THE BELIEFS, PRACTICES AND DEVELOPMENT OF THREE TEACHERS OF SCIENCE IN THE PRIMARY SCHOOL

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Abstract

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This thesis explores the beliefs of three teachers about effective primary science practice, and the ways these develop in the context of a climate where there are few school resources for primary science training.

The research proposes a new theoretical model combining Lave and Wenger's communities of practice (1991) with Bourdieu's science capital social theory (2004) to explore the impact of science knowledge, culture and science social contacts on the development of beliefs about science, science teaching and the teachers' position and agency in the school to enable learning from others.

A case study methodology was used, with three local primary teachers, employing participative observation and semi-structured interviews to gather data on beliefs on primary science and professional development. The data was evaluated using thematic analysis.

The three teachers identified a range of beliefs about effective teaching strategies in primary science, including enquiry, linking ideas to observables in activities and dialogic learning approaches which appeared to be influenced by each teacher's type and amount of science capital.

There appeared to be little science expertise or CPD in schools, to support science teaching especially during the first years when teaching strategies are established. Some teachers were not part of any external 'community of practice' and found online resources unhelpful for developing pedagogy.

The combined theoretical model was found to be effective in recognising the teachers' previous experience in science and its impact on their present beliefs.

The first few years of teaching is identified as an important window for developing beliefs and practices in primary science.

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Chapter 1-Introduction

Primary science teaching is a small part of a primary teacher's role. The removal of the science testing in 2010, and therefore schools' accountability for attainment in science, has meant that science has dropped down the primary school's list of priorities and there is sparse CPD (Continued Professional Development) (Ofsted, 2016). Less than 5% of primary teachers have studied a science at degree level (Royal Society, 2010), often creating school environments with little expertise in science knowledge and sometimes little pedagogical expertise in science. This thesis presents a picture of three primary science teachers in Bristol schools. It researches the teachers' beginnings; their background; their education; beliefs about science education and its purpose; and their views on the children they teach. It reviews their current beliefs about effective practice as well as what happens while they are teaching science. The data is drawn from my own observations and the reports from the teachers on their own experiences and practices. The final part of the research analyses how they develop their pedagogy in science and how they can develop in the future. The thesis will explore the potential opportunities for supporting the development of practices in primary science in teachers' early careers.

1.1 Primary Science Teachers and Teacher development in the Current Economic and Educational Context

This section aims to provide a historical, personal and economic context to the picture of primary teachers' science background, CPD training opportunities, retention in the profession and the science curriculum which they are required to teach. It provides a context and argument for considering beliefs that impact on teaching of science in the primary classroom. Firstly, I consider the primary science curriculum and the skills and knowledge needed to teach the content.

1.2 Primary Science Teachers

In England, primary science teachers, work within the context of the English National Curriculum for Science (DfE, 2013). The curriculum contains the chosen framework of what should be taught but also conveys the syntax of a subject in schools with different emphases on various elements, for example, the balance between skills, knowledge and scientific domains.

The structure and content of the curriculum will impact on the pedagogy in primary science teaching. The English National Curriculum for Science (DfE, 2013) emphasises ‘working scientifically’ by structuring the curriculum into three sections biological, chemical and physical science content which is required to be taught alongside enquiry skills and processes:

> *… focusing on the key features of scientific enquiry, so that pupils learn to use a variety of approaches to answer relevant scientific questions* (DfE, 2013, p7).

The curriculum guidance emphasises the need for the majority of science learning to take place in a practical context, especially at primary ages. This indicates a hypothetico-deductive view of science in the curriculum as well as one of science as a social activity as described by Abd-El-Khalick, (2003). This curriculum structure and discourse are likely to influence both teachers' beliefs and practices in science.

1.2.1 Primary Teachers' Subject Knowledge and Confidence

The English National Curriculum for Science requires teachers to have a wide range of skills and knowledge to teach the required content and skills. The seminal model of teacher knowledge proposed by Shulman (1986) coincided with a government emphasis on substantive or content knowledge as a vital element of a teacher's competence to teach. His model identified the different types of knowledge that he believed a teacher needs to teach effectively in the classroom. He suggested that content knowledge contains not only the '*facts of a subject but also needs syntactic knowledge'* (1986, p 13); defined as the methods and verification processes of a subject; and an understanding of the curriculum, its aims, pedagogical content knowledge and knowledge of the children. His timely work on types of subject knowledge teachers require, just before the introduction of the new curriculum in the England in 1989, appeared to have a direct influence on the English Teacher Training Agency's curriculum for teacher training (1998) as well as influencing the design of teacher education courses around the world. Shulman's emphasis on the substantive subject knowledge in a subject, alongside the introduction of the National Curriculum, was a stimulus to a government focus on primary teacher science subject knowledge in the 1990s.

