jacket traps the cold air on the inside thus maintaining a low temperature, 'I think it's trying to keep the cold (.) inside the space it's in'. However, when asked to explain how the jacket does this, how does it manage that (line 94), she cannot provide a reason, 'I'm not really sure' (line 95).

5.12 Conclusion

To conclude, the first part of this analysis chapter explored how a group of learners from diverse backgrounds, in a science lesson, in a secondary school, applied their understanding of the concept of *insulation* to an everyday problem set by their teacher. The pupils predict the outcome of an experiment the class carried out during lesson time. The result of the experiment was witnessed just prior to the end of the lesson.

One of this chapter's aims was to explore the linguistic representation of the pupils' understanding of insulation as they applied their understanding of the concept to a problem-solving task. Although the concept of *insulation* is not

referred to by the lexical item 'insulator' until line 264, the ability of the pupils to carry out the problem-solving task depended on their understanding of the concept that was expressed in language that resided in the pupils' encyclopedic linguistic knowledge of heat and heat transfer. It specially examined the epistemic modal-worlds created by the participants during the class discussion (section 5.6-7) and during two small group discussions (5.4 and 5.9). Integrated into the text-world analysis was Nuyts' modal (2001) of epistemic modality, which incorporated a subjectivity-intersubjectivity cline into its framework. The notion that an epistemic modal-world construction has an intersubjective dimension, in that it can show other members of the group how we wish our propositions to be understood, was integrated into the text-world analysis, in particular, in the analysis of the predicate *I think*.

It was noted that much of the language used by the pupils to refer to the situational context was ambiguous. It was demonstrated that this ambiguity acted as a catalyst to open new perspectives on the situation.

A Text World Theory framework was applied throughout the analysis. The model was modified to make it more suitable to analyse pedagogical discourse. In introductory section 5.2.2, Werth's 1995 knowledge framework was introduced as being a preferred starting point for a model that represents the participants' knowledge base, as it included a more detailed description of the mental faculties participants bring to a learning situation. Furthermore, it was established that Werth's model is not incompatible with Shulman's pedagogical content knowledge model. Although further attention would be needed to make a full integration of these two models.

Building on the first analysis chapter, part one of this chapter demonstrated how the text-world framework is particularly useful in analysing how the knowledge base that each participant brings to the situation, structures their understanding of the learning event. As the focus was on how the participants *negotiate* meaning, attention was drawn to how changes in both the physical and social contexts, in particular, in how the participants' shifting identities influence the manner in which they use their knowledge to bring coherence to

a situation. Mr Dalel shifted identities between a 'knower', who acted as a knowledge resource and an 'orchestrator', who managed the learning process. The pupils during the problem-solving task appeared to become more active learners because they realised that they had gaps in their knowledge that they wanted to be filled to make the situation coherent. The analysis of the lesson provided an account of how the group members worked collectively to further their understanding. The interview analysed how two individual pupils, namely Rose and Sanja, reconstructed and made sense of the lesson. Moreover, it analysed how the two pupils draw on their own memories, i.e. remote text-worlds, as well as their own knowledge base to talk about their understanding of the snowman task.

Section 5.11 showed how two pupils Rose and Sanja responded when shown a video recording of the class discussion of the problem-solving task on insulation (25.03.15), a discourse-world positioned in a different spatiotemporal position to the interview. The two pupils were asked to state what they thought during the episode that took place before they had seen the result of the experiment. They were also questioned about what they thought after they saw the result of the experiment.

In terms of how the pupils linguistically represented the abstract concept during the interview, neither of the pupils referred to the coat on the snowman as an insulator. The language used by the pupils during the task tended to describe their experiential knowledge of putting on clothes. Neither of the pupils provided a full scientific explanation of the function of the coat, namely, that it slows the process of heat transfer from the warmer air outside to inside the coat, thus preventing the snowman from melting. Neither pupil considered the effect of the sun.

The CONTAINER and SOURCE-PATH-GOAL image schemas appeared to play a dominant role throughout the entire reasoning process for both pupils. Drawing from her own experiential knowledge, Sanja thought, before she saw the results of the experiment, that the coat would heat up the snowman. The coat was conceptualised by Sanja as a CONTAINER, either acting as a source of heat (before

seeing result of experiment) or as a barrier which traps the cold air in (after seeing the result of experiment).

Rose did not think the jacket/cardboard would cause the snowman to melt, either before or after seeing the result of the experiment. She again drew from her own experiential knowledge and reasoned that coats kept us warm because they trapped the warmth from our bodies, using the CONTAINER schema to structure her thinking. As the snowman does not radiate heat she reasoned that the coat/cardboard would not have an effect. Rose's response demonstrated the ability to draw on a wider range of information, beyond what was given to her or foregrounded in the discourse, than Sanja to make sense of the situation. The effect of this was that it gave the impression that her reasoning skills were more advanced.

The text-world approach to analysing the data shows how the pupils' immersion in the realities of the text-worlds created during the lesson and interview did not appear to trigger the need to consider the surrounding temperature. The ability to problem solve, in this context, appears to depend on pupils' ability to manage several text-worlds at once and build text-worlds from sources of information that the teacher does not explicitly give in his own narrative. The approach indicates that although being able to immerse oneself in a text-world is a necessary part of the problem-solving process, an over immersion does not encourage the pupils to take an outsider perspective and view the situation objectively. Furthermore, the text-world approach shows that although the pupils' reasoning was grounded in their use of image schemas, their ability to solve the task required them to restructure these schemas in a way that would lead to a conceptualisation of the coat as an insulator

Chapter Six: Representation of the concept of heat transfer in speech, writing and in visual representations

6.0 Introduction

Chapter 4 looked at how the abstract concepts of *heat*, *temperature*, *heat transfer*, and *conduction* were either re-introduced or introduced by the teacher into the classroom discourse over two lessons. The main focus was on the discourse of the teacher during the lessons. Chapter 5 focused on how the pupils applied their understanding of the abstract concept of *insulation* to a problem-solving task. The principal aim of this chapter is to examine the way in which the abstract concept of *heat transfer* is linguistically represented by a group of learners during a discussion/writing task and during a stimulated recall interview (01.04.15), with two pupils who were observed during the group task.

The starting point of this exploration is an interview with Mr Dalel (Part One), which took place in the afternoon on 25.03.15. During this interview, I (Sally) and the teacher, Mr Dalel, discuss the pupils' learning of the concept of *heat transfer*. A number of important topics emerge from the text-world analysis of this interview, all of which explore the relationship between the pupils' understanding of the concept and the knowledge the pupils have about language from the perspectives of both myself and Mr Dalel. The main topics which emerged from the teacher interview were 1) how the pupils linguistically represent the ontological nature of *heat transfer* 2) learning of abstract concepts such as *heat transfer* in terms of how the pupils appropriate the language 3) the perceived tendency of pupils to find metaphorical language difficult. These topics act as a springboard for the rest of the chapter, in that each topic directs the analysis of a group discussion/writing task and a pupil interview. In the interview, the pupils are asked to verbalise, write and draw

their mental images demonstrating their understanding of the abstract concept of *heat transfer*. The text-world exploration of the teacher interview draws from the perspectives of both myself and Mr Dalel. By adding the teacher's perspective, the focus for the analysis is based on an intersubjective understanding shared by both the myself, the researcher and teacher, two members of a scientific teaching community.

One further important aim of this chapter is to explore the effectiveness of the text-world framework for exploring the development of abstract concepts in a school environment. Part one of this chapter will show how by applying a text-world approach, the teacher and myself draw on different conceptual layers to give their evidence. This analysis will demonstrate that this approach is particularly suitable for analysing face-to-face interviews between researchers and teachers, as it acknowledges the different ontological statuses of these layers, and therefore a nuanced understanding of the credibility of the evidence provided by the participants becomes possible.

The group discussion/writing activity, that is analysed in Part Two A of this chapter, takes place at the end of the lesson on *heat transfer* (18.03.15). As part of the description of the discussion/writing task's discourse-world, the analysis explores the nature of the linguistic knowledge that the pupils need in order to carry out the task (see section 6.2.2 below for a more detailed description of Werth's account of linguistic knowledge). This chapter extends Werth's original account of linguistic knowledge to make it more suitable for classroom contexts. Thus, part two A of this chapter fulfils the third aim of this thesis in that it develops Werth's original account of linguistic knowledge, an aspect of the Text World Theory's discourse-world.

The first part of this exploration in Part Two A involved examining what encyclopaedic knowledge the pupils might have of the five set words that the teacher intended the pupils to use, during the set task. Drawing from a usage-based view of language acquisition, which upholds that the meanings and associations language users have of language is 'a function of the utterance context in which it is embedded' (Evans 2006: 492), it was deemed necessary

to gain a detailed qualitative understanding of how the words had been used in the classroom discourse prior to the writing task. In order to do this, I used the concordance software 'lextutor' to analyse this discourse, by uploading the transcript (appendix one). This tool enabled me to isolate the stretches of discourse in which the set words had been used. By highlighting and pinpointing collocations of these words a clearer understanding of their usage was achieved. Further aspects of the pupils' linguistic knowledge were then explored by analysing the language used besides the set words, in both the discussion and in their writing. Part Two A of this chapter concludes with a summary of the component parts of linguistic knowledge, an aspect of the discourse-world, required of pupils to achieve the task from a text-world perspective.

To gain further insight into two pupils' understandings of the abstract concepts of *heat energy* and *heat transfer* as they carried out the writing task, Part Two B of this chapter analyses a pupil stimulated recall interview, which took place in April after the Easter break. During this interview the pupils, who were two of the participants (Karla and Zarif) in the group discussion/writing task, carried out a stimulated recall on the discussion/writing task and are asked to verbalise the images that passed through their minds as they watched the recording. Extending from this, the two pupils were then asked to externalise their mental images by means of a visual representation.

The acts of externalising mental images in either verbal, written form or as visual representations, are viewed here as acts of interpretation rather than being a direct window onto the minds of the pupils. During the interview, the pupils are required to scrutinise and interpret the sign-system of the conversational text of the stimulated recall as they transfer it to a visual sign-system. This process known as transmediation (Suhor 1984), affords reflection at a meta-cognitive level, which enables the pupils to explain their interpretations more easily and with more detail to others (Short et al. 2000 cited in Giovanelli 2017: 3). Thus, this technique afforded a further opportunity

to explore the linguistic representation of heat transfer by two pupils from the class and the linguistic knowledge required of the pupils.

As this chapter has three overlapping sections, each with its own focus, the main events and aims of this chapter are summarised as follows:

Table 6.1. Main events and aims of chapter

Part One	**Part Two A**	**Part Two B**
Interview with Mr Dalel Time: afternoon 23.03.15	Group discussion/writing task. Time: morning lesson. 23.03.15	Stimulated recall of two of the pupils observed in part two A: Klara and Zarif. Time: morning 01.04.15
Purpose of interview: to explore with Mr Dalel the pupils' understanding of abstract concepts and role of language in this process. Topics emerge that act as springboard for part two A & B. **Aims of thesis met:** **Research aim: One:** explores linguistic representation of concepts from both	Pupils discuss and write an explanation of heat transfer using their understanding of particle theory of matter. **Aims of thesis met:** **Research aim: One:** explores three pupils' linguistic	Pupils discuss and draw visual representations of concept of heat transfer in response to observing themselves in episode analysed in part two A. **Aims of thesis met:** **Research aim: One:** explores two pupils' linguistic and

researcher's and teacher's perspectives. **Two:** applies TWT to face-to-face interaction **Three:** demonstrates effectiveness of TWT framework to provide a detailed account of how topics emerge throughout interview.	representation of heat transfer during group discussion/writing task. **Two:** applies TWT to group discussion/writing task. **Three:** develops linguistic knowledge, an aspect of Werth's original TWT framework to make it more effective for studying classroom interaction and knowledge building.	visual representations of heat transfer during face-to-face interaction. **Two:** applies TWT to face-to-face interaction and visual representations drawn by pupils. **Three:** develops TWT to explore visual representations as a means of representing understanding of abstract concepts.

6.1 Part one: teacher interview (25.03.15)

The following section analyses one of the teacher interviews which acts as the starting point for the remaining analysis in this chapter. The reason for carrying out this interview is as follows. I had the impression during the pupil interview, which took place that morning (25.03.15), that one of the pupils understood the concept of heat transfer *well enough* (see Chapter 4 section 4.4.5).

However, whilst I watched the recording of the interview after it had taken place, I became soon aware of the ambivalent nature of the language used by the pupil to express her ideas. I decided to find out from the teacher during the interview that took place later that day (25.03.15), whether these impressions of the pupil's conceptual understanding of heat corroborated with the teacher's own experience. During the interview, the teacher and myself exchange their views on the role language plays in learning science.

From the analysis, topics emerge, caused in part by the main research questions of the thesis that I had in mind at the time of the analysis, which then act as focal points for the analysis of Part Two: the pupils' group work and interview (25.03.15). Thus, the thematic framework and focal points for the analysis of the pupils' group work and interview, that constitute the second part of this chapter, resulted from my analysis of an interview I had with an experienced professional science teacher. The focal points (listed on page 216), reflect the perspective taken also by the science teacher, not just by myself, of the relationship between language of science and the learning of science. Involving the teacher in the development of the analytical framework allowed for the first research aim of this thesis to be refined in such a way that specific aspects of the linguistic representation of some concepts could be analysed in greater depth.

The text-world approach to analysing the teacher interview proved particularly suitable as it shows *how* these topics emerge in dialogue with both participants drawing on their own knowledge frames and experience. The framework distinguishes between different conceptual levels (the discourse-world of the interview, the discourse-world of the analysis, the text-worlds and modal-worlds) it therefore can potentially provide a very rich account of how the topics come into being. As pointed out by van der Bom (2015), in her analysis of interviews in which she herself was a participant, when I approached the transcripts and data a while after the interview took place I, the analyst, communicate with myself as a co-participant of the earlier discourse-world of the interview. The text-world framework is able to manage this ontological

complexity and provide a detailed insight into my own beliefs and ideological frameworks, which I then bring to the analysis of the transcripts of part two of this chapter. It was decided to keep the analysis of the teacher interview separate from the analysis of the pupils' group work and interview as the overall purpose of the analysis is to show how the two participants discussed the pupils' learning and how the topics emerged.

The following is the transcript of the interview with the teacher that took place in the teacher's classroom, after the last lesson of the school day on 25.03.15.