There has been a continued on-going concern about primary teachers' knowledge and experience of science since the introduction of the National Curriculum for Science in 1989 (Sorsby, & Watson, 1993; Sharp & Grace, 2004; Murphy et al., 2005; The Royal Society, 2010; POST, 2011). The concern centres on the belief that primary teachers' subject knowledge in science is not sufficient or secure enough to teach science at Key Stages One and Two of the National Curriculum (QCA, 2000). OFSTED identified that they often found examples of weak subject knowledge in primary teachers' teaching (2009; 2016). Half of the teachers surveyed in a study by Murphy and Beggs (2007), identified lack of subject knowledge as being the contributing factor to their lack of confidence in science. However, their confidence in science teaching was higher than for teaching music, IT and technology (Murphy and Beggs, 2007; Score 2008). Primary teachers' lack of qualifications in science was confirmed by a survey in 2000; Dillon et.al. found that the percentages of primary teachers who had, at least, an A level or higher qualification were 31% for biology, 16% for chemistry and 11% for physics. All primary teachers who were born after 1979 are required to have a minimum of a grade C in GCSE science to enter initial teacher training.

Teachers' lack of confidence with science subject knowledge lie mostly in the domains of the physical sciences rather than biological sciences. This is reflected in the low level of uptake of those physical science subjects at 'A' level by girls (Sharp and Hopkins, 2007, Ofsted, 2011). This can subsequently affect the pupils' learning in science. Ofsted (2011) state that improvements in teachers' confidence in science not only lead to a positive impact on pupils' performance but also to the children's engagement and enjoyment. This suggests, therefore, the teachers' levels of confidence can have a greater impact, than their actual knowledge, in their choice of strategies and actions within a lesson.

When teachers were asked about their levels of confidence in science teaching, 57% stated that they had (as opposed to 'some' or 'little, or no') confidence in teaching science at Key Stage 2, which was lower than the figures for the other core subjects: English (66%) and Mathematics (63%), (Dillon et al., 2000). The teachers reported less confidence in teaching science enquiry than teaching physical processes. This indicates that primary teachers are less confident in the inquiry approaches than substantive subject knowledge in science which could have a major effect on their use of inquiry in science. This may be due to barriers that teachers identify to doing practical work in science. In the Score report (2008) the teachers stated that curriculum constraints, resources and time were some of the conditions that made practical enquiry difficult. Perhaps this is reflected in their expression that they were less confident in enquiry work. Although the teachers in Dillon et al.'s research (2000) suggest that their lack of substantive science knowledge is the reason for their lack of confidence in science teaching, others argue differently. ITE (Initial Teacher Education) with a focused emphasis on improving substantive subject knowledge has been found to have had minimal effect on the students' knowledge by the end of the course but often have reported improvements in confidence (Carter, Carre and Bennett, 1993). However, Cripps and Clark (2012) identified that proficiency in science subject knowledge does not always wholly influence a teacher's choice of methodology. They state:

> .. *it is not enough to address content knowledge, pedagogy and pedagogical content knowledge in teacher education. There is also a need to influence prospective primary teachers' views of themselves as scientific thinkers and practitioners and to nurture their emotional commitments to the teaching of science* (Cripps and Clark, 2012, p. 474).

Therefore, a sound substantive knowledge in science may not always lead to sound science pedagogy.

Whether teachers are confident in science content knowledge, pedagogical content knowledge or neither will impact on their self-belief and their ideas about effective teaching. The opposite, the impact of beliefs about the nature of science, will also impact on teachers' beliefs about their own knowledge and practices. Day (2006) discusses the ways in which beliefs, identity and practice are all interrelated. Nias (1989) also described the relationship between the personal and professional in the identity of teachers and recognised the impact that the professional context, in this case a school, can have. Primary teachers come to teaching through a variety of routes, much wider than subject based secondary teachers. Primary teachers' identities are likely to be complex due to their variety of life experiences. All these influences will have an impact on teachers' beliefs and practices.

1.2.2 CPD Opportunities for Primary Teachers in Science

If, as suggested above, primary teachers may lack confidence in their science subject knowledge and pedagogical knowledge of enquiry, opportunities for teachers to build on this knowledge should be reviewed. Currently, primary teachers have limited opportunities to develop their science teaching (Wellcome, 2014). This section considers the changing provision of CPD in primary schools and the current local provision. Prior to the 1980s, most continuing professional development (CPD) was provided for primary science teachers by the local education authority, subject organisations with a small amount from publishers and university education departments.

This concern about primary teachers' subject knowledge resulted in actions such as the Grant for Education Support and Training (GEST) funded 20- day science co-ordinators courses and a National Curriculum for ITE in science in 1998 (TTA, 1998). Harlen, in 1995, reported on teachers' lack of confidence and subject knowledge. Revisiting this theme 10 years on in 2005, Murphy and Beggs reported a growing confidence and subject knowledge amongst teachers. This may be due to the GEST courses or new teachers better trained in science. However, the rhetoric of substantive subject knowledge, science knowledge in this example, seems to continue in government circles such as the Parliamentary Office of Science and Technology (2005) as well as in the wider European arena (Osborne and Dillon, 2008).