Date: 25.03.15 Time: After last lesson of school 4pm

R: I've just got a section from the lesson last Wednesday when you had the diagram on the board of the rod you had just the Vaseline rod demonstration and then had the diagram and you asked Rosen about you put conduction is the process of transferring heat you know and then you this is the section so do you remember it vaguely

T: I remember it a bit

R: do you want me to show you it takes about 3 min I mean we can stop it when

T: go on then

R: yeah you in action

T: ok go on then

Watches clip (u-uh) from T

T: yeah I do remember that yeah go on

R: ok so we don't have to I've got it written out and you can read it so question is in your own words what did you want to get across to the pupils

T: yeah ok well

R: cos I have an idea but

T: we were looking at the atoms we were looking at the metal and how the first step was how the metal heats up and then transfers energy to well the atoms on the outside become heated therefore they become more energetic and transfer energy through vibrations to the atoms next to them which then transfers energy to the atoms next to them and so the energy of vibration that is kinetic energy gets transferred from the bottom to the top and that was illustrated by the atoms becoming red and more atoms becoming red and so there is a process taking place and so I was thinking what do they understand by a process because a process is something which involves steps

R: steps so how

T: one thing leads to another to another

R: m-mm

R: so you had an analogy of the

T: so I used the analogy of the cereals that just popped into my head because it was breakfast they just had their breakfast

R: no no it's good it's good

T: m-mm

R: what would you say are the main also from your own experience from having taught this before what would you say are the

T: in this

R: in this

T: in this particular lesson or

R: just in that the

T: conduction

R: yeah

T: I think the difficult idea probably will be trying to imagine the particles I think transferring energy by and large I don't think that's a particularly difficult concept

R: do they have a problem with heat

T: what do you mean

R: the concept of heat

T: the concept of heat they have more difficulty with yeah um because the concept of heat they don't understand that because I've asked them a couple of times since then if you've got boiling water at 100 degrees Celsius and you've got 250 ml of that boiling water and you got 50 ml of boiling water in another flask you've still got a temperature of 100 degrees Celsius for both flasks which one is going to have more energy they often say they smaller cos the smaller volume yeah so they are having difficulties with that concept

R: in your view do they see heat as something separate from vibrating particles

T: yup I think that they do

R: because I'm seeing that in the interview this morning that came through

T: yup I've actually shown them a video of a clip of particles vibrating and it's a really interesting little I'll let you see it if you want they still don't seem to make that connection because it's actually an animation of particles moving and they are both moving at the same speed therefore they have the same temperature

R: because they understand your demonstration of them all lining up we talked about that they can put that in terms of particles vibrating they seem quite happy with that but what I'm noticing is there seems to be another line of thought running almost parallel of heat transfer so it's almost as if there are two separate things like particles vibrating and then there's heat transferring

T: yeah

R: and it's almost as if the language is

T: the link yeah they are not making that link yeah

R: I wouldn't say a barrier because it almost it's not because it's all you've got to express it you know as well as models and so on but it came through this morning

T: with Suzy

R: with Suzy and what's the name of the other one with the white

T: Yelina

R: 🡻Yelina and it was how they were talking about heat it was something different to how the particles moving so they just see it as two separate things

T: heat is travelling along the bar or along the rod[

R:]almost through the particles they see it as a kind of substance

T: yeah

R: that is what you agree

T: I would agree I get that sense as well they are not linking the idea necessarily that heat is actually particles vibrating you are absolutely right

R: great so I just wanted to clarify that with you

T: I think you're right

R: I need to look at the interview in more detail but it's little words like through they are words in here that have double meanings I mean through has something like 7 senses or something there are different ways that you use it and I think they use it sometimes in an alternative way they are used to a different way it confuses them

T: I'm sure it does through tends to indicate that it's R & T Through a door

T: an empty space

R: and they might think it's through the particles they are not seeing it as um direction we use it or scientists use it in this context it'd be used more as direction

T: through something absolutely sure

R: and this is what I'm just trying to get at I'm trying to analyse the language in that way and trying to understand what is blocking in quite a micro way and

100 disentangle it that is what I'm up to everything you are doing is supporting
101 them

102 **T:** yet

103 **R:** yet it's the finer it's getting down to the meanings of all these words and how
104 they appropriate these meanings

105 **T:** because they tend to take them in according to their everyday usage

106 **R:** yes exactly and I think they are learning some of them do pick up and start to
107 appropriate it the way you intend them to use it they do

108 **T:** they do some of them do some don't

109 **R:** and with Suzy they've obviously got the Chinese coming in

110 **T:** it makes it a lot more difficult for a lot of bilingual kids I expect

111 **R:** I have a Chinese colleague who is going to translate because they have a
112 different they are going to have different language resources to describe the
113 same thing and that's going to come in as well

114 **T:** and they tend to take things more literal in a literal way rather than trying to
115 abstract it a little bit

116 **R:** exactly and here's there's lots of metaphorical uses of the language

117 **T:** I agree

118 **R:** Well that's it thank you

Extract *6*.1 Teacher interview 25.03.15, appendix four, lines 1- 118

The interview takes place in the teacher's classroom. The teacher and I, Sally, are sitting at one of the tables at the front of the classroom and we are both facing my laptop on which I play a short section from the lesson on heat transfer. I have my notes of the pupil interview (morning 25.3.15) in front of me on the table.

The discourse-world of the here-and-now interview situation, which becomes the main text-world of the analysis process, features throughout and is maintained with the world-building deictic pronouns *I* and *you* (see lines 1-6: these words are marked up in red). Text-worlds, some fleeting and some more sustained are created through the use of these and other world-building elements by the participants during the interview. Both the teacher and Sally use short passages of language which are image rich (e.g. T: *heat is travelling along the bar or along the rod* (line 79) and R: *almost through the particles they*

see it as a kind of substance (line 80)) to exemplify the difficulty the pupils have with the concept of heat and the language used to represent their thinking. The text-worlds created in these instances are often unspecified in space and time.

Mr Dalel and myself also create more developed text-worlds, in which the time and/or place are established, of either a teaching situation (e.g. lines 17-25) or interview situation (e.g. lines 77-78), which again serve to illustrate and provide evidence for the particular difficulties that pupils experience with the concept. In these instances, the world-building pronoun *they* is used to refer either to the pupils in the class during a specific teaching event (e.g. line 24) or the three pupils who were interviewed (line 77) earlier that day. At other points during the interview, the referent of the pronoun *they* is less easy to determine (e.g. line 56), especially in the case of Mr Dalel who might be referring to all the pupils he has taught or the class, or a blend of both.

Thus, the interview served as a platform for both Mr Dalel and Sally to make generalisations about the pupils' knowledge by drawing from text-worlds, created from their own experience of either teaching or interviewing the pupils. Although the other participant, in the discourse-world of the interview, does not feature as an enactor in these text-worlds, I would argue that they can nonetheless be classified according to Text World Theory as partly participant-accessible, as it can be assumed that both the teacher and researcher find what the other says as credible and reliable. In line 45, the researcher starts the discussion of the pupils' ontological understanding of the concept of *heat* by asking the teacher his opinion, 'do they have a problem with heat?'. This sets up an epistemic modal-world which features repeatedly throughout the interview. The teacher responds to the researcher's question by asking for clarification. His question, which contains the mental process *mean*, advances the epistemic-modal-world.

46 **T:** what do you ↓mean

47 **R:** the concept of heat

48 **T:** the concept of heat they have more difficulty with yeah (0.5) um

Extract *6*.2 Teacher interview 25.03.15, appendix four, lines 46-48

Mr Dalel responds immediately. The certainty of his claim, 'that they have more difficulty with yeah', is established by him providing an account of an instance from his own teaching experience. Here, he constructs a text-world with a time-zone located in the recent past by using the present perfect, 'I've asked them a couple of times since then' (lines 49-50). His authority as a teacher and the fact that he exists in the same ontological level as Sally (i.e. they both share the same discourse-world) gives his text-worlds a strong degree of credibility.

To demonstrate his belief that the pupils have difficulty with the concept of *heat*, Mr Dalel describes an unrealised scene of an experiment involving the pupils, which is built up with a series of possessive relational processes (e.g. you've got boiling water):

48 **T:** the concept of heat they have more difficulty with yeah um because the
49 concept of heat they don't understand that because I've asked them a couple
50 of times since then if you've got boiling water at 100 degrees Celsius and
51 you've got 250 ml of that boiling water and you got 50 ml of boiling water in
52 another flask you've still got a temperature of 100 degrees Celsius for both
53 flasks which one is going to have more energy they often say they smaller cos
54 the smaller volume yeah so they are having difficulties with that concept

Extract 6.3 *Teacher interview 25.03.15, appendix four, lines 48-54*

Mr Dalel reports what the pupils say, 'they often say they're smaller cos the smaller volume' (line 53), after they have seen the experiment. Here, the use of the reported speech does not create a world-switch as it belongs to the same deictic environment (Werth 1999: 221). Although Mr Dalel views this as evidence that the pupils 'are having difficulties with that concept' (line 54), by establishing an epistemic-modal-world, he does not offer an explanation of the reason.

This lack of information prompts Sally into probing Mr Dalel further. Drawing from her own knowledge gained from the pupil interview, which took place that morning, I establish a further epistemic modal-world by asking in line 55, 'in your view do they see heat as something separate from vibrating particles?'. Once again, Mr Dalel without hesitating says, 'yup I think that they do', indicating that he agreed with the researcher's statement. Both Mr Dalel and

myself continue contributing to the discussion by referring to other specific events which illustrate this phenomenon further (lines 57-68).

Two world-switches are created by the myself and teacher during the short episode R: 'because I'm seeing that in the interview this morning' (line 57) and T: 'yup I've actually shown them a video of a clip of particles' (line 58) constitute partially participant-accessible worlds which are not distant from the other participant's own experience and therefore serve the function of adding credibility to the participants' statements as well as adding to the building of shared/mutual ground that develops as a result of the interview.

Throughout the interview, both Mr Dalel and myself discuss how the pupils' ability to appropriate language is related to their understanding of the scientific concepts. They agree that the pupils tend to use the words more in accordance with their everyday use than how a scientist would use the word:

102 **R:** yet it's the finer it's getting down to the meanings of all these words and how
103 they appropriate these meanings

104 **T:** because they tend to take them in according to their everyday usage

Extract *6*.4 Teacher interview 25.03.15, appendix four, lines 103-105

The topic under discussion is one which carries a degree of uncertainty about it. After all, the pupils are enactors in the text-worlds created by myself and Mr Dalel and therefore cannot be asked. The language used by Mr Dalel and myself reflect this; it contains a number of hedging expressions e.g. tend to, almost, a kind of, devices shown to be frequently used to create a distance between the speaker and what is being said (Prince et al. 1982, Skelton 1988), thus indicating uncertainty in this context. The subject is also subjective in that Mr Dalel's and Sally's opinions are based on their own encounters with the pupils. It follows that as the phenomenon is one that both participants cannot see and has been experienced privately, it is difficult to communicate. Deignan et al. (2013) claim that conceptual metaphors are frequently used when talking about subjects that are difficult to express. This appears to be the case here, as the participants use conceptual metaphors to conceptualise the phenomenon under discussion. For

example, the researcher uses the SEEING IS KNOWING metaphor twice in lines 55 and 57 and the teacher uses the conduit metaphor *I get that sense* (line 83) to express how he has experienced the pupils' learning.

During lines 55-84, Mr Dalel and myself reach an agreement on what the pupils' conceptual difficulty with heat is, namely, that they do not equate it with the movement of particles. This is illustrated in lines 83, when Mr Dalel says, 'I would agree. I get that sense as well. They are not linking the idea necessarily that heat is particles vibrating. You are absolutely right'. The change in tense from the past continuous, 'they were talking about heat it was something different' (line 76), to the present simple tense, 'so they just see it' (line 77) causes a shift in the temporal parameters. The new text-word is in a timeless perpetual zone and the special boundaries of the new text-world have shifted from the interview room (line 76) to what might be a classroom or in the case of the researcher a blend of both the interview room and classroom. The effect of this shift from specific events to unspecified temporal and/or spatial worlds is that it gives the statements a sense of permanency and truthfulness.

76 **R:** ↓Yelina and it was how they were talking about heat it was something
77 different to how the particles moving so they just see it as two separate
78 things[

79 **T**:]heat is ↑travelling along the bar or along the rod

80 **R:** almost THROUGH the particles they see it as a kind of substance

81 **T:** yeah

82 **R:** that is what you ↑agree

83 **T:** I would agree I get that sense as well they are not linking the idea necessarily
84 that heat is actually particles vibrating you are absolutely right

Extract 6.5 *Teacher interview 25.03.15, appendix four, lines 76-83*

In line 86, I introduce into the discussion, the observation that words used in a science classroom often have more than one sense, and thus could potentially be a source of confusion for the pupils. Specifically, I and Mr Dalel discuss how the pupils' use of the word 'through' might be different to how he wishes his

pupils to use the item in the context of the lesson, and how this could hinder their conceptual understanding of the subject. This episode is primarily characterised by epistemic modal-worlds as both the researcher and teacher are talking about what they are thinking. Both I and Mr Dalel agree that it is the more usual, prototypical sense (i.e. moves between) that the pupils tend to assign to the word. This is illustrated by the following exchange (lines 86-95):

87 **R:** I need to look at the interview in more detail but it's little words like through
88 they are words in here that have double meanings I mean through has
89 something like 7 senses or something there are different ways that you use it
90 and I think they use it sometimes in an alternative way they are used to a
91 different way it confuses them

92 **T:** I'm sure it does through tends to indicate that it's **R & T** Through a door

93 **T:** an empty space

94 **R:** and they might think it's through the particles they are not seeing it as um
95 direction we use it or scientists use it in this context it'd be used more as
96 direction

97 **T**: through something absolutely sure

Extract 6.6 *Teacher interview 25.03.15, appendix four, lines 86-95*

The sense of the word 'through' that I and Mr Dalel are describing in lines 87-95 has 'a clear spatial scene' (Tyler and Evans 2003: ix). The sense is derived from the pupils' direct bodily experience with their physical surroundings 'involving entities that are related in a particular spatio-configurational way (ibid: ix)'. The scientific sense, however, that the word is used to describe the movement of heat is 'pass along', which foregrounds the notion of movement and direction.

In summary, the main aim of the interview was to provide the space for the teacher and myself to be able to articulate how we see the pupils learn abstract concepts in terms of how able they are to appropriate the language, thus establishing a shared sense of the phenomenon. The interview revealed important clues into our own beliefs. For example, I, by saying, 'some of them do pick up and start to appropriate it [the language] the way you intend them to use it' (line 106-107*),* indicate with the words 'pick up' and 'start to

appropriate it' appear to ascribe to a usage-based view of language acquisition. In response, the teacher acknowledges my claim, 'they do some of them do (.) some don't', indicating too that he finds this approach to understanding language acquisition reasonable but adds that some pupils find this process easier than others. Both myself and Mr Dalel believe this process is more difficult for bilingual learners and the teacher articulates this position further by claiming, 'and they tend to take things in a more literal in a literal way rather than trying to abstract it a little bit' (line 114). At the time of the interview, I interpret this as being the result of the fact that much of the language in science classrooms is metaphorical, 'exactly and here's there's lots of metaphorical uses of the language' (line 116).

This analysis provided an in depth, nuanced account of how the teacher and Sally created text-worlds in response to the discourse of the interview, in different spatiotemporal positions to the discourse-world that the teacher and myself inhabited. The credibility and trustworthiness of the evidence that the participants provided can be explored in terms of degree, depending on the extent to which the worlds are accessible or not to the other participant, either in terms of where and when they were situated in relation to the discourse-world of the interview, the status of who gave the evidence and finally, in terms of the familiarity of the enactors and situations described in the text-worlds to the other participant. The structuring of these worlds depended on the knowledges and ideologies that the participants brought with them. My present interpretation of the interview and my present connection I have with myself and the teacher in the interview is mediated through the transcript of the interview. As noted by van der Bom (2015), during a text-world analysis of a transcript, the analysist just becomes an eavesdropper on the situation (Goffman 1981; Werth 1999:17-18 cited in van der Bom 2015: 95). The effect is that I view my own contributions with a degree of distance and my interpretation is influenced by my new set of ideologies and knowledge frames that I have acquired throughout my study.

The text-world analysis shows how the various topics emerged between two people who have had experience teaching science. This is an important point because the topics that will be explored in part two and three of this chapter are topics that not only address the thesis' overall aims but are also seen to be relevant to a practising teacher, not just myself the researcher, thus strengthening the scientific trustworthiness of the analysis. As established in sections 3.1 and 3.10, the realist paradigm relies on multiple perspectives on the same reality. This interview took place three months into the data generation stage. Although familiar with classroom context, exploring my own belief worlds with that of the teacher, by means of a text-world analysis, developed my own knowledge and critical understanding of the learning events.

The rest of this chapter explores the pupils' understanding of *heat transfer* by analysing how they linguistically represent the concept in a group discussion/writing task. The topics which emerged from the interview provide an extra layer of depth and nuance to this analysis. The topics are as follows:

- how pupils linguistically represent the ontological nature of heat transfer;
- learning of the abstract concept of *heat transfer* in terms of how the pupils appropriate language;
- the perceived tendency of pupils to find metaphorical language difficult.

To investigate these three topics, a text-world analysis of a group writing task is carried out, in which the pupils are using the language to represent their understanding of *heat transfer*. The focus of the analysis is the linguistic knowledge of the pupils and how this knowledge relates to the language in use prior to the task. To explore the ideas further of two of the pupils, Zarif and Mahta, who were two of the participants during the writing task, a text-world analysis of the stimulated recall interview is made.

6.2 Part two A: the group writing task and its discourse-world

In this section, the discourse-world of the group writing task will be explored. As stated previously in the literature review, the discourse-world deals with the immediate situation which surrounds the participants as they communicate with

one another (Gavins 2007a:9). This involves not only the physical surroundings of the participants but also the knowledge frames they bring to the situation. Therefore, this section will look at the physical arrangement of the pupils in the classroom, the setting up of the task by the teacher that highlights the purpose of the writing task and finally an account of the knowledge frames that the pupils need to bring to the task. A specific focus on the pupils' linguistic knowledge (Werth 1999: 96) will be made.

The group writing activity takes place during the last twenty minutes of the lesson on conduction on (18.03.15). The teacher sets this activity up towards the end of the lesson. The pupils are sitting in their usual seats and the teacher is standing in front of his desk at the front of the classroom. He moves between the desks as he talks to the pupils. The key words are written on the whiteboard. The actual writing task is referred to the first time in line 256 after he talks briefly to the class about the significance of explanations in science in general and their relationship to understanding the *heat transfer* demonstration (analysed in Chapter 4) that took place at the beginning of the lesson:

250 **T:** what do we mean by evidence Zarif

251 **P6:** proof

252 **T:** kind of proof (.) nearly or a VERY very strong possibility (2.0) that that is
253 the case so that's what science is a bit like it's a BIT LIKE DOING LOTS OF
254 EXPERIMENTS and trying to EXPLAIN why something is happening ↑ok

255 that's what (2) it's like so (3) that's what (4) that is right (5) that's trying to
256 explain ↑why we've seen what we've seen.. so it says write a few
257 sentences

Episode 6.7 *Lesson one 18.03.15, appendix one, lines 250-257*

6.2.1 Discourse-world - the purpose of the writing task

In lines (250-257) the teacher builds up in the minds of the participants a mental representation of an aspect of what 'science' is. The pronoun **it** (1) and (2) both have a recent direct antecedent 'science', and are used repeatedly to maintain his concept of science in the minds of the participants. The concept 'science' will have accumulated for each of the participants in variable ways over time

depending on their own experiences in and out the science classroom. However, much of this knowledge that the participants bring to the text will be shared/mutual as the pupils belong to the same class. The teacher presents and foregrounds two attributes of science with material processes, namely 'doing lots of experiments' and 'trying to explain why something is happening', that the pupils have already experienced during that lesson. Although his version is only a partial version of what the discipline of science is, its purpose here is to provide a rationale for the group writing task. The text-world created has no specified enactor but it is, however, ontologically close to the pupils' recent discourse-worlds. Therefore, it seems reasonable to assume that the pupils might momentarily create representations of themselves as the enactors in this text-world, thus creating a rich albeit fleeting text-world.

The teacher starts to trigger a world-switch back to the discourse-world by indexing the writing task by both pointing and using the demonstrative 'that', in '**that**'s what (4) **that** is right. (5) **that**'s trying to explain why we've seen what we've seen' (line 255). Here the teacher appears to toggle between the text-world of 'what science is' by summarising and emphasising the notion of explaining with the introduction of the writing task, in which the pupils are going to write an explanation of what they saw.

Thus, the writing task is first set up by situating it in the wider context of understanding that explanations play an important role in science. The teacher constructs a deontic modal-world informing the group of what they need to do for the task, 'so it says write a few sentences and describe the process of conduction try and use the words heat, spread, vibrate, solid and particles in your answer' (lines 256-258). He continues by emphasising that the task requires them to explain, 'in science you are often going to be asked to explain things and explain means to give reasons as to why not just what happens which we know what happens the harder bit is to understand why it happens' (lines 266-268). The task is guided in that the teacher has provided the pupils with five words that they should use first in their group discussion, 'you have a good discussion using those words think about what you could write' (line 274), and

then in their written answer, make sure the the words go into your answer' (line 277). The instructions of the task are written up on the board and on the sheet in their booklets.

6.2.2 Discourse-world: linguistic knowledge of pupils

The intention of the teacher is that the pupils produce in groups a short, written explanation by means of a group discussion, using five words (heat, particles (nouns), spread, vibrate (processes), solid (adjective/noun). The success the pupils have in achieving the task will depend not only on their interpersonal skills, but also on their linguistic knowledge of how to use these set words for the purpose of the task at hand.

In Werth's original monograph linguistic knowledge and cultural knowledge are sub-categories of general knowledge, which is defined as 'all that information which is in principle available to all individuals by virtue of their membership in larger social groupings' (1999: 96). In a classroom in a school in the UK, it is assumed that much of this general knowledge will be shared amongst many of its members. As the class was diverse, with many of its pupils having linguistic and cultural backgrounds other than English, the linguistic and cultural knowledges that the bilingual/EAL pupils have, will consist of variable amounts of English and other languages. Two of the pupils Mahta and Zarif, who were members of the group writing task, were bilingual pupils who had lived in Britain since birth. However, due to the constraints of this study it was not possible to gather sufficient amount of data on these pupils' linguistic and cultural backgrounds that could inform detailed interpretation of their output during the task. Furthermore, Zarif's and Mahta's level of English was high and there appeared to be no marked effect on their output that might have been a result of their bilingualism.

Werth's coverage of linguistic knowledge highlights how a text-world approach views linguistic knowledge to be closely connected to other cognitive systems, which contrasts strongly with the generative linguistic tenet that it is a separate cognitive 'organ' made up of separate sub-categories (ibid.). Werth's account is, however, brief and does not provide detail on more specific aspects of what

linguistic knowledge might look like, its relationship with other cognitive faculties such as memory and its role in the knowledge building process, that might take place in a classroom. This section, Part Two A, contributes to the text-world framework in that it aims to elaborate and describe in detail what a group of pupils' linguistic knowledge might be as they approach a group writing task in the classroom. By drawing on Fillmore's *Semantics and the nature of language* (1976), Langacker's Foundations of Cognitive Grammar (1987a), van Dijk's proposal for macrostructures and van Dijk and Kintsch 1983 and Bortolussi and Dixon's framework on memory (Figure 2.3.), a qualitative account of how the pupils' linguistic knowledge reflects their overall understanding of the topic is made.

From a cognitive linguistic perspective, linguistic knowledge, which is part of the discourse-world, is interlinked with other cognitive systems. In other words, linguistic knowledge, memories and experiential knowledge 'may all provide input for each other' (Werth 1999: 98). The meanings that the pupils ascribe to the set words will have arisen from how the pupils have experienced the words previously: they 'propose a mode of construal of that entity' (Holme, 2009: 161). Fillmore already noted that our knowledge of lexis and grammar depend on 'contexted experiences; that is, the contexts within which we have experienced the objects, properties or feelings that provide the perceptual or experiential base of our knowledge of the meaning of the word (or phrase, or grammatical category) may be inseparable parts of those experiences' (1976:24). The flipside of this is that, if the prominence and attentional views of language are correct (see Chapter 2, section 2.6), by observing the pupils' language choices, it becomes possible to observe which part of the learning context they may be choosing to foreground and attend to. This close relationship between thought and language in on-line situations as examined in this chapter has been noted by Slobin (1996), in his 'thinking for speaking' conception, which claims that the language we use whilst speaking directs our attention to certain ways of filtering our experiences of the world.

To Fillmore, linguistic knowledge consisted not only knowing about lexis and grammar but also what he termed as cognitive or interactional frames, a type of linguistic knowledge, 'in which the language user interprets his environment, formulates his own messages, understands the messages of others, and accumulates or creates an internal model of this world' (Fillmore 1976: 23). This knowledge is essentially experiential, the kind of knowledge that exists as memories of prior experiences, and is necessary if a concept is to be attained. Langacker (1987a) refers to this experiential knowledge in relation to his notion of construction grammar in the following way:

> an abstract characterization that is fully compatible with all the members of the category it defines…; it is an integrated structure that embodies the commonality of its members, which are conceptions of greater specificity and detail that elaborate the schema in contrasting ways (Langacker 1987a: 371)

Thus, an important aspect of linguistic knowledge is our ability to recognise the various symbolic units in our language (e.g. paper clip, solid, travel) as instances of abstract categories or schemas (e.g. [COUNT NOUN], [MASS NOUN], [VERB]). Langacker refers to this ability as *schematization*.

Language users need to be able to recognise in what ways a lexical or syntactical item can be seen as an instance of a schema. This syntagmatic knowledge, derived from the pupils' ongoing exposure to repeated patterns in the language, enables the pupils to transform each smaller symbolic unit into more complex composite units (i.e. heat [NOUN], the heat [D NOUN] or [NOUN PHRASE] (Langacker 1987a). In other words, the knowledge that the pupils have of how certain words colligate are motivated by these schemas.

Closely related to this, is the ability to recognise that a symbolic unit is a typical example of a schema, in other words, the ability to see the symbolic unit as an instance of a prototype. This is referred to by cognitive linguists as *categorization* and is an example of a construal operation (Croft and Cruse 2004: 46).

The language the pupils use acts as 'points of access' to encyclopaedic knowledge or domains of knowledge (Evans 2006: 494). The position taken here, therefore, is that the linguistic knowledge the pupils have of how to use language (including the set words) is a function of how they have encountered the words in use prior to the discussion/writing task. Thus, in order to gain an insight into how the pupils' mental pictures of the abstract concept of *heat transfer* were created during the writing task it is necessary to explore the linguistic knowledge the pupils have whilst carrying out the discussion/writing task in relation to the language (lexical and syntactical structures) they use. To do this, I first explored how these five set words were used by Mr Dalel and pupils, prior to the writing task by finding patterns of word use that contributed to the pupils' mental representation of heat transfer created by the textual realisations found in the discourse. The latter was achieved by using the concordance software 'lextutor' to analyse the tapescript of the lesson. This corpus approach is used as a supportive technique as it simplified the search for these patterns over larger stretches of discourse.

In summary, the linguistic knowledge of the pupils relates to how the language was used prior to the writing task. Important domains of linguistic knowledge that they need in order to use the set words, for example, in their verbal output and writing are 1) acquired knowledge of what each of the five words (or symbolic units) represent to members of the group within the context of the topic heat transfer. And consequently, 2) knowledge of what the larger more complex symbolic units (e.g. the heat [NOUN PHRASE]) represent (Taylor 1993) in the evolving context of the lesson. In order to be able to combine the smaller units of 1) into the larger units of 2) during the writing task, the pupils also require 3) syntagmatic knowledge derived from the pupils' construction schemas (Langacker 1987a). Finally, they need an understanding of the unit's prototypicality.

6.2.3 Linguistic knowledge of pupils and discourse of classroom

Prior to the writing task, the pupils were exposed to the multi-modal discourse of the classroom, which was predominately teacher talk and images on the

whiteboard and in textbooks. By observing how closely the words co-occur in the discourse, it becomes possible to speculate whether the pupils associate certain words together and thus regard them as collocations; the higher the frequency of the words co-occurring the more likely it is that the pupils will associate the words with one another in their minds (Halliday and Hasan 1976; Hoey 2005). To explain this phenomenon more closely in relation to this specific lesson the following will examine the use of the words *particles, solid* and *rod*, by the whole class and the teacher.

The concordance 'lextutor' shows that the word 'solid' collocated, five times with 'particles', three times as a noun (1, 4 and 5) and twice acting as an adjective (3 and 4). A collocation is taken here to be 'the readily observable phenomenon whereby certain words co-occur in natural text with greater than random frequency' (Lewis 1997:8).

Table 6.2. Concordance lines illustrating collocation of SOLID with PARTICLES

1.Line 2351	**PARTICLES** in a	**SOLID**	are tightly packed together
2.Line 2354	pretty tight the	**SOLID**	**PARTICLES** in the cold are
3.Line 2355	yesterday there were	**SOLID**	**PARTICLES** in the last topic
4.Line 2362	**you are just now PARTICLES in a**	**SOLID**	vibrate
5.Line 2363:	terms of the **PARTICLES** of the	**SOLID**	

It is assumed that the pupils would associate the words *solid* and *particles* based on the frequency that they occurred together in verbal discourse. Interestingly, the words *particles* and *rod* do not co-occur together in the classroom discourse

prior to the writing task. However, in the context of the lesson, the pupils have encountered images of particles with images of rods. As stated previously, the linguistic knowledge a pupil has is closely related to the pupils' other cognitive systems, including the visual and other perceptual systems. To both Fillmore (1982) and Langacker (1987a), the words in a given context activate knowledge structures, including those in the perceptual domain. In Langacker's account, the word can act as the profile, or the focal point within a larger unit or the base. For example, the word hypotenuse is the profile of which the multi-word item right angled triangle acts as a base. Therefore, in the context of this lesson the word *particles* might for many pupils be the profile for the base concept *rod* as they had seen a diagram, such as the one in figure one below, of a rod made up of particles.

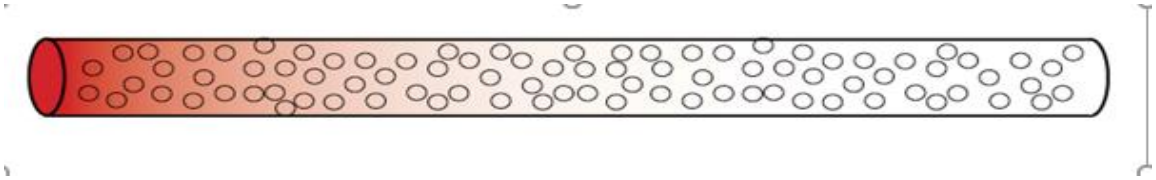


Figure 6.1. Rod with particles

In the topic 'Chemistry Matters', that had been covered three months previously, the pupils were also shown diagrams in which the word *particles* was the focal point. However, in these diagrams there is no clear visual base.

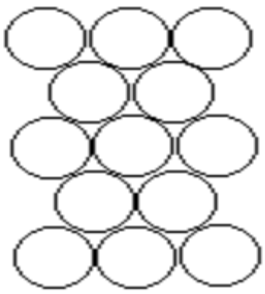


Figure 6.2. Particles of a solid

Although difficult to speculate on the power of these images over words, and to ascertain with any great certainty whether an image seen three months previously would still be remembered by the pupils, this analysis shows that in

the context of the classroom it is probable that the pupils associate the concepts *particles* and the entity *solid*, or *rod*, together as a result of the exposure the pupils had with the words/images being in close proximity with each other in the verbal discourse or in images.

In summary, although it is not possible to enter the pupils' minds and pinpoint the exact meaning they associate with the words *heat, spread, vibrate, solid* and *particles,* by studying the language used, with the help of investigating the words in concordance lines prior to the writing task, it becomes possible to explore some of the associations and knowledge structures the pupils might have with the set words and how they might use and appropriate the words to represent and co-construct their abstract thinking in the context of the group writing task. The following will analyse how the pupils actually used the words set by the teacher during the task.

6.2.4 Text-world analysis of group writing task

As soon as the pupils' attention shifts from Mr Dalel at the front of the class towards the writing task itself the discourse-world of the pupils also changes. The teacher is no longer the main producer of the discourse under analysis. The main participants of the discourse-world (lesson) in focus are the three pupils sitting around the table at the back of the classroom on the left near the window. The three participants are Zarif (P6), Mahta (P1) and Klara (P20). On the table are their booklets, notepads, pencil cases and the recording device.