A series of cuts to Local Education Authority (LEA) budgets by the Conservative Government in the 1980s, continued by the Labour party, had an impact on CPD provision. Further cuts were accelerated by the coalition government when they came to power in 2010. The rationale behind the cuts was to create a market of services for schools as well as to cut government spending. The Cabinet Office stated in 2011:

> *Wherever possible public services should be open to a range of providers competing to offer a better service* (p.9).

Whether the service is better or not is debatable but between 2011 and 2015 there was certainly a cut of 28% in funding to LEAs (Hatcher, 2015). One of the results of these actions is the reduction of spending on LEA training for non-maths and English subjects in the curriculum.

As well as a cut in LEA budgets, teachers and schools began to be judged by criteria defined by the DfE in 1994. In addition to the use of the Teaching Standards to review teacher performance, school effectiveness is now judged on student outcomes predominantly in maths and English, since the abolition of Science Standard Assessment Tests in 2009 (SATS). This may be another feature of what Power (1997) describes as an audit society where success is measured by quantitative measures. This has resulted in training focusing on raising achievement in the subject areas that are reported as school success criteria (Hatcher, 2015) and consequently less provision for science-based training, and indeed all non-core subjects, for primary teachers (Wellcome Trust, 2014; Colcough, 2018). Wellcome found that 30% of primary teachers had experienced no science CPD for over a year (2017). Ofsted (2013) found in their review of secondary and primary teaching that there was a direct correlation between a school's commitment to science CPD and the children's achievement in science but also recognised there was little science support for schools from LEAs. The government's consultation and response on teacher development especially in their first couple of years of teaching indicates there is some national concern over a lack of training for teachers; they are proposing to extend the Newly Qualified period to two years. (DfE, 2017; DfE 2018).

The Government's strategy to support the teaching of science over the last decade was to provide support through National Regional Science Centres, offering a full timetable of courses, as well as online resources and forum through the National STEM learning Website. The regional centres have now been closed and there are now a series of regional science partnership contacts and national training mostly based at the York centre. At present, in the Bristol area, the regional training by the National Science Centre has been reduced to a couple of courses a year and an annual science teacher conference (National STEM Website, 2016). School federations, such as the Bristol Primary Teaching School Alliance also offer courses cut across the curriculum (Bristol Primary Teaching School Alliance, 2016). The teaching alliance provides primary science mentors, as does the LEA, who can be bought out of their classroom to provide support for other science teachers. The National Stem Organisation can arrange for the provision of school-based training and mentors (Stem Learning, 2016). The Association for Science Education (ASE) continues to provide non-statutory training and information for primary science teachers with the regional events and the annual largest subject association conference in Europe.

However, the Wellcome Trust's report on the state of primary science teaching (2014) heralds a growing concern about the nature of CPD for science teachers in primary schools. They note that primary leaders favour generic CPD to subject-specific as it is more cost-effective in a time of financial pressure but that these are often a poor match to the needs of the teachers and also lack contextual elements of subject-specific training that change practice (Cordingly and Buckler, 2014). Ofsted (2013) also called for high-quality subject-specific training in science, supported by reports from the Wellcome Trust (2014; 2017), and yet budgets often are prioritised to subjects reported to the public.

In my local area of Bristol in 2018, CPD courses for science education are infrequent, with the closure of the South West Science learning centre and the demise of the Local Education Authority as a training provider leaving even less provision. Alongside this, the teaching profession loses up to 10% of the workforce a year (DfE, 2016). Expertise and experience in primary science held by the leavers will inevitably be lost. Without training others to take their place, or having primary science teacher role models, a downward spiral in the quality of science education is likely. The achievement of children nationally and in international comparisons has already seen a drop in recent years (Standards and Testing Agency, 2014; Martin, Foy, and Arora, 2011).

If, as discussed, primary teachers are lacking in expertise in science and primary science pedagogical methods and there are limited opportunities for CPD, it raises the question of how they judge effective science teaching and how they develop their beliefs, and therefore practice, in science teaching.

The current situation of little science CPD in schools might appear to necessitate the use of peer support and training in schools. School-based training using peers has been identified as a preferred learning context by teachers in their early careers (Ritchter, 2011; Grosemans et al., 2015) as well as using socially constructive and situated learning principles (Brown et al., 1989; Wenger, 1989a; Wenger, 1989; Lave and Wenger, 1991 Lave, 1996). The observations and theories of Lave and Wenger (1991) and Wenger (1989) argue that situated or participatory learning within a community of practice is an effective way of learning about the skills, culture and knowledge of a role. A school could act as this community of practice and through working alongside 'masters' in science education, being part of a science teaching community, the teacher would learn the current socio-cultural knowledge, agreed knowledge in science education communities, involved in primary science education. My research explores the ways the three teacher case studies draw on their own beliefs to inform their practice but also how they develop their practice in this climate of little external support for the teaching of science.