It must be noted that the aim of the writing task is twofold in terms of knowledge building. First, it provides a space for the individuals in the group to arrive at a stronger mutually agreed knowledge base. That is, the common ground shared by the pupils should increase. Secondly, the act of externalising their ideas to an audience in both verbal and then written form affords each individual the opportunity to introspect, scrutinise and re-adjust their own mental images and knowledge bases.

By analysing how the pupils linguistically represent their understanding of *heat transfer*, a partial glimpse of the knowledge structures the pupils have, is

gained. The following analyses the writing task by first looking at how the pupils use the five set words and how this relates to how the words were used in the discourse prior to the task. It will then look at the other language the pupils use, besides the set words, to gain further insight. First of all, the episode is presented in full.

278 **T:** you've got about 10 minutes to get that done now I want to see a good
279 job ↑ok get busy. (1.0) get busy ↑and that means you don't work by
280 yourself you work with someone. NO you're not writing on your own
281 you're not doing any writing at the moment you're just talking about
282 what you might write with people in your group (.) you agree a group
283 answer (1.0) roughly a group answer (.) go on get busy

284 **P6:** heat spreads through (.) the rod and particles start to vibrate heat
285 spreads through the rod (1.0) and the particles start to vibrate [F writes
286 this down

287 **P1:** he said we're not writing yet oh heat spreads through the rod
288 (whispering) – he's come back)

289 **P20:** HEAT spreads thro…ugh the rod

290 **P6:** and the particles start to vibrate (1.0)

291 **P1:** and (writes this down) (1.0) the par::ticles [writes this down] vibrating
292 (whispers) then (.) the particles start vibrat(glottal)ing

293 **P20:** it spreads further down the rod (2.0) like the part(glottal)icles are
294 vibrating which makes (.) which passes it on to other particles

295 **P1:** how are we meant to use ↑solid

296 **P20:** huh?

297 **P1:** how are we gonna use solid

298 **P6:** heat spreads through the rod

299 **P20:** the ↑copper rod is a solid

300 **P20:** the heat spreads through the rod and the particles start vibrating

301 **P1:** then (.) vibrating (whispers)

302 **P20:** and it keeps going along the solid rod (2.0) and we're talking about the
303 copper rod (.) right now

304 **P6:** the heat spreads through the rod and the(n)? particles start to vibrate

305 **P20:** I wrote the heat spreads through the ROD and the particles start
306 vibrating (.) and it keeps going along the ↑rod until the paper clips have

fallen off (3.0) an [older student enters the room] T: well go and have a look

P6: I wrote the heat spreads through the rod

T: did you find it .. have you tried the office (15.0)

P20: ok (drops pencil) and then er (.) see afterwards (.) being burnt can it ↑bend

P6: no

P20: ↑wa

P6: it won't bend

P20: it ↑won't

P6: it won't bend

P20: I know but we could still write the solid can bend

P6: we don't have to use (.) solid

P20: I didn't wear goggles that's bad [inaudible]

T: ok boys and girls (.) let's start transferring your notes into the booklet

P6: the heat spreads through the SOLID ROD and the particles start to vibrate and it keeps going along the solid ROD until the paper clips fall off

P20: my friend gave it to me [off task]

P6: are you guys done yet

P20 & 1: whispering

P1: yeah I wrote it… where's the rubber

P20: there's one on this pencil but it probably won't work because it's quite flat

P6: [sighs]

P1: rubs out something

P20: hate that noise

P20 & 1: [whispering]

P20: ok we're done (3.0) heat spreads through the rod and it start[

T: ok boys and girls start transferring your notes you got into your sheets (someone sneezes) (5.0)

338 **T:** have you finished F (2.0) are you sure you've got all the key words on
339 the board?

340 **P20:** yeah

341 **T:** have you? got heat spread vibrate solid particles in your answer yeah?

342 **P1:** don't know where ..to use solid

343 **T:** well, basically it's a ↑solid rod that's the EASIET one to use

344 **P20:** solid rod

345 **T:** that the solid rod is heated yes

346 **P20:** ok[Group starts copying out answer]

347 **T:** dedededede (singing to himself) (4.0)

348 **P1:** looks like splurge… I need a tissue (15.0)

349 **P20:** okay the heat spreads through the ↑solid rod and the particles start
350 vibrating (.) and it keeps going along the so↑lid rod until all the paper
351 clips have fallen off (.) it sounded like a poem (1.0) the heat spread
352 through the [loud] solid rod and the particles start vibrating and it keeps
353 going along the solid rod [laugh] until the

354 **P1**: I wrote solid rod for the first rod I wrote get what I mean

Extract 6.8 *Lesson one 18.03.15, appendix one, lines 278-354*

6.2.5 Analysis of pupils' use of set words

The pupils are given the task of writing an explanation on heat transfer using their understanding of the particle theory of matter. They are told that they should use *heat, spread, vibrate, solid* and *particles* in their answer. Mr Dalel does not indicate what part of speech these words are. This task is presented to the pupils as a group writing task, in that the pupils are told to spend their time discussing in a group what to write. The effect of this is that in the discussion there is a high frequency of repetition (e.g. lines 287 and 291) and focus on the actual word choice. This supports what has been noted in the literature that the act of writing, which in this case involves both discussing and then writing, renders the language more permanent and open to critical reflection (Olson 1994).

287 **P1:** he said we're not writing yet oh heat spreads through the rod
288 (whispering – he's come back)

289 **P20:** HEAT spreads thro…ugh the rod

290 **P6:** and the particles start to vibrate (1.0)

291 **P1:** and (writes this down) (1.0) the par::ticles [writes this down] vibrating

Episode 6.9 *Lesson one 18.03.15, appendix one, lines 287-291*

The frequency of use of each of the items is listed in the table below. All the inflected forms of the lexeme (or head word) that occurred in the discourse have been included as they carry the same basic sense. The figures in the right-hand column represent the frequency of the lexemes shown in the left-hand column.

Table 6.3. Frequency of set words found in discourse prior to group writing task

lexical item	frequency
spread	0
vibrate – vibrating - vibration	4 – 11 - 4
solid - solids	15 - 6
particles - particle	19 - 1
rod - rods	35 - 5
heat – heated - heating	58 – 1- 1

All the words had been used during the lesson by the participants, except *spread*. Therefore, the linguistic knowledge required by the pupils to be able to use the word spread in the task could not be derived from their exposure to the language of the classroom prior to the task. As it is a word that is used frequently in casual

conversation (i.e. a margarine spread, to spread butter), it is highly likely that the pupils have encountered the word outside the classroom.

The pupils are told what the five words are, and they also see them written on the board in a horizontal line. They both hear and read the words as a text. That is, the pupils' minds do not encounter them as single, stand-alone lexical items but as words that are interconnected. The first word *heat* primes the pupils for the words which follow (Hoey 2005). In other words, the word *heat* sets up a set of expected associations with the words *spread, vibrate, solid, rod* and *particles*.

During the lesson leading up to the writing task the word *heat* collocates with the material processes:

heat *is transferred*

heat *gets transferred*

heat *has been transferred*

heat *is travelling*

heat *doesn't stay in one place*

(Source: concordance lines)

Hoey states a word becomes 'cumulatively loaded with the contexts and co-texts in which it is encountered' (2005:8). In the case of 'heat', the pupils have repeatedly heard and read the word in this lesson in association with processes that denote movement. *Heat* is in each of the above cases the trajector (an object) which moves along a SOURCE-PATH-GOAL landmark. The text producer chooses which construction to take depending on which element of the scene is being foregrounded. As explained in sections 4.3.6 and 4.3.7, the past participle draws our attention to the GOAL part of the landmark. As exemplified in Chapter 4, profiling is an example of a construal operation. The word *spread* had not been used prior to the writing task, it may therefore be not construed as a

prototypical example of a verb to symbolise movement in this context. However, Zarif immediately uses the word with heat, 'Heat *spreads* through…' This pattern is used by Zarif and Klara repeatedly (10 times - heat spreads, 1 time - it spreads: 'it' refers to heat) throughout the writing task. As the word 'spreads' is closely associated with the concept of movement, it is substituted for the motion processes, that the teacher used (is transferred, gets transferred, has transferred, is travelling). The pupils' choice to collocate 'heat' with 'spread' strongly suggests that heat is imagined to be a substance that moves along a PATH. In order for the pupils to represent this image to each other in speech and writing, they require knowledge of what the syntactical pattern in 'heat spreads' (figure + motion process) represents to the group i.e. its construction.

One further feature of the group writing task's discourse, is that the pupils use *rod* and not the set word *solid*. In fact, Mahta asks in line 295, 'How are we meant to use solid?', indicating either that she is unsure of the association of the abstract term solid with the heat transfer process or she is unsure how to use the term in the same text with the term *rod* or she is unsure what part of speech the word is. In the classroom discourse leading up to the task, the term rod was used 35 times (rods 5) and solid was used 15 times (solids 6) (see table 6.2), indicating that the pupils had ample exposure to both words. Although the pupils should be familiar with the word solid, Mr Dalel used it mainly when providing the formal definition of conduction (7 times – see e.g.s **a)** and **b)**, and less so when talking about the movement of particles (only twice – see e.g. **c)**.

a) conduction is the process where heat is transferred through a SOLID
b) conduction explain in terms of the particles of the SOLID what this
c) just the way you are just now particles in a SOLID vibrate just ever so (role play simulation)

The pupils' preference for the term *rod* over the term *solid* during the writing task may have therefore two reasons: i) they associate the term *solid* with formal definitions of the heat transfer process, as indicated by the concordance lines **a),b)** and **c)**; and ii) the term *solid* may be less easy to visualise due to its abstract nature as part of a text-world during the writing task, as illustrated in Figure 6.2, in which the word *solid* did not have a visible base in any of the

diagrams shown to the pupils in previous lessons. One further reason, as indicated by P20's use of the term as an adjective in line 306, is that the pupils appear to be more familiar with its everyday use as a qualifier.

This section has analysed how the pupils have appropriated the language set by Mr Dalel, in order to explore the linguistic knowledge used by the pupils to carry out the task. It has shown that i) the use of the pupils' language strongly reflects the use of the language in the verbal discourse that occurred prior to the task, as well as images in the discourse preceding the task, ii) pupils linguistically represent heat as a moving figure along a path iii) pupils appear to have more difficulties using abstract words such as 'solid'. This might be due to the nature of the task set, as it does not require the pupils to provide a formal definition of the *heat transfer* process, which they may associate the term with or they might find it easier to visualise a *rod* as it is something they have seen as opposed to a *solid*, which is more abstract.

6.3 Macro- and micro- worlds

In addition to analysing how the pupils appropriate the five set words, it is also important to examine the language that the pupils chose to use instead of these words. The fact that the pupils frequently use the set words that had been previously used in the lesson might be caused by the pupils having a good verbatim memory for the language used in class. In other words, the pupils may have recalled well the surface structure (Bortolussi and Dixon 2013) of the language used in the classroom (see 2.7.1.2). According to the 'three levels of representation model' (see Chapter 2, Figure 2.3), this surface structure level of recall does not, however, indicate sufficiently whether the pupils have necessarily understood the concept. By looking at the language produced by the pupils that is different from the language used previously in the lesson, it is possible to look at the 'text base level' of representation (see section 2.7.1.2) (Bortolussi and Dixon 2013). As established in section 2.7.1.2, this level of representation looks at the semantic meaning (ibid. 2013), therefore a glimpse into the pupils' own understanding of the concept. The highlighted words (in red) in the transcript indicate how the pupils view the *relationship* between

heat, rod, particles, vibrate and solid as the words that they choose are predominately process words and prepositions that combine the set words together:

289 **P20:** HEAT spreads thro…ugh the rod

290 **P7:** and the particles start to vibrate (1.0)

291 **P1:** and (writes this down) (1.0) the par..ticles [writes this down] vibrating
292 (whispers) then (.) the particles start vibrat(glottal)ing

293 **P20:** it spreads further down the rod (2.0) like the part(glottal)icles are
294 vibrating which makes (.) which passes it on to other particles

295 **P1:** how are we meant to use ↑solid

Extract 6.10 *Lesson one 18.03.15, appendix one, lines 289-295*

(own words of pupils highlighted in red)

What emerges from analysing the pupils' language other than the five set words is that the pupils correlate heat with the movement of particles. In the following example Klara and Zarif co-construct the idea that heat and vibrating particles are in some way related. 289: Klara (P20): heat spreads **thro…ugh the** rod; line 290: Zarif (P7): **and the** particles **start to** vibrate.

Interestingly, Klara (P20) creates a text-world of the world that they have seen and touched, 'heat spreads through the rod'. Zarif (P7) continues on from Klara (20) by trying to establish a text-world of the non-perceivable micro-world 'and the particles start to vibrate'. However, the effect of Zarif's use of 'and', in addition to the lack of any indication that the location has shifted from a macro-level to a micro-level, is that the addressee is not fully prepared for a world-switch to the micro-level. The overall effect of this is that the addressee toggles between the two worlds and as the text-world of the micro-world has not been clearly established, the two worlds remain *merged*, as shown in Figure 6.3.

The cause of the vibrating particles in the micro-world is not given. As the purpose of the writing task is to provide an explanation for the vibrating particles, the addressee borrows from macro-world the foregrounded 'heat', which could, if the addressee (listener or reader) had no reason to believe

otherwise, fulfil the function of the cause. The effect of this merger is that it is not clear whether they view the movement of particles *as* heat energy

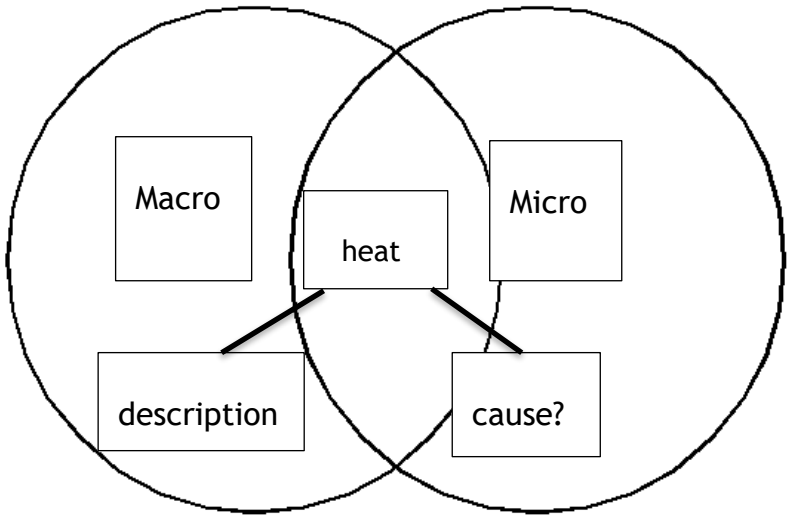


Figure 6.3. Merging Micro- and Macro-Worlds

(established scientific viewpoint) or as a separate phenomenon that causes the particles to vibrate. This merging of the two text-worlds is an example of the cognitive mechanisms of conceptual blending at work. Elements of the two, separate text-worlds (e.g. heat) blend together. In this instance, the blending of the two text-worlds potentially leads to confusion.

One further observation needs to be noted here. During the interview with the teacher both myself and Mr Dalel were under the impression that the pupils had a tendency to use the preposition 'through' in the sense of between, as in 'to go *through* the door (sense 1). However, during the entire writing task the pupils use the preposition 'through' in the sense of 'along' when describing the macro-world, 'Heat spreads *through* the rod' (sense 2). The close proximity of the merging micro-world has the effect of destabilising the sense of the word *through* (sense 2) and rendering it more like sense 1. This tendency of the pupils to blend two text-worlds in this manner goes towards explaining the *perceived* tendency of the pupils to view heat energy as an ontologically separate phenomenon to vibrating particles as observed in the interview with the teacher.

One further possible effect of this frequent blending of two text-worlds is that it could lead to the impression that pupils have a tendency to find metaphorical language difficult, as the teacher said, 'they tend to take things in a more literal in a literal way rather than trying to abstract it a little bit' (teacher interview (25.03), line 114). I would claim from this analysis that the difficulty the pupils have in understanding and representing their ideas does not result from the pupils' inability to use language figuratively *per se*, which is in line with the view of many scholars working in the field of child development of language and thinking (e.g. Cameron 2003; Gentner 1977; Vosniadou 1987; Winner 1988 cited in Píriz 2008). I would argue that the difficulty they face during this writing task is related to the competency of the pupils to create, separate and maintain the macro- and micro- text-worlds and trigger clear world-switches when intended.

Part Two A has focused on how three pupils used language to carry out a discussion/writing task. By observing the linguistic choices made it became possible to observe which part of the learning context they wish to foreground. The analysis of the lexical and syntactical features of the language displays what Fillmore termed as cognitive or interactional frames, a type of linguistic knowledge, which is essentially experiential and relies on the pupil having a memory of prototypes. Section 6.3, demonstrated that in addition to the lexical, syntactical and experiential knowledge, pupils require knowledge on how to organise their language. It is to this aspect of linguistic knowledge I will now turn to in more detail.

6.4 Formal knowledge structures

Both Fillmore and van Dijk (1985, 1980) recognised that there exists one further type of knowledge structure, other than lexical, syntactical and experiential, namely formal knowledge structures. Van Dijk and Fillmore noted that cognitive frames enable us to perform such cognitive acts as perception, action, and language comprehension. Fillmore noted that cognitive frames are strongly associated with the notion of prototypicality in that the receiver or producer of the structure needs to be able to *categorise* it according to its schema. Van Dijk also recognised this organising principle too, and referred to these formal

knowledge structures as ‘macrostructures’ (1985). He saw that they serve an important organisational function in the knowledge building process. They have different rhetorical purposes (e.g. narrative, instruction, report, description, explanation etc) and are essentially propositional in nature. More recently from the field of English for Academic Purposes, Bruce (2008) identifies these as ‘cognitive genres’ as they reflect how the mind organises information to carry out different rhetorical purposes.

Section 6.3 demonstrated that the pupils’ skill in organising the information in their writing is developing, and that their ability to represent their knowledge of the abstract concept of heat transfer in explanations depends on their knowledge of these cognitive genres. However, for pupils to be able to comprehend the discourse and be able to create mental models for introspection, an ability to create a situation model (see figure 2.6) is required. To do this, the pupils will use their expectations of the situation and draw from their knowledge frames.

By comparing the pupils’ writing with a model answer that the teacher gave during an interview (18.03.15), the importance of being able to organise information to achieve its rhetorical purpose becomes apparent:

The heat spreads through the solid rod and the particles start vibrating and it keeps going along the solid rod until all the paper clips have fallen off.

Figure 6.4. Group’s writing

When asked for a ‘model’ answer, this is what the teacher said:

What I would say is that the copper rod carries heat energy. The copper rod is made of particles, packed quite closely together. When one end is heated, the particles in the solid vibrate more quickly. These particles collide with the other ones, which then vibrate more quickly, and that's the way heat energy is transferred. That is what I would have written.’ (from interview 18.03.15).

Figure 6.5. Teacher’s model answer

As noted by Seah, Clarke and Hart (2011), in their analysis, using the method of constant comparison (Glaser and Strauss, 1967) of both pupil, textbook and curriculum documents, school science explanations of heat energy in physics typically involve the following components:

- A reference to the macro structure (e.g. the rod, the paper clips i.e. what is visible)
- A reference to the micro-structure (e.g. the particles)
- A reference to the cause (e.g. the heat supplied to one end of the rod)

Seah, Clarke and Hart (2011:862)

As might be expected, when comparing both the teacher's and pupils' explanations (figures 6.4 and 6.5) it becomes apparent that the teacher's references to each of these components is more detailed and is more clearly signposted and structured (e.g. when, these, which). From this, it is possible to conclude that the teacher has a more secure and developed knowledge of the explanation schema required to represent his understanding of the *heat transfer* process than the pupils.

The aim of Part Two A, has been to examine the ways in which the abstract concept of heat transfer is linguistically represented by a group of learners and their teacher in a secondary school setting during a group discussion/writing task. More specifically, it has looked at the linguistic knowledge required to be able to do this. It has demonstrated that the pupils' understanding of the abstract concept is inextricably linked with their linguistic knowledge. It has further shown that although the text-world framework is a suitable starting point for analysing how pupils represent this knowledge linguistically, Werth's original account of linguistic knowledge is brief. This analysis has developed this aspect of the framework in order to provide a more detailed description of the linguistic knowledge required by a group of pupils during a group discussion/writing task. It is argued that integrated into this model should be a reference made to the levels of representation to distinguish between simply a verbatim understanding of the language and an ability to create situation models that include referents open to introspection.

In summary, this knowledge is made up of the following components, namely, lexical and syntactical constructional knowledge (schematization and experiential knowledge); construal operations (e.g. profiling and categorization) and finally, the knowledge about formal knowledge (macrostructures or cognitive genre). These knowledge types are shown on the left-hand side of Figure 6.6. Integrated into the model are the three 'levels of representation' that indicate the extent to which each of the three linguistic knowledge types, shown on the left of the table, are part of the language user's memory and knowledge frames and cultural schemas. Rather than viewing the three linguistic knowledge types as discrete items, it may be more helpful to see them as an integrated system that operate simultaneously during tasks such as the discussion/writing task analysed in Part Two A. This was illustrated by Klara's merging of the macro- and micro- worlds, which resulted from Klara not being able to identify clear referents and world-switches through spatial deictics, that would be part of a more developed formal knowledge structure.

Component part	**Details**	**Three Levels of Representation**
Lexical and syntactical constructional knowledge (schematization and experiential knowledge)	Knowledge of how lexical items and syntactical patterns have been used in context. Shared understanding of what items and syntactical patterns refer to within discourse community. This includes knowledge of whether the referents belong to the micro- or the macro-world.	the surface structure, the textbase and the situation model
Construal operations	e.g Knowledge of profiling effects of constructions (e.g. heat is travelling vs. heat has travelled) e.g. Ability to recognise item structure as an instance of a prototypical schema (categorization)	

Formal knowledge structures Frames/macrostructures (Fillmore 1985; Van Dijk 1980), 'cognitive genre' (Bruce 2008)	Knowledge of rhetorical purpose	and the situation model

Figure 6.6. A model of linguistic knowledge required of pupils during task

6.5 Klara and Zarif's stimulated recall interview

The analysis of the group writing task in the previous section shows that the pupils recognise and understand that there is a strong association between the phenomenon of heat energy and vibrating particles. After analysing the group writing task, I decided to explore the pupils' (Zarif, Klara and Mahta's) understanding by means of a stimulated recall interview. The interview took place one month after the lesson on 22.04.15 after the Easter holidays and a school trip. Mahta was not present on that day but Zarif (P7) and Klara (P20) were both willing to take part. Both pupils were shown a video recording of themselves carrying out the group writing task and asked to talk about the mental images that passed through their minds as they carried out the task. They were then asked to externalise these mental images by means of a drawing. The transcripts from the interview were analysed using the Text World Theory framework although references to other areas of cognitive linguistics, for example, Langacker's cognitive grammar and metaphor and metonymy will also be referred to.

The interview took place in the school's 'visitor room' close to the pupils' classroom. The video was shown to the pupils on the researcher's laptop as the researcher sat facing the two pupils at one of the tables in the room.

Extract of stimulated recall interview

R: So do you remember you did that you kind of wrote something together ok and I've written ↑what you have said out and I can play you just a little bit (.) until it gets to that painful threshold where you don't want to listen to it any more but if I could play just a little bit back to you. WHAT I'm really interested in is what I reckon when I do something (.)

like that or at least when I do I have a kind of mental picture of what it is that is going on in my head I kind of imagine the rod and the heat and the particles and what I'd like to know if you describe your mental picture to me so how do you IMAGINE the HEAT how do you IMAGINE the particles or do you is there something going on in your mind

P7: I thought there was just a ↑big line with circles inside it that just shake

R: ok ok can I TRIGGER your so I'll play you a little bit and then if you (.) but be honest if you don't imagine anything then don't make it don't make it too much so you know if you don't imagine anything that's interesting too so don't feel you have to please me [laughs] by fabricating some (.)so we'll just I'll play you a little bit

Recording: Teacher: so if you try in pairs to write 10 lines 8 lines to explain to explain something that's what I want you to do I want you to explain using those words up there you understand? You've got about 10minutes to get that done and I want to see a good job. Ok get busy. That means you don't do it by yourself you do it with someone no you're not writing on your own you're not doing any writing at the moment you're just talking about [particles vibrate] what you might write with people in your group you agree a group answer a rough clear group answer go on get busy

P20 he said we shouldn't be writing yet we should be talking about [1.0 inaudible]

R: So when you say heat SPREADS through the ROD wh what do you imagine heat to be doing

P7: The heat would be (.) erm (.)it would move through

R: U-ha

P7: through so I just like imagine it being a red COLOUR then erm (?) then it's going down the rod.

R: And do you visualise the ↑particles at the same time when you think of that what are they doing

P7: So when the red colour hits the particles they just start to shake

R: right ok uha Ok and you think of it in kind of ↑steps maybe the heat spreads through the rod AND the particles start to vibrate it's almost like he says it's like in steps so then the ↑heat and then the particles vibrate is that how you imagine it do you think it's different or

P20: I just imagine the particles like knocking

R: right so you don't think of heat as something (.) separate

P20: shakes head

55 **R:** can I ask you really really quickly just separately don't copy from each
56 other to ↑draw what you imagine it can be a really quick sketch (.) cos
57 we can't spend the whole day doing it so if I put you Karla over here
58 (1.0) and you draw (.) what is in your head. So there's a red pencil and a
59 normal pencil and you Zarif if you do the same there you go

60 (34 seconds P7&P20 drawing)

61 **R:** you can label it if you want (.) so you can say this is (.) the these are the
62 particles if that helps.

63 **P20:** {inaudible]

64 **R:** [Laughs] just draw something and label it paper clip. [Laughs] that's fine

65 **R:** That's probably enough you know that's great

Episode 6.*11* *from Pupil interview 22.04.15. Appendix six, lines 12-65.*

6.5.1 Externalising mental images of text-world

6.5.1.1My roles and the function of talk

During the pupils' interview, my roles were twofold. First, I was a 'listener' and a 'recorder', where I would be noting down (with fieldnotes) and making a recording (with audio-recorder) the events of the interview with the aim to gauge what the pupils believed to be the ontological nature of heat, in other words what experiential knowledge of heat transfer they were entering the interview with. My second role as 'prompter' and 'challenger' (see lines 39-40 and 53) however, was based on the belief that the interview process generated new knowledge. Throughout the interview, the pupils were asked to provide accounts of their mental representations. This process, rather than being a simple act of transfer consists of dynamic interactions between the external representations (presented to the pupils by the interviewer) and the mental representations of the pupils. As Vygotsky observed the act of externalising one's mental images, either through language or drawings, transforms the act itself, which thus generates new knowledge (Wertsch 2001).

In line with this idea is Slobin's thinking-for-speaking hypothesis, which was briefly referred to in section 6.2.2, in which he states that our minds are 'trained

in taking particular points of view for the purposes of speaking (Slobin 1996:91). The act of speaking and considering how to represent our ideas to others causes us to construe phenomena in a particular way. The language we use foregrounds certain semantic domains, whilst making others less prominent (Slobin 2003). Thus, speaking is not a simple act of translating the content of one's mental images into a verbal code but it is an act of transformation, as observed by Vygotsky.

6.5.1.2 Language of pupils describing mental images

The first salient feature of the dialogue between the researcher and pupils is that the pupils are forthcoming in describing their own mental images. The reason could be that they are asked to describe something of themselves, which cannot be judged as being either right or wrong. The pupils, especially Zarif, provide rich descriptive accounts of their mental images. The language Zarif uses to describe these images consists of several everyday terms, e.g. 'I just imagine it being like a red colour (line 43), [the particles] just start to shake (line 47), I just imagine the particles like knocking' (line 52).

During the interview (line 41-47) Zarif describes heat being 'like a red colour' (line 43), which 'move though' (lines 41), 'is going down the rod' (lines 44), 'and hits the particles' (line 47). He chose to use two out of a number of paradigmatic alternatives (travels, moves, goes along/across/down/through) to describe the same cognitive content. As established previously, *heat* is here the figure (or 'trajector') and the *rod* serves as a reference point, base or the ground (or 'landmark'). Both *heat* and the *rod* constitute the 'macro-world'.

By foregrounding *heat* this way, it is construed as a separate entity to the particles, which make up the rod, 'so when the red colour [the heat] hits the particles they just start to shake'. As in the group writing task, Zarif has merged the macro-world of the heat and rod with the micro-world of the particles. However, when the researcher challenges the pupils 'right so you don't think of heat as something separate?'. Klara denies this by shaking her head indicating

that she accepts that heat and vibrating particles are the same thing despite the ambiguity of the language that the implies the converse.

Although the language used during this episode is still ambiguous despite my probing (e.g. line 53), providing the pupils the opportunity to explore their own mental images in this manner, facilitates the process of externalising their implicit thinking. To do this, they need to think carefully about how to represent their thoughts to another person. A salient feature of this episode is the pupils' use of metonymy to represent their mental models. Metonymy is understood here to be essentially a conceptual process, in which one conceptual entity is accessed via another (Radden and Kövecses 1999). It can be expressed in language, for example, 'he is such a hot head'. In this episode, Zarif chooses to use 'the red colour' as the metonym (source concept) for 'heat' (target concept), when asked what he imagines is happening (line 43). This is interpreted as a metonym rather than a metaphor because the class have seen images of glowing metal. In this moment, a joint attentional frame is set up between the researcher and pupil, 'which sets the context for the reading of the specific communicative intentions behind a word or utterance' (Tomasello, 2003: 89). The researcher's use of the word 'imagine' triggers Zarif to shift his perspective to one that foregrounds the visual aspect of heat. This act reflects Warren's observation that 'the essence of metonymy is highlighting' (2002: 123). In other words, Zarif appropriates language to highlight properties of abstract concepts he wishes to foreground to his audience.

Asking the pupils to externalise their thinking verbally, does have some limitations. With this particular example, one limitation of articulating verbally private mental images of the heat transfer process is that the speaker tends to focus on one aspect of the image at a time. Key to understanding the heat transfer process is the ability to conceptualise the process holistically and be able to appreciate the inter-relationship between the separate entities. Expressing this verbally could be challenging for pupils especially when their first language is not English.

6.5.2 Drawing mental images

As stated by Cox (1999) linguistic (verbal) representations tend to be very expressive as frequently the producer of the representation leaves the relationships between the entities unspecified or indeterminate. In text-world terms, the group writing task analysis indicated in section 6.3 that the speakers tend not to mark clearly any deictic shifts that would help firmly establish a new text-world. Stenning and Oberlander (1995) propose that visual representations compel a greater degree of specification. This 'specificity' of visual representations underpins my choice to probe the pupils' understanding in their interview by asking them to draw a visual representation of the mental images in their minds, as they were engaged with the writing task set by the teacher. My aim was to probe and also challenge the pupils into being as specific as they could about the relationship between heat and the particles in the solid to provide more vivid and salient evidence of their understanding of heat transfer.