1. 3 My Personal Context

My personal context, from my experience in developing teachers, is an important part of this study. This experience has motivated me and led me to identify this research. My use of participant observation as a tool for gathering data on the case studies means that I am also a part of the data. I recognise the impact of my own science capital on my own qualification choices, status within a primary school at the introduction of the National Curriculum for Science (1989) and my role as a broker of pedagogy, described by Wenger, 2000) as an advisory teacher in a London Borough. The lens with which I analyse the data will also be influenced by my own experiences even when attempting to be very conscious of my own beliefs and bias in data analysis.

At the time, the advisory teacher model was influenced by the model proposed by Showers, Joyce and Bennett (1987) who reviewed research on a variety of strategies used in training of teachers: sharing of knowledge or theories, demonstration of practice or skills, simulated teaching skills or practices and peer coaching. The authors believed that peer coaching was the most effective strategy for improving teacher knowledge and also was the most effective strategy to help teachers transfer pedagogies to the classroom. The advisory teacher model, drawing on the Showers et al. model, encouraged the advisory teacher to run courses, but also meet with heads and teachers to identify the school's needs in a curriculum subject and to plan and teach alongside staff in the school. This model could also be thought of as a kind of situated learning, described by Lave and Wenger (1996) as the teachers and I socially constructed our pedagogy together by teaching, planning and reflecting on our teaching together while carrying out the role of the teacher within the classroom; not a simulated experience on a training course.

When my funding for the advisory role came to an end I started in teacher education, primarily in science education where I have worked for over 20 years. Models of teacher education have changed during this period, mostly due to government edict. I still work with practising teachers as well as ITE students and find it surprising that I still find the processes and influences of a variety of circumstances on the development of teachers' pedagogies and subject knowledge fascinating. Some of my role involves simulated learning away from the classroom in the university where students practise science activities and pedagogies. Other parts of my job involve observation of students in the situation of the classroom, giving feedback on teaching expertise.

The combination of coming from a science background, my interest in the development and brokering of those teaching practices, as well as a recognition of the influence of primary science communities of practice has had on my own development has led to this study.

My concern and interest lie with the ways teachers form practices without some of the support and training that I was fortunate enough to receive and to give within my roles in science education

1.4 The Thesis

This thesis uses a socio-cultural theoretical framework to analyse the situated learning of the three teachers within their places of work, in some cases through existing communities of practice drawing on the socio-cultural theories proposed by Lave, Wenger and Brown. (Brown et al., 1989; Wenger, 1989a; Wenger, 1989; Lave and Wenger, 1991 Lave, 1996). The thesis also uses the social theory of Pierre Bourdieu to inform the relationships between the case study teacher and other members of the communities of practice.

The research uses a case study methodology and tools of participative observation and semi-structured interviews to gather data about the case study teachers' beliefs and background as well as their views on effective practice in primary science education and the barriers to effective practice. The analysis also explores how the teachers in the case studies can develop their beliefs and practices in the current economic climate in schools.

1.5 Chapter Summary

This chapter sets out the personal context of the author as well as the national and local context of primary science teachers in the Bristol area of England, where the research is located. The current political and economic influences on the CPD provision for primary science have been identified. There is no doubt that the creeping marketisation of education and the demise of science in the primary curriculum have had an impact on the provision of CPD in science by schools and government, local and national. Teachers in primary schools are unlikely to come from a background of higher education science qualifications (Royal Society, 2010). Many feel unconfident in teaching science especially investigative science, yet the curriculum requires practical investigative type activities to be taught to children in schools (Dillon et al., 2000; Wellcome, 2017). These contextual conditions will inevitably have an impact on the data gathered and what the data reveals.

The current situation described above may appear to be a situation that merits concern. A newly qualified teacher or one with a couple of years' experience has little opportunity to develop his/her own skills and knowledge of science teaching outside the school community. Primary teachers come to the role of primary science teacher with very different experiences and capital in the sciences and have different training needs.

This research aims to consider the science capital that three primary teachers bring to their role of a science teacher in schools, analyses their science capital, their beliefs and resulting habitus and their role within the community of practice within the school and what they use to develop their own practices in science.

The research uses the theories of the communities of practice and situated learning advocated by Lave and Wenger (1991; 1998) There are no studies to my knowledge of the literature in science education that integrates Bourdieu's social theory with those of Lave and Wenger to analyse the capital a teacher brings to their role (1999; 2004).to enhance the understanding of the primary teacher's position in the school.