This method of communicating their ideas in a visual as a diagnostic tool allows its participants the opportunity to 'critique the clarity and coherence' of what they have drawn (Ainsworth et al 2011:1). Furthermore, using visuals in this way underpins much of what cognitive science, including Text World Theory supports, in that the mind makes sense of what it experiences by constructing mental models that are often visual in nature (Giovanelli, 2016, Barsalou, 2009; Bergen 2012, Werth 1999).

After exploring their mental images verbally, Sally decided to probe further by asking the participants to draw an illustration of their mental images. The pupils were told that they could 'draw what they imagined' (line 56) if they wished. They were given a blank sheet of paper and a box with an assortment of pencils, including colouring pencils. The pupils were separated and were not able to see what the other pupil had drawn.

The pupils' drawings become concrete entities that belong to the discourse-world (Giovanelli 2016:33), of the interview, together with the video on the

laptop and the other participants. They become physical objects of that discourse-world that represent, sharpen and assist with the creation and learning of the pupils' text-worlds. The illustrations drawn by Klara and Zarif's were similar in that both pupils drew the outline of a rod and that the

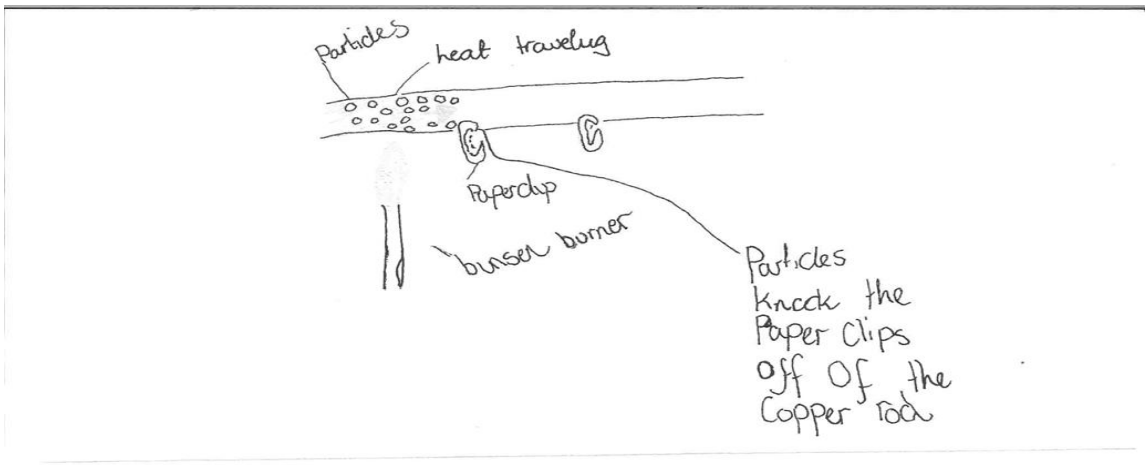


Figure 6.7. Klara's drawing

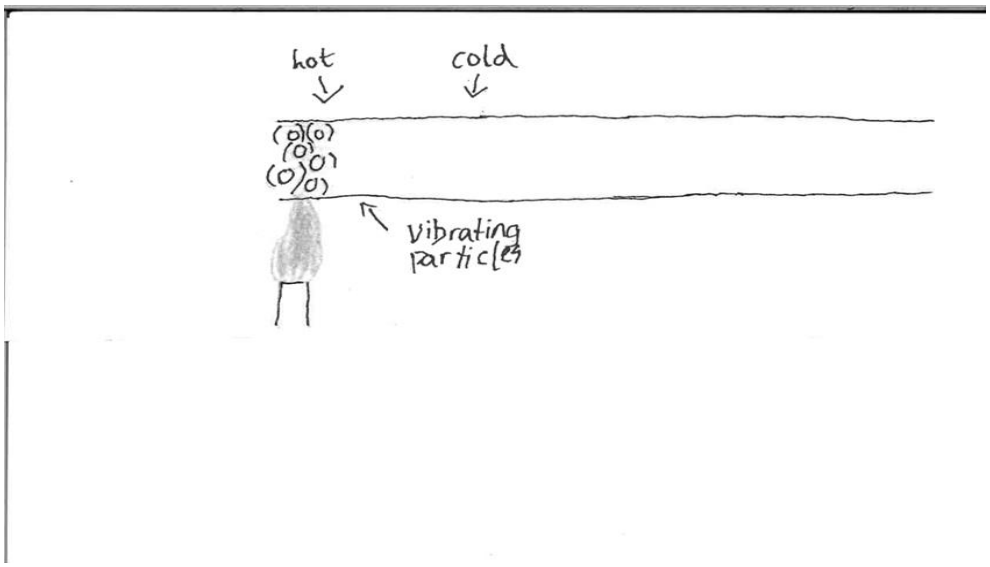


Figure 6.8. Zarif's drawing

rod's particles were represented as small circles inside the rod, which mirrored how the pupils had seen particles previously in the lesson. One striking difference however, between the two drawings was that Zarif decided to show that the 'hot' particles were vibrating by drawing curved

lined around the particles. This is an example of metaphor, in which the lines round the circles (source concept) stands for vibrating particles (target concept), in this particular context.

This extra level of detail was picked up on after the interview when the researcher questioned Zarif about his drawing. In this exchange Zarif said 'they [pointing to the circles/particles] are knocking into each other making the rod hot'. The researcher responds by asking 'do you see heat as something that moves between the particles, then?', to which Zarif replies 'No'.

In sum, this section Part Two B has analysed a stimulated recall interview with Zarfif and Klara, during which they externalise their thoughts and mental images both verbally and with illustrations. The aim of the interview was to probe the pupils' thinking about the ontological nature of heat and to investigate their ability to appropriate the language to represent their thoughts. Finally, also in line with the three themes that underpinned the investigation in this chapter (see section 6.1), it examined the pupils' ability to use metonyms as a foregrounding device.

6.6 Conclusion

The purpose of this chapter has been to examine the ways in which the abstract concepts of heat transfer and heat energy is linguistically represented by a group of pupils in face-to-face interaction, in writing and in visual representations. It first examined the perspectives of myself and the teacher of the pupils' understandings of these concepts and the role language plays in the learning process. Topics emerged from this discussion, which acted as a springboard for part two A and B. The teacher interview was analysed using a text-world approach. The analysis demonstrated the effectiveness of this framework (thesis' third aim) in that it highlighted the different conceptual layers involved during the interaction, during which the two participants provided evidence for their beliefs. The text-world approach effectively and rigorously distinguishes between more and less

credible evidence, thus providing an attractive alternative analytical framework for qualitative discourse analysis of interviews.

The main topics which emerged from the teacher interview were 1) the pupils' linguistic representation of the ontological nature of heat transfer 2) learning of abstract concepts in terms of how they appropriate the language 3) the perceived tendency of pupils to find metaphorical language difficult. All three topics are related to the first aim of this chapter, namely, to examine the ways in which the abstract concepts of heat transfer and heat energy are linguistically represented. A summary of the main findings from part two A and B that fulfil the first aim of this thesis is as follows.

The analysis in part two A and B shows that although it is never possible to determine the pupils' views on the ontological nature of heat with any great certainty, the act of externalising their views to others, in either verbal or image-based form provides the pupils with the space to scrutinise and develop their own text-worlds. The ontological beliefs during the group writing task were expressed more ambiguously, as demonstrated by the macro- and micro- worlds merger analysis (section 6.3), than during the pupil interview, in which the two pupils demonstrated a willingness and ability to construct and represent their thoughts in alternative ways that showed a high degree of specificity. Although there are limitations to what an adult might infer from a pre-adult's representations in an environment, in which there would have existed a certain power hierarchy between the researcher and pupils, both Klara and Zarif denied when challenged that heat was a separate substance to the vibrating particles, which is a viewpoint in line with the scientific one. Part Two A developed Werth's framework by developing his original account of linguistic knowledge, an aspect of the model's discourse-world, thus making the framework more suitable for analysing discourse of learning environments. Although this knowledge is presented in this chapter as a layered system (see table 6.2), van Dijk (1980) reminds us that each layer is subsumed by the next layer to form a network -based process, rather than a system in which each layer operates discretely from each other.

This chapter has demonstrated that there exists a very close correlation between pupils' learning of abstract concepts and language in online situations. Indeed, many of the difficulties the pupils face stems from how well they are able to appropriate the language, in both verbal and visual form, that they had used during the lesson to fulfil the purpose of the task. This seems to suggest that a greater awareness on both the part of the teacher and pupils of how their language choice reflects the way they perceive, and experience the world around them, and how they can use language to reflect what their attention is drawn to, in the real world (see chapter two, 2.6), may help them use language more effectively in the classroom to express their thoughts.

The findings from the analysis in this chapter suggest that the pupils, in fact, do not appear to find using metaphorical language difficult *per se*, but require opportunities in different modes to represent their thinking, using both literal and figurative language to become accustomed to using these forms to represent their ideas in different contexts. That said, more abstract concepts such as *solid*, did appear to cause some difficulties possibly due to it being associated with formal definitions or being less easy to visualise. This chapter has shown that learners need opportunities that allow them to explore the different macro- and micro-text-worlds of the topic at hand, and understand how we indicate to our addressee world-switches between these worlds. Thus, as part of the linguistic knowledge required by pupils established in this chapter, pupils need language used to create and maintain text-worlds.

As pointed out by Piriz (2008), a pervading belief in the field of children's cognitive development is that figurative language and thinking is associated with the advanced stages of cognitive development. Indeed, during the teacher interview, I too felt inclined to hold this belief. After all, the language of science consists of numerous examples of conventional uses of figurative language that pupils find challenging. However, this analysis has demonstrated that figurative language (and thought) is not a competency of adults alone and that pre-adults display the ability to use figurative

language. Zarif's metonymic depiction of hot red metal, in his drawing, was a striking example of how Zarif was able to choose a metonym that effectively reflected his understanding of heat transfer in the context of the interview.

What has emerged from this chapter is that the process of co-constructing and representing their mental images either verbally for a writing task or by using visual representations to others in small group settings, affords a high degree of meta-cognitive awareness. This process of externalising implicit images in a manner, that is intersubjectively understood by members of a group, requires the pupils to think in abstract terms. This observation supports the claim made by Schwartz (1995) that the process of abstraction appears to emerge from representing thoughts to each other.

Chapter 7: Conclusion

This chapter will review and critically reflect on the main findings, evaluate the evidence and outline some of the implications of this thesis. It will start by providing a short overview of the key theoretical and methodological underpinnings of the study. Section 7.2 will draw together the key findings, by providing evidence for each research question. In section 7.3, an outline of the contributions this thesis has made towards both Text World Theory and conceptual change research will be given. Finally, sections 7.4 and 7.5 will discuss the limitations and the implications this study has for future research.

7.1 Summary of theoretical and methodological underpinnings to research

In order to provide a linguistic account of how a group of learners and their teacher are able to think and learn about scientific abstract concepts - phenomena that they have never seen nor touched it was necessary to first explore the two main accounts of conceptual change in the literature: namely, the knowledge-as-theory and the knowledge-as-pieces perspectives. A review of the relevant literature was made, in Chapter 2, of the main social and cognitive processes thought to be involved in bringing about conceptual change in both of these two models: social interaction; learners' ontological beliefs of concepts; models; modelling and metaphor; and finally, metacognitive awareness and understanding. The first part of Chapter 2 concluded by proposing that in order to acknowledge both the dynamic and accumulative aspects of learning abstract concepts, a model of conceptual change that merged elements from both the knowledge-as-theory and knowledge-as-pieces models should be made. It proposed a view of learning that involves a gradual formation of coherent networks of different knowledge elements (i.e. propositional language, image schema, narrative and imagery) over time. As will be outlined in the contributions section 7.3, the findings of the thesis have also implications for evidencing the plausibility of this learning model, in addition to proposing possible

additions, that may have significant implications for both the science education research and teaching community.

I argued in Chapter 2 that a cognitive approach to understanding language and meaning appears to be a suitable one to investigate conceptual development, as it acknowledges that our knowledge about language is a product of our interactions with the social and physical world, and is therefore derived from and informed by the language we use. These are important points, as I established in Chapter 2 that conceptual development in the science classroom involves both a learner's social interaction and their interaction with external models in the physical environment (e.g. visuals, apparatus of a demonstration) (Amin et al. 2015).

In Chapter 2, I rationalised my choice to adopt a cognitive discursive approach, namely the Text World Theory framework, as it offers a seemingly suitable model to describe and explain how the classroom processes are involved in conceptual development. It provides a means of tracking the moment-by-moment developments in addition to establishing a plausible account of how the online dynamic structures (text-worlds) accumulate over time to become more stable knowledge frames.

In line with the experiential realist position that underpins the text-world approach, I outlined how the research paradigm, which guided my investigation, was a critical realist approach. I explained my rationale for adopting this position by describing how throughout my investigation, I assume that there exist independent structures (e.g. private thoughts, heat energy, atoms) in a classroom environment, which become accessible to myself an active subject, the researcher, only though my subjective construal of them. I highlighted that as the purpose of my investigation was to examine the various structures and processes, and provide an account of how they interact during the conceptual development process, a longitudinal case study, with a predominately qualitative naturalistic inquiry approach, allowed me to gain proximity to the complex world of human experience in a classroom setting that I was investigating. I argued that a longitudinal

approach was necessary as a prolonged engagement with the classroom environment meant that the phenomenon under investigation, namely, conceptual development, was more likely to manifest itself as it afforded an in-depth understanding of the context of the classroom dynamics and the syllabus.

As I rationalised in Chapter 3 that gaining multiple perspectives on a learning event would strengthen the credibility of the investigation (Guba, 1981; Barbour 1998; Healy and Perry 2000), I adopted research methods that allowed me to incorporate the perspectives of both the teacher and pupils. I therefore included stimulated recall sessions and interviews with both the teacher and small groups of pupils focussing on specific learning episodes recorded in a previous lesson. Finally, in section 3.8, I explained how I ensured scientific trustworthiness of the study, concluding that the quality of the analysis was achieved by ensuring that the analysis of the transcribed data of the classroom discourse and interviews was 'rigorous, retrievable and replicable' (Simpson 2004:3).

7.2 Summary of findings and implications

The following sections 7.2.1- 7.2.3 will summarise the main findings of this study, by looking at each chapter in turn, in relation to the thesis' three research aims:

1. To examine the ways in which the abstract concept of heat energy (and related concepts) is constructed and linguistically represented by a group of learners and their teacher in a secondary school setting.

2. To examine the ways in which the Text World Theory framework can be applied to the analysis of the development of abstract concepts in discourse.

3. To examine the effectiveness of the Text World Theory framework for exploring the development of abstract concepts in a school environment.

Although the following summary of the findings is organised according to these three research aims, the interconnected nature of the aims means there is inevitably a small overlap between the findings of each question.

7.2.1 Linguistic representation of abstract concepts (research aim one)

The following will outline how the scientific abstract concepts of *heat, temperature, heat transfer, conduction* and *an insulation* were linguistically represented using the Text World Theory framework, which opened the possibility to track the conceptual development of these abstract concepts by a group of first year secondary pupils together with their science teacher. During the five short episodes, in Chapter 4 (4.1-5), the concepts were either introduced, or re-introduced into the discourse. Prior to introducing the terms *heat transfer* and *conduction* into the discourse in section 4.3 the teacher and pupils first built text-worlds depicting parts of the *concrete* here-and-now world of the apparatus of the demonstration that the teacher wished to foreground, using the deictic and referential elements supplied by the discourse. First building a mental representation of the immediate concrete world that the more abstract world can be hooked onto appears to be a necessary step in the concept building process, whose significance is further supported by the claim made by Schwanenflugel (1991) that abstract concepts require a situational context to give them meaning.