To inform and explore the issues described above, the main research question has been formulated as:

What are the beliefs about effective teaching practices in three primary science teachers and how are these developed?

Within this main question lie the sub-questions;

1. What impacts on the three teachers' beliefs and practices?

2. What are the primary teachers' views and beliefs about effective science teaching?

3. What are the three teachers' views of barriers to using effective practice in primary science?

4. How do the three teachers develop their pedagogy in the current educational climate?

1.6 The Structure of the Thesis

In this chapter I set out the current national and local context of science teaching and primary science teachers as well as the curriculum context in which the teachers are working. I also covered my own personal context that has led me to this study.

The second chapter discusses the theoretical frameworks which underpin the thesis as well as the current literature on influences on teachers' practice in science education and how they form these beliefs. There then follows a consideration on what is meant by effective teaching and a review of the current pedagogies prevalent in science education.

The third chapter looks at my research methodology, methods and my rationale for my choice of methods and consideration of ethical concerns. It provides an overview of the research process.

The fourth to sixth chapters present the data and data interpretations from the three teacher case studies. I consider the case study teachers' beliefs about effective primary science teaching, explore the influences on their beliefs and their development as teachers of science

The concluding chapter compares the main themes from the three case studies and presents a model for integrating the theories of lave and Wenger and Bourdieu to support the analysis of teachers' previous life experiences on their power and agency with the primary school. It identifies limitations of the research, possible areas for future study and concluding remarks.

Chapter 2 Literature Review

2.1 Introduction

The previous chapter identified the political and educational context to the field research in 2015. This chapter presents my theoretical framework for the research as well as the current theories of effective science teaching pedagogies. The research and theory are drawn from the international science education community, particularly in the USA and EU, who have a significant influence on our own practice in science education in the UK. The literature review is divided into two parts; the first outlines the theoretical frameworks on how teachers learn and situated learning in the workplace. The second part reviews current literature on effective pedagogy, which influences primary science education that teachers and schools experience through their own initial teacher education, training, on-line materials, Ofsted inspection frameworks and briefings, and articles in journals.

Part 1 of this literature review and theoretical framework describes how I view socio-constructivist learning by teachers throughout their lives, forming their beliefs and influencing practices in science teaching in the primary school. Within the primary school context, I draw on a variation of socio-constructivism, known as social cultural theory, to describe the learning that teachers experience from being part of a community of practice for science teaching, using the theories of Brown et al. (1989), Wenger (1998) and Lave and Wenger (1991). However, Lave and Wenger, Brown and Wenger's models of situated learning have been criticised for not taking enough account of that which an individual brings to the community of practice. I argue for the additional use of Bourdieu's social practice theory model (1999), which recognises the impact of the social, economic and cultural science capital that teachers bring to their role as science teachers and the impact that capital can have on schools.

Beliefs are embedded within society and influenced by a national view of science; its values and practices. Therefore, in Part 2, I seek to provide a context and to locate my own research in the social cultural world of science education literature: I consider some of the literature on how beliefs are formed and the effective practice in primary science by the science education community with a focus on enquiry in science. This section will locate the practice and beliefs demonstrated by the three teachers involved in my research.

2.2 Part 1 - Learning Theories, Belief and Identity

In Part 1, I propose to develop and explain my theoretical framework concerning the way teachers gain their knowledge of pedagogical content knowledge, knowledge of the content and the pedagogies best suited to teaching the content, that provides the basis for their beliefs and actions in primary science teaching (Shulman, 1986). I will define a theoretical framework to provide a model of the development of the science teachers' practice within their own schools and through contact with other practitioners, whether national science education bodies or small networks of teachers. The framework will explore various theories and argue for a synthesis as one theory may not explain all aspects of the complex myriad of human variables that a teacher brings to the classroom. In this part, I will also explore the nature of belief and identity of the primary teacher.

2.2.1 The Location and Definition of Terms used in the Discussion

Many of the terms used in this thesis represent complex constructs and are defined and discussed in their relevant sections; the locations of the discussion of the terms are identified in this paragraph. Constructivism is defined as the process in which an individual is active in taking on or rejecting new ideas, when interacting with the environment to build an understanding of the world. Socio-constructivism suggest a similar process of learning to constructivism but recognises the importance of social interaction and the sharing of cultural beliefs and ideas in the construction of ideas, see section 2.2.2. Socio cultural theories of learning draw on the works of Brown and Duguid and Lave and Wenger which highlight the importance of the learning that happens when carrying out real life activities in the cultural context of the place and community carrying out the task. Further clarification of these terms and associated terms is in section 2.2.3.

A key theme in the thesis is beliefs about 'effective teaching'. Although I use this term throughout this thesis, I recognize that there are problems as the definition is reliant on what the reader believes are the goals of teaching. In this thesis, I have taken a lead from Turner-Bisset (2001) who suggest effective teaching is measured by the response of the children; whether the children have progressed in their understanding, practiced or developed skills or scientific attitudes. However, this thesis does not evaluate the progress of the children; it explores the beliefs about effective teaching held by the case study teachers. Belief can be described as a term that describes the structure and content of a person's thoughts and which affects the way they perceive events and actions (Enyedy et al, 2006) The concept of belief is considered further in section 2.2.6. Social theory, such as the theories of Bourdieu discussed in section 2.2.5, can be defined as the application of theoretical frameworks or models to aid the analysis and explanation of social systems, activities and structures (Bera, 2018). Primary science refers to the current science curriculum (DfE, 2013) and its dominant pedagogies and conventions in English Primary schools at the time of the research. Teacher identity is discussed guided by Shwartz et al. (2012) who suggest that identity is not just the 'who are you' but the 'who you act as being' in interpersonal and group interactions, plus the recognition these groups or individuals give you in return. This is discussed further in section 2.2.7.

2.2.2 Constructivist and Socio-Constructivist Learning Theory

An overarching theme in this thesis is the knowledge and beliefs that teachers have about science and teaching science, how these beliefs are formed and how they can be developed. Constructivism and socio-constructivism provide a theoretical model by which knowledge of science and science pedagogical knowledge are acquired by teachers and children.

Constructivism and socio-constructivism have been dominant theoretical paradigms in education for over fifty years, especially in science education research and practice, as theories of learning (Piaget, 1952; Vygotsky, 1978; Tobin, 1990; Lemke, 2001) The theory of constructivism is derived from Piaget's models of cognitive development (1952), the main premise of which is that:

> *the learner is active in the learning process; that learning is the result of interaction with a problem context where the learners construct their own knowledge* (Tobin, 1990. p.3).

Piaget's theories emphasise that everyone's learning is an active process, where an individual actively takes up or rejects knowledge. Piaget recognises that there is a societal element to learning but this is not a central part of his theories, unlike Donaldson (1978) who demonstrates achievement in children, beyond Piaget's cognitive stages, by providing a familiar context and social reference.

Socio-constructivism, takes elements from constructivist theorists, describing the process of learning initially proposed by Vygotsky (1978). It recognises the active uptake of knowledge by the individual, in this case the teacher, but acknowledges the contribution made by the social context, where the knowledge is mediated by others. This theory also recognises the contribution of the environment, such as the classroom, as well as the symbolic nature of the knowledge gained, in this case school science. As Bruner explains, Vygotsky's belief is that the world of concepts and beliefs comes from 'others' (Bruner, 1985, p32). According to Piagetian theory, the primary cause of learning in individuals originates from links made within the brain with influences from the social environment, while socio-constructivist theories locate the causes of learning in the influences of external social practices (Hall, 2007).

The constructivist and socio-constructivist learning theories can be used to describe the way that teachers learn scientific knowledge and the pedagogy they teach, as well as influencing the way they learn themselves. In their own science education, the teachers will have experienced the socio-constructivism of scientific knowledge through discussion in science classes, or at home, as well as through socio-cultural indoctrination into the world of science, its status in society and its methods. In initial teacher education (ITE), teachers may be introduced to subject knowledge in science of which they are unsure, plus new pedagogies for teaching science. The socio-constructivist learning theories might also describe the way they learn about science teaching during their ITE, when planning with a colleague or when introduced to the school's science policy, or scheme of work, and from the school's cultural approach to science teaching.

2.2.3 Socio-Cultural Learning Theories in Learning to Teach

My research uses the socio-cultural learning theories of Lave, Wenger and Brown, with particular reference to their models of 'situated learning', 'communities of practice' and 'legitimate peripheral learning', to model the way in which teachers learn from one another in a school situation and how teachers can develop their practice (Brown et al. 1989; Wenger; 1989a; Wenger; 1989; Lave and Wenger, 1991; Lave, 1996). I also discuss some of the critiques of the theories. Socio-cultural learning theories, although not a unified theoretical field, recognise how communication and learning are shaped by our environment and culture, where meanings are jointly constructed (Mercer and Littleton, 2007). I explore how these models are relevant to teachers' learning of science and science pedagogy, particularly in schools. I also use them to describe the continual processes of learning to be a proficient science teacher and as a reference to the way teachers think children learn science.

Cobb and Yackel (1996) have argued that thought with societal origins, described in Vygotskian theory, constitutes a *transmission* model in which "*students inherit the cultural meanings that constitute their intellectual bequest from prior generations*" (p. 186). This theory is enhanced by the *participation* model of cultural development (Lave and Wenger, 1991; Rogoff, 2008) which describes the process of learning and offers an alternative way to overcome the duality posed by the influence of society versus the individual. These theories will now be considered.