During the course of the demonstration, the participants constructed and managed multiple mental representations, including epistemic modal-worlds. It was shown how hypotheticals introduced the pupils' background knowledge into the discourse. For the pupils to make sense of the situations, hypotheticals were created (sections 4.3.5, 4.4.3 and 4.5.3), that triggered a blend of two input spaces, one anchored to the discourse-world, such as the apparatus and the other from the pupil's memory. Section 4.3 further demonstrated how the language used to refer to the concept of *heat energy* and *heat transfer* in this context, in addition to the shape of the apparatus, situated in the discourse-world, appeared to evoke the SOURCE-PATH-GOAL image schema. This was significant in providing evidence for how abstract concepts develop in discourse as it played a key role in the concepts'

dynamic construction, and metaphorical representation of the participants' ideas to each other within the group.

The text-world analysis in Chapter 4, provided further evidence that other image schemas (or p-prims in conceptual change theory) appeared to structure much of the discourse and play a role in foregrounding elements (e.g. **heat** moves along the rod) that the teacher wished that pupils to pay attention to. For example, in addition to the SOURCE-PATH-GOAL schema during the demonstration, the CONTAINER schema featured strongly during the lesson on insulation. The qualitative analysis throughout this chapter demonstrated the fluid nature of these schemas, which appeared to evolve and shift over time depending on the purpose of the exchange. Section 4.4.5 provided a striking example of how, within the context of the interview, the form of schemas evoked were heavily influenced by the task set, and how my interpretation of the responses, was influenced by the context. This supports Kimmel's observation that although image schemas have a stable quality to them they are also fluid and dynamic susceptible to the constraints of the sociocultural context (Kimmel 2005:297).

Noteworthy is how the concept of insulation was linguistically represented in discourse as the pupils applied their understanding of the concept to a problem-solving task in Chapter 5. Interestingly, the concept of *insulation* was not referred to by the lexical item 'insulator' until line 264. The linguistic analysis demonstrated how the ability of the pupils to carrying out the problem-solving task seemed to depend on their understanding of the concept that was expressed in language that resided in the pupils' encyclopedic linguistic knowledge of heat energy, heat transfer and insulation. Evidence for this was provided in section 5.7, when P1 referred to the thermal properties of a jacket in 'if the jacket was warm'. One further feature of the language, also demonstrated with this example, was that its ambiguity appeared to act as a catalyst for the pupils' conceptual thinking during the problem-solving activity. This supports claims made by Nerlich and Clarke 2001, Littleton and Mercer 2013:9 that the ambiguous nature of

language can act as a tool to provide new perspectives, thus, encouraging conceptual development amongst the pupils.

Despite the micro analytical approach to investigating my data, I claim in Chapter 6 that it is often difficult to determine the pupils' understanding of the ontological nature of heat with any great certainty. Much of the pupils' language during the group writing task was ambiguous in that they used the figure-path-goal construction, in which heat was represented as a moving figure, thus construing heat as an independent structure from the rest of the apparatus. Furthermore, as the pupils do not indicate a clear world-switch between the macro- and micro- levels (6.2.2), the receiver of the message could interpret *heat* as being the cause of the vibrating particles. During the interview, due to my probing and giving the pupils the opportunity to draw illustrations (figure 3 and 4), Klara and Zarif had the chance to review and clarify their understanding of the heat transfer process. Zarif used several different paradigmatic alternatives to 'heat travels along'. He described heat being 'like a red colour', which 'moves though', 'is going down the rod', 'and hits the particles'. These alternatives are significant as, I argued, they offer a glimpse into his own perspective and acted as a means of externalising his own implicit thinking. Zarif further demonstrated his ability to use metonymy effectively as a means of foregrounding aspects of heat he perceived to be important in line 36 e.g. 'the red colour' (source concept) for 'heat' (target concept), when asked what he imagines is happening, thus reinforcing Warren's point that 'the essence of metonymy is highlighting' (2002: 123).

7.2.2 Application and adaptation of Text World Theory framework

Although already referred to in the previous section, the following will provide further details of how the Text World Theory framework was used and adapted to carry out the analysis. In all three analysis chapters, the Text World Theory framework was used to analyse the transcripts of both the lesson and the interviews with the pupils and teacher. In all the analyses, the text-worlds created were the result of face-to-face interactions between either two participants, as in the teacher interviews, or between participants

working in small groups or in larger groups, as in the whole class analyses, thus contributing to the recent interest by text-world theorists to apply the model to spoken discourse. The participants were either interacting with texts, visual diagrams and illustrations or with physical objects that all formed part of the participants' discourse-worlds. Each chapter adapted the text-world framework in some way to explore a particular salient feature of the text. To gain a further insight into how the text-world framework has been applied, the follow will examine some of the main adaptations that this thesis has been to the original framework.

Brandt's (2005) adaptation of Fauconnier and Turner's Conceptual Integration Theory (1998, 2005) was integrated into the text-world analysis of how the pupils blended mental input spaces to create new knowledge, in Chapter 4. In section 4.3.5, 4.4.3 and 4.5.4, I demonstrated how the discourse evoked a blended world. The application of this framework to the purposeful, pedagogical context of the classroom was useful as it revealed the importance of the context, represented by the discourse-world, in determining the potential elements of the input spaces which could be projected into the blend. The analysis provided a means of identifying potential areas of confusion for the pupils.

As epistemic modality featured strongly during the discussions in Chapter 5, the epistemic modal-worlds created by the participants during the class discussion (section 5.6-7) and during two small group discussions (5.4 and 5.9) were examined. Integrated into the text-world analysis was Nuyts' model (Nuyts 2001) of epistemic modality. I argued as this model has an intersubjective dimension, in that it can show other members of the group how we wish our propositions to be understood, it integrates well into the text-world framework, especially during the analysis of face-to-face interactions. More specifically, it was used to analyse the predicate *I think* during group work. The resulting analysis showed that despite the predicate's multifunctionality, a salient feature of the item is that the speaker, a participant in the discourse-world, assumed a degree of

responsibility for what they said. I claimed, from a text-world perspective, the predicate appears to 'peg' the discussion into the discourse-world.

In all three analysis chapters, the text-world framework was applied to the analysis of the interviews between myself and the teacher and pupils. A central feature of the interviews was the stimulated recall, which introduced past scenes from lessons that the participants had experienced. The Text World Theory framework was applied to the analysis of the multi-layered structure of these interviews (see figure 5.4 text-worlds of stimulated recall interviews). This approach is built on previous work by van der Bom (2015) who first applied the framework to a series of face-to-face interviews. The text-world analyses of the interviews recognised how the discourse-worlds of the lessons became the text-worlds of the interviews and that the ontological status of these worlds was different (i.e. some seemed 'more real' than others).

7.2.3 The effectiveness of the framework

The previous section highlighted some noteworthy applications and adaptations of the text-world framework in this thesis. The following will critically evaluate the effectiveness of this framework, which from a theoretical perspective, offers many attractions for providing evidence for how a group of learners linguistically represent abstract concepts.

The Text World Theory framework proved to be well-suited to the task of providing a fined-grained analysis of how abstract concepts are constructed and linguistically represented in discourse. By adopting a cognitive discursive model, such as the text-world approach, that acknowledges both the social, physical environment and psychological aspects of the participants with its 'discourse-world', I set out to undertake a fully contextual approach to analysing language use. One useful feature of the framework is that it enables the analyst to track the events as they took place over time and space, showing how concepts emerge over time and in different spatial settings (e.g. Chapter 4 section (4.2). With the framework I was able to analyse the physical (e.g. demonstration) and social aspects of the

participants' discourse-worlds (e.g. Chapter 5 group work) and the evolving conceptual spaces or text-worlds. One prominent aspect of the analysis was that it showed the close interdependent relationship of the formation of the abstract concepts with the concrete conceptual world of here-and-now. This was well illustrated in section 4.3, when the teacher and pupils first built text-worlds depicting parts of the apparatus of the heat transfer demonstration that the teacher foregrounded by using the deictic and referential elements supplied by the discourse, thus providing some evidence for the ontology of abstract concepts and the processes involved in the development of abstract thought.

Furthermore, the Text World Theory framework acknowledges the complex relationship between language and other cognitive faculties, such as memory, perception and attention. The text-world approach holds the position that language both constructs thought, but also according to cognitive linguistic principles (Lakoff and Johnson 1980, 1999) reflects and represents the cognitive processes of the learner. This perspective on language, that in the literature is referred to as experiential realism (Lakoff and Johnson 1980), allows for the analysist to examine how abstract concepts both emerge and are represented in discourse, making it a particularly suitable framework for this thesis. These aspects of the model were shown to play a crucial role in the conceptual development process throughout the analysis, but featured particularly predominantly during 1) the problem-solving task in Chapter 5, when the pupils drew on their own experiential knowledge, 2) during the pupil interviews, when Rose and Sanja (5.12.1) draw on their 'clothes' schema to make sense of the task and 3) during the interview with Klara and Zarif, when they used illustrations to foreground elements of their mental representations. This interdisciplinary outlook of the text-world model made it an interesting framework for opening avenues to explore the relationship between language and conceptual thinking in classroom contexts.

In addition to the discourse-world level of analysis, the text-world model also allowed for a close examination of the construction and interplay of different

conceptual worlds, set up through temporal and spatial shifts, as well as modality and metaphor, that were shown throughout the thesis to be prevalent in the learning of science. The model provided a necessary, plausible and rich account of the cognitive architecture of the mind during the learning of scientific concepts.

Noteworthy, was the interview of two pupils, Rose and Sanja, to find out how they interpreted the past events of the classroom, by means of a stimulated recall task to probe their understanding of the conceptual content of the learning episode. I showed how the two pupils drew on their own past memories, (remote text-worlds), to talk about their understanding of the snowman task. The effectiveness of the framework was demonstrated by examining the extensiveness of the metaphorical CONTAINER and SOURCE-PATH-GOAL image schemas throughout Sanja and Rose's reasoning process. Although both pupils drew from their own experiential knowledge frames, Rose's response showed she was able to draw on a wider range of information than Sanja, to make sense of the situation. The text-world interpretation showed how for these two pupils, their immersion in the realities of the text-worlds, created during the lesson and interview, did not always trigger the need to consider information beyond what was immediately present.

The text-world approach to analysis effectively demonstrated that the ability to problem solve, in this context, appears to depend on the pupils' ability to manage several text-worlds at once and build text-worlds from sources of information that the teacher (and researcher) do not explicitly give. The analysis indicated that although being able to immerse oneself in a text-world is a necessary part of the problem-solving process, an over immersion does not encourage the pupils to take an outsider perspective and view these worlds more objectively. Furthermore, the text-world approach appears to show that although the pupils' reasoning was grounded in their use of image schemas, their ability to solve the task required them to restructure these schemas in a way that would lead to a conceptualisation of the coat as an insulator. This latter observation, derived from the text-world analysis seems

to support the knowledge-as-pieces view of conceptual change that conceptual development involves a reconfiguration of knowledge networks.

The effectiveness of the framework was further shown during the teacher's interview in Chapter 6. The text-world analysis demonstrated that the interview was not only steered by my own beliefs but also those of an experienced teacher. The analysis demonstrated the suitability of this framework for face-to-face interaction in that it highlighted the various conceptual layers present during the interaction in which myself and Mr Dalel provided evidence for our beliefs. The text-world approach convincingly distinguishes between more and less credible evidence, by acknowledging the different ontological statuses of the discourse-world shared by both participants of the interview discourse-world and the text-worlds that evolve during the discussion. The text-world analysis allows for an exploration of the credibility and trustworthiness of the evidence in terms of degree, depending on, I argued, the extent to which the worlds are accessible or not to the other participant, either in terms of where and when they were situated in relation to the discourse-world of the interview, the perceived status of who gave the evidence and finally in terms of the familiarity of the enactors and situations described in the text-worlds to the other participant.

7.3 This study's contribution to research

It is hoped that this study has made some contribution towards both Text World Theory research and conceptual change research. As far as I am aware, this is the first time that the Text World Theory framework has been applied to a classroom setting to investigate abstract thought and concepts in this way. One of the main contributions this thesis makes towards the theory is the application of the model to a multimodal setting, such as the classroom, in which multiple participants engage in learning. This builds on previous work that has applied the Text World Theory framework to face-to-face situations (Whiteley 2010; van der Bom 2015). With its ability to link the fine-grained micro linguistic analysis to the broader social, physical and psychological contexts of the classroom it offers an exciting new approach to the existing field of classroom discourse studies. With regards to its

application to the study of the learning of science, I indicated in Chapter 2 that the text-world framework sits well with and complements existing frameworks within the socio tradition, namely, Mortimer and Scott's (2003) socio-cultural framework, Halliday's model of social genre and register (Seah et al. 2011). In fact, this thesis uses Mortimer and Scott's framework to provide an overview of the lesson and the teaching purposes of the episodes in Chapter 4, before commencing with the micro analysis of discourse revealing the cognitive architecture of the participants' minds. As the text-world framework is characterised by its ability to track and explore a multitude of conceptual worlds established through spatial and temporal shifts, as well as modality and metaphor, it offers the conceptual change researcher the possibility to observe how concepts emerge and develop under the influence of all aspects of discourse, not only that of metaphor (e.g. Amin 2008; Deignan and Semino 2017).

Specific contributions to the Text World Theory framework include its application to the writing process, in which learners are required to conceptualise at both the macro and micro level (see 6.2.2). Applying the framework highlights the importance of the pupils' language to indicate conceptual shifts to each other, thus avoiding unnecessary ambiguity. Further elaborations to the theory include the incorporation of Nuyts' (2001) socially-interactive model of epistemic modality into its framework. And finally, in Chapter 6 I developed an aspect of the framework's discourse world, namely the linguistic knowledge component.

This study set out to describe and explain the processes that bring about conceptual development amongst secondary pupils in a science lesson. Chapter 2 proposed a model of learning that involved a gradual formation of coherent networks composed of propositions, image schemas and imagery. This section will briefly review this conceptual change model in light of the findings of this study and propose how this study brings fresh insights to this proposed model. The fine-grained analysis of the learning interactions and processes established that there were indeed instances when the propositional language, image schemas and imagery served to structure and

represent the pupils' conceptual thinking. In section 4.5. I examined how Mr Dalel, by writing a highly abstract, semantically dense propositional statement *conduction is the process where heat is transferred through a solid* on the board signaled to the pupils an important point that needed to be remembered. I demonstrated by unpacking the proposition how it represented much of the learning that had taken place during the demonstration and Simulated-Role-Play. Aware of the abstract nature of the word 'process', Mr Dalel further supported the pupils' understanding of the language by drawing on an analogy of the process of making a bowl of cereal. Thus, as claimed in section 2.4, propositional language does indeed appear to play an important role in the conceptual development process, serving as a placeholder, which can gain meaning by being interpreted through basic conceptual structures such as image schemas (SOURCE-PATH-GOAL), in addition to other models and analogies (Carey 2009).

Throughout Chapters 4,5 and 6, I demonstrate the central role of image schemas (p-prims) in structuring and representing the participants' abstract concepts. A central claim of the knowledge-in-pieces model of learning is that conceptual development involves a gradual realignment of these image schemas. This study strongly suggests that this realignment depends on the pupils being able to apply and interpret the image schemas that they use. There are instances when the image schemas are applied in a productive way that develops the pupils' conceptual understanding (e.g. during the demonstration) but there are also instances when the use of the image schemas leads to misconceptions. An example of this is during the pupil interview (Chapter 5), when Sanja suggests that the jacket is the source of heat, and not the sun. So, although Sanja correctly evokes the SOURCE-PATH-GOAL image schema in her reasoning, she has not applied it appropriately to the problem-solving task. Similarly, the use of the pupils' imagery to recall either past events (e.g. in Chapter 5 when Rory recalls building a snowman with his cousin) or image future ones (e.g. when the pupils are required to imagine what will happen to the Vaseline during a demonstration), provided input necessary for the reasoning process to take place. However, as many of the images of the pupils are evoked from past experiences that take place

outside the classroom, pupils need to realign them to fit in with the learning at hand.