The participation model of teacher learning represents knowledge and skills development as a transformation of an individual by their participation in a socio-cultural activity. Transformation (rather than internalisation) occurs as participants start performing the activity and assume increasing responsibility; in essence, redefining membership in a community of practice, and, in fact, changing the socio-cultural practice itself through their own contribution to the activity (Lave and Wenger, 1991).

Meanwhile, Brown et al. (1989) describe their theory of learning as 'situated activity'. By this, they are stating that learning cannot be separated from its context, culture or activity. They suggest all learning opportunities are influenced by the social and physical surrounding of that activity as well as the previous cultural, subject knowledge that the activity is based on. They describe how situated learning provides locally developed knowledge that cannot be obtained from experiencing canonical accounts from managers; information accepted by an institution as being authoritative. Lave and Wenger attempt to clarify the term 'situated learning' by asking what activity is devoid of a social interaction, illuminating their view of participants' roles at different stages of belonging to a community (1991). As well as the idea of situated learning, the theories of Lave and Wenger emphasise the importance of the 'social' aspect of learning. The 'situation' will always involve people or the environments or products of human endeavour and culture.

Lave and Wenger (1991) focus their theories on the learning and the acculturation of a student into a subject or skill by the activity of a community. They describe the community as a group of individuals with the following features: a common enterprise, which is understood and recognised by participants and a community which functions with a:

> *'mutual engagement which aligns individuals working together; and a 'shared repertoire' of communal resource* (Wenger, 1998. p.73).

The community of practice may be local and on a small scale or even national on a large scale; for example, in schools it may be a year group team, while nationally it may be the Association for Science Education. Members of communities may belong to different communities at the same time. The focus of each community is on the learning that the group does together rather than the institution for which they work (Wenger, 1998). These situated learning theories suggest that learning to teach will happen in the classroom, in a real-life context with a staff team of other teachers who influence practice, rather than from a book or teacher education lectures.

Lave and Wenger's, (1991), 'legitimate peripheral participation' theorises the process of the learning, in particular, the trajectory of a new individual coming into a community of practice. They define legitimate peripheral participation as follows:

> *Learners inevitably participate in communities of practitioners and that the mastery of knowledge and skill requires newcomers to move towards full participation in the socio-cultural practices of the community* (Lave and Wenger, 1991, p29).

They describe how a newcomer to a community, like a new teacher, functions on the peripheries of the community initially. They state that such novices perform minor tasks and associate with other novices, ordinary members and even masters of the community. In talking, being and acting out the essential tasks of the community, the novice learns the tasks, makes sense of the knowledge and is provided with models by the masters. The learning happens, and the novice changes, resulting from the shared practices, negotiated understandings and functions of the community. Therefore, the learning and enculturation by the community of practice result in the novice becoming a different person. This novice then may achieve full participation into the community. Lave and Wenger emphasise that the masters do not necessarily actively teach the novices but represent a model of what full participation might look like. Yet, the authors propose that it is the day to day involvement in the life and activities of the community that spreads the culture of the community (Lave and Wenger, 1991; Lave, 1996).

Lave and Wenger, (1991) argue that this theory encompasses more fully the wider social and cultural elements of social learning than the theories of Vygotsky, which could be seen as presenting a view of learning that has an acquisitional element to the process of learning rather than participatory, albeit in a social context.

Sfard (1998) warns against being too bound to one metaphor of learning against another. She suggests that metaphors of learning, such as acquisition and participation, can lead to theoretical distortion, which could be unhelpful. She argues that an interpretation of learning as purely a participatory activity may lead to the '*disappearance of a well-defined subject matter'* (p.10). She suggests that neither learning metaphor alone is sufficient to fill the entire field of learning, so living with a mixture of contradictory metaphors is necessary. Within my research, Lave and Wenger's original work on apprentices could provide a better understanding of learning in school contexts by extending our understanding beyond the theories of Vygotsky, which, they state, are too focused on the acquisition of knowledge (Lave 1996, p149).

2.2.4 Application of Socio-Cultural Theory to Primary Science Teacher Learning.

I now consider the use and implications of applying Lave and Wenger's theoretical frameworks to the process of teachers' learning about science practice and knowledge in primary schools. My argument will examine the distinct nature of science teaching in the primary school and some of the critiques of learning theories and their relevance to a research context.

Primary school science is a subject in the primary curriculum that is distinctive in its nature. Science's mix of skills, processes, attitudes, pedagogies and subject knowledge, puts high professional demands on generalist primary teachers. As stated in the previous chapter, less than 5.2% of primary teachers come to the profession having studied science at higher education level (DfE, 2013). Limited time on initial teacher education courses for science education can result in teachers entering the profession insecure in their own science subject knowledge and unsure of the pedagogical approaches to develop the range of skills, processes and knowledge required by the National Curriculum (2013). However, primary science lessons offer an opportunity for children to learn from their own practical science experiences and to gain a greater understanding of the natural and physical world around them. It provides time for thinking skills such as prediction, using abstract models, evaluating evidence, as well as for cross-curricular skills such as measurement, classification and data handling. Science in primary schools can also give children an understanding of the workings of scientists and provide them with a science literacy, an understanding of the conventions and ways of working in science, which will help them to interpret scientific research in adulthood and enable them to make more informed decisions (Harlen, 2014).

The range of skills, knowledge and understanding of the nature of scientific activity poses a challenge to many new primary teachers when it comes to teaching science. For example, they may have an incomplete understanding of the scientific knowledge needed to teach the National curriculum programme of study; they may not understand the ways scientific knowledge is created or validated; and they are likely to have had little experience of teaching science in a primary classroom due to the dominance of English and maths. However, as described above, over time the new teacher becomes part of the school's community of practice in all aspects of their role, including the teaching of science. They will be introduced to the resources other teachers use, a school science programme of study, possible assessment resources or methods. The established teachers will talk about their own science teaching and, through the practices and language used by the staff about their teaching, the new teacher will be enculturated into the approach to science education within that school. There may also be science leaders in the school, who model and share their expertise in science. Gradually becoming an established teacher in the community of practice, the new teacher will experiment in the classroom in science, form and refine pedagogies and develop their subject knowledge.

In considering whether a primary school is a community of practice, Wenger (1998, p.1) describes a community of practice as a '*social learning system*'. Is that social learning system the school the teacher works for or the local authority science leaders' meetings or is it the internet community, where teachers find resources and ideas for teaching? The idea of communities of practice and situated learning are important to consider as school teachers introduce children to the world of science but are themselves physically removed from the scientific community. This learning is described by Lave as 'de-contextualised' (Lave, 1996, p.7). Perhaps she is implying that we are only creating situated school science learning, not science learning. Lemke also questions whether school science that teachers deliver can ever be an ‘authentic’ scientific activity; he asks whether:

> *the particular view of scientific rationality we offer is an idealization, or a travesty, of the true scientific spirit* (2001, p17).

Children and their teachers are not located in research laboratories and almost exclusively reproduce the work of others rather than explore new theories. However, Lemke’s assertions imply that teachers should only teach subjects in which they have professional or active experience, which is an unrealistic proposition for a primary school setting. This view of Lave’s ‘*de-contextualised science’* (1996) supports the idea that science education is a community influenced by, but different from, the world of science. The communities may share some values, methods and subject knowledge but that they operate in different fields with different goals. I believe it is precisely the role of the science teacher to share the methodologies of science in the de-contextualised environment of a primary school.

Brown and Duguid (1991) also describe how teachers introduce pupils to the culture and community of the classroom, which pretends to be the culture of subject disciplines with practices and procedures that would not be recognised by the real practitioners. It could be argued that it is important for the teachers to have had experience of a scientific community of practice to help children have an ‘authentic’ scientific experience. Yet as stated in a previous chapter, few primary teachers come with science ‘A’ levels let alone experience of a scientific community. Of course, an alternate argument is that there is not necessarily one set of scientific beliefs and practices in scientific communities anyway (Osborne, 1996).

Another concern with applying the theoretical frameworks of Lave and Wenger to learning by teachers could be the differences between the apprenticeship process and teacher education. Cox (2005) argues that the examples of ‘craft learning’ differ in the studies carried out by the Lave and Wenger, who researched learning among apprentice tailors. Similarly, student teachers on teaching practice may take on minor ‘teaching assistant’ roles when starting in a new classroom and build up to teaching the whole class, which can be compared to the idea of legitimate peripheral participation identified by Lave and Wenger (1991). However, the nature of primary education means that a student is required to teach all the subjects of the curriculum from the start when it is inevitable they cannot have much mastery of all these as a newly qualified teacher (NQT). Although they have not gained significant knowledge or experience in teaching these subjects, they perform like an experienced teacher, planning, teaching and assessing the subjects across the curriculum. Schools do not give newly qualified teachers minor tasks within their weaker subject knowledge areas to develop their learning in the manner of the 'legitimate peripheral 'activity model. It could be argued, in support of Lave and Wenger's model (1991), that NQTs do not usually take on middle management roles within schools in their first year and so are still on the periphery of the school community, while being full participants in the classroom from day one. Hodkinson and Hodkinson (2003) mirror this concern in their exploration of a secondary school art department. The authors identify that legitimate peripheral participation does not always describe the dominant mode of learning among teachers. They also point out that Wenger (1998) conversely concedes that *'special measures may be taken to open up practice to newcomers'* (p.102). As the model of an NQT teaching across the curriculum in their classroom does not appear to be congruent with the legitimate peripheral learning described by Lave and Wenger (1991), it is more appropriate to apply their model to the learning that occurs when taking on the more central school role of a subject leader or specialist.

Eraut (2002, p.3) questions the idea of a learning