Most significantly perhaps, this study establishes the key role that language plays in this conceptual development process. Indeed, the pupils' understanding of the concepts expressed in and through the propositional language, image schemas and imagery can only develop with an awareness and sensitivity towards the language used in the classroom. The cognitive discursive analysis demonstrated that in addition to the propositional language that they engage with, the image schemas and imagery that are evoked, a key component of any conceptual development process must also be the linguistic knowledge (see Figure 6.6) that the participants bring to the learning situation. Chapter 6 extends Werth's original linguistic knowledge framework by developing a model that is more suitable for classroom contexts.

One area of conceptual change research that was not explicitly dealt with in this study was the pupils' meta-cognitive awareness of their own learning process. One notable claim of conceptual change research is that pupils' meta-cognitive awareness promotes and accelerates conceptual development (see section 2.3.4). In Chapter 6, I propose that many of the challenges the pupils face stem from their ability to appropriate the language in verbal, written and visual form. As I argued for the central role that language plays in the development of concepts, it would be reasonable to suggest that further exploration of both the pupils' and teacher's meta-cognitive awareness of language would be a fruitful area of investigation.

7.4 Limitations

It is important to mention the limitations of this study, in which there were a number of challenges faced both during the data collection stage and later during the analysis.

With regards to the data collection, my role as a guest researcher to the school meant that I needed to ensure that my presence did not disrupt the

lesson unnecessarily or interfere with the pupils' learning. My presence in the classroom and the weekly extraction of small groups of pupils from the first ten minutes of each Wednesday morning's class had an undoubtable effect on the learning environment and therefore the research process. My presence could never be fully eliminated. I mitigated the effects of this by responding sensitively to unexpected changes with the time table, maintaining communication links with the teacher both briefly before the lesson and by email, in addition to adhering to a rota, that ensured the pupils took it in turns to be interviewed. Seeing each pupil for a short time meant that it was not possible to track individual changes in developmental understanding in great depth. An improvement to the study could have been made if two to three pupils had been interviewed more frequently over the four-month period of investigation. However, from an ethical perspective this is problematic as it would mean treating them differently from the rest of the class.

Furthermore, the analysis could have been strengthened by having more details about the individual pupils' backgrounds, in particular their linguistic backgrounds. Several of the pupils were bilingual and having a greater understanding and appreciation of the other languages known by these pupils would have provided me with a wider knowledge base when interpreting the data, especially when interpreting the responses from Julien and Suzy (both Mandarin speakers).

Adopting a flexible approach to interviewing the pupils and Mr Dalel that involved, for example, a stimulated interview provided me with an alternative method to collecting data than the standard semi-structured interview. In the earlier stages there were some occasions when I needed to wait longer for the participants to respond, rather than responding to my own questions to fill a pause. My interview technique did, however, develop with time, and consequently I was able to gain some interesting and rich insights into the participants' perspectives.

There were also certain challenges involved with using the text-world analytical framework. The first is reflected in my decision to map out in Chapter 4, the socio-cultural aspects of the classroom using alternative frameworks than the text-world model. This indicated a possible weakness in Werth's framework, particularly with regards to the discourse-world, which encompasses the mental faculties of the language users, including their hopes and intentions during communication. The intention of the teacher in the lesson is taken here to be the pedagogical purpose of the learning event, determined by myself through discussions I had with the teacher. This understanding is derived from both Mr Dalel's and my own engagement with the curriculum and syllabus outlined in section 3.6. Thus, the teaching purposes were also shaped by social factors beyond the micro-world of the immediate classroom and were shown by my socio-cultural analyses (see for example 4.2.1 and 4.3.1). Although this approach allowed for some exploration of how the social dynamics feed into and formed part of the discourse-world, a more robust model would be welcome.

One further aspect of the text-world model was that at times it was not always possible to deal with multiple meanings, especially in relation to the participants' epistemic stance (see Chapter 4 analysis of 'does anyone know what metal this is?' p19 and Chapter 5: 5.4). As the framework tends to focus on referential meaning, the illocutionary force of many of the statements could only be tentatively inferred by examining the social context.

Another feature of the text-world framework that needs to be noted is that despite its suitability for tracking events as they unfold over time, the very nature of the analysis has consequences for how much of the original data I was able to analyse and include in this thesis. Text-world analyses tend to be very detailed and consequently I was only able to include a small proportion of all the data I had collected. This meant that I could only describe and explain the development of the participants' conceptual thinking over a relatively short space of time. Despite this, the unit of learning chosen offers a coherent insight into the pupils' thinking. Although there is a large amount of data that has not been included in this thesis, the

prolonged engagement with the class over the four-month period allow me to become very familiar with the classroom context, which was crucial for the analysis process. Furthermore, as the analysis requires close attention to the microstructures and dynamics of the interaction, it is easy to lose sight of any diachronic changes that occur over stretches of time longer than a few minutes. By applying a small-scale corpus tool of the classroom language in Chapter 6, it became possible to note the use of the linguistic structures in focus over the period of a lesson, which went some way towards incorporating more rigor and depth to the analysis.

7.5 Future directions

The main aims of this thesis are to provide a cognitive discursive account of how abstract scientific concepts develop during a series of learning events and to evaluate the effectiveness of the Text World Theory framework for this purpose. The results of this thesis point towards further directions for research that will now be elaborated on.

It is hoped that this study has contributed towards a clearer understanding of the role language plays in bringing about conceptual development amongst a group of secondary school learners in a science lesson. Due to time constraints it was not possible to analyse all the data I had collected on the pupils' learning of energy but also other scientific concepts, such as life. There exists the possibility therefore to explore my data further, adding to our understanding of this process in different learning situations (e.g. reading) that have not been covered in this thesis. As different sub-topics in science require the understanding and application of different abstract concepts, it would be interesting to carry out similar investigations of how pupils acquire not only the abstract concepts of physics, but also biology and chemistry, not only during the first year of secondary school but at different age levels too. The approach taken in this thesis could also be applied to different subject areas, as all academic disciplines require learners to think abstractly.

Considering the cultural and linguistic diversity of many classrooms in the UK, it would also be interesting to investigate how pupils' linguistic knowledge other than English affect the conceptual developmental process. Recent developments in the field of second language acquisition in the classroom acknowledge the importance of multilingual learners' first language(s), in the learning process (Garcia and Li Wei 2014). The approach adopted here could make a significant contribution to this field, as it would focus on *how* multiple linguistic knowledge(s) form part of these pupils' discourse-worlds and subsequent text-worlds.

Further investigation of this process from a cognitive linguistics perspective would appear to offer both researchers and teachers important insights into the nature of the conceptual development processes. More specifically, further investigation would provide research informed practitioners more knowledge about how the language of the classroom can be optimally structured to afford conceptual development. As previously indicated, further knowledge about the extent to which teachers' knowledge about language (KAL), in particular from a cognitive linguistics and usage-based perspective, impacts on the pupils' understanding and application of abstract concepts would be a very fruitful area of investigation.

This thesis has set out to develop our understanding of how we are capable of learning about scientific phenomena that we are not able to directly detect through our senses. In so doing, it has investigated how a group of learners construct and linguistically represent the abstract concept of heat energy by applying and extending Werth's original text-world framework to the language used during a series of learning episodes. It is hoped that the knowledge gained from this research may inform both researchers and practitioners by providing a more enabling model of language that can be used when thinking about and doing science.

APPENDIX A Transcript conventions

Transcription conventions:

↑↓	Arrows indicate marked shifts into higher or lower pitch after the arrow
WORD	Upper case indicates increase in volume
?	Question mark indicates a raising intonation
.	Full stop indicates stopping fall in tone
::	Colons indicate prolongation of sound
[]	Square brackets indicate overlap
(.)	Short pause
(3.0)	Pause of 3 seconds

APPENDIX B List of can do statements on Heat and Light

(See chapter 3)

List of can do statements at front of pupils' booklet on Heat and Light

Heat and Light

At the end of this topic you will be a successful learner if you can:

1. Distinguish the difference between heat and temperature
2. State that heat flows through a solid by conduction
3. Explain conduction in terms of vibrating particles
4. State that a material which lets heat flow easily through it is a good conductor
5. State that a material which does not let heat flow easily through it is an insulator
6. State that air is a bad conductor of heat and is used for insulation
7. Give examples of good heat conductors in the home
8. Plan and carry out an investigation to determine which materials keep a container of water warm for the longest time
9. State that heat flows through liquids by convection currents
10. Give everyday examples of convection currents
11. Explain convection currents in terms of density
12. State that heat flows through gases by convection currents
13. State that heat is transferred in straight lines in all directions by radiation
14. Measure the change in temperature due to heat loss by radiation from dull and shiny surfaces
15. State that heat rays are also known as infra-red rays
16. Give examples of infra-red radiation
17. State that light travels in straight lines
18. Use in context the terms normal, angle of incidence, angle of reflection, refraction and angle of refraction.
19. Measure the angles of incidence and reflection
20. Measure the angle of incidence and refraction
21. State that a spectrum is produced when white light is passed through a prism
22. Identify the colours of the spectrum and the order in which they appear

APPENDIX C Data Collection Log

(see Chapter 3)

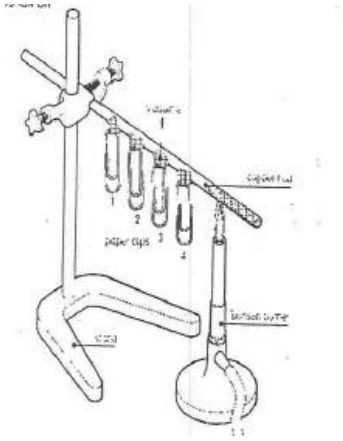
Date	Lesson	Data Collected	
26.01.15	Revision Chemistry Matters	T & G recordings	
2.2.15	1. The Microscope	T&G recordings	
4.2.15	2. The Microscope	T&G recordings , two interviews with pupils; interview with teacher	
5.2.15	3. Onion Slide (Life characteristics)	T&G recordings, audio group	
16.2.15	4. Plant and Animal Cells	T&G recordings	
18.2.15	5. NO PUPILS (Chinese NY)	Teacher interview	
23.2.15 (Monday)	6. Cutting out cell diagrams	T recording	
25.2.15	7. Cell models (sweets)	T&G recording, pupil interview	
26.2.15	8. Cell specialization	T&G recordings (group poor quality)	
2.3.15	9. Reproduction	Group audio	
4.3.15	10. Reproduction	Pupil interview, T interview Pupils' writings on 'A cell is specialized because'	
11.3.15	11. Revision lesson before test (Thurs)	1. audio 2. Group/T video (sound off)	
18.3.15 Unit two	12. Conduction	1. pupil interview (on test and text book materials) Teacher video* Group video Group audio (writing)* Interview with teacher on tests	
25.03.15	13. Insulation	1.Pupils stimulated recall	

		interview (on rod demo) T&G videos, group audio T interview (audio)*	
1.04.15	14. Insulation conduction	1. pupil interview on snowman T&G video	
22.4	15. Convection	Group/T video Pupil stimulated recall T interview	
29.4	16. Radiation	Pupils interview on convection and problem solving)	

APPENDIX D End of unit test question on Heat Transfer

End of unit test question on heat energy and transfer:

During an experiment Matthew finds that when the end of a copper rod is heated the Vaseline melts and the paperclips fall off



Describe how particles of the solid copper rod carry the heat energy (2)

Teacher's response in interview 18.03.15

'What I would say was that the copper rod carries heat energy. The copper rod is made of particles, packed quite closely together. When one end is heated, the particles in the solid vibrate more quickly. These particles collide with the others, which then vibrate more quickly, and that's the way heat energy is transferred. That is what I would have written.' (from interview 18.03.15).

APPENDIX E Sample ethics Plain Language Statement and Consent form

Plain Language statement to parents:
An Investigation of Teacher and Pupil Reflection on Learning in a Science Classroom
Researcher: Sally Zacharias at the School of Education, University of Nottingham

Dear Parents and Carers of S1 pupils,

Your son/daughter is being invited to take part in the above research project. Before you decide whether to allow your son/daughter to participate it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

I am currently employed with the School of Education, University of Glasgow and am a qualified science teacher. As a doctoral researcher (with Nottingham University), I am investigating the relationship between talk and learning in a secondary science classroom. Part of my research will involve finding out what both the teacher and the learners consider to be successful learning. Your son/daughter has been chosen to participate in this project because he attends a local school in Glasgow and their teacher has several years of classroom experience. Not only will the research will provide valuable information for teachers on teacher training courses, but it should also promote a positive learning culture in your son/daughter's lessons, as well as support your son/daughter's language development.

The study would take place during spring 2015 and it is estimated that it would involve me observing lessons over a three month period. I would ensure, with Mr XXXXX, that there would be no disruption to your child's learning. The pupils will be asked to contribute in the following way, if you agree to their participation. They would be video-recorded during each lesson and asked to respond to the lessons by means of a short questionnaire and would be invited to a few short interviews (max. 15 mins). These will be held on the school premises, such as a classroom. I would occasionally ask some pupils to have their written work photographed.

I intend to protect the teacher's, the pupils' and the school's anonymity and the confidentiality of the responses to the fullest possible extent, within the limits of the law. Their names and will be kept in a separate, password-protected digitalized computer file from any data that they supply. In the final report, the teacher and the pupils will be referred to by a pseudonym. We will remove any references to personal information that might allow someone to guess their pupils' identity. I have received a full Disclosure and Barring check.

Once the thesis arising from this research has been completed, a brief summary of the findings will be made available, by myself upon application. It is also possible that the results will be presented at academic conferences and journals. However, I will ensure that no images of the children will be put in the public sphere. The data will be kept securely for seven years from the date of publication, before being destroyed. Please be advised that your child's participation in this study is completely voluntary. Should your child wish to withdraw at any stage, or to withdraw any unprocessed data they have supplied, they are free to do so without prejudice. If you would allow your son/daughter to participate, please indicate that you have read and understood this information by signing the accompanying consent form and returning it in the envelope provided.

Kind Regards,

Sally Zacharias PGCE, MA



PARENTS' CONSENT FORM

An Investigation of Teacher and Pupil Reflection on Learning in a Science Classroom

Researcher's name: Sally Zacharias

Supervisor's name: Dr Philip Hood and Dr Jane Evison

- I have read the Participant Information Sheet and the nature and purpose of the research project has been explained to me. I understand and agree for my son/daughter to take part.
- I understand the purpose of the research project and my son/daughter's involvement in it.
- I understand that I may withdraw from the research project at any stage and that this will not affect my status now or in the future.
- I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.
- I understand that I will be audiotaped / videotaped during class time and interviews.
- I understand that data will be stored in a secure location on the researcher's personal computer. Only the researcher will have access to the files via a personal password.
- I understand that I may contact the researcher or supervisor if I require further information about the research, and that I may contact the Research Ethics Coordinator of the School of Education, University of Nottingham, if I wish to make a complaint relating to my involvement in the research.

Signed …… (parent/carer)

Print name …… **Date** ……

Pupil's name ……..
Contact details

Researcher: *Sally Zacharias ttxsz8@nottingham.ac.uk*

Supervisor: *Dr Philip Hood and Dr Jane Evison (Philip.Hood@nottingham.ac.uk; Jane.Evison@nottingham.ac.uk*
School of Education Research Ethics Coordinator: educationresearchethics@nottingham.ac.uk

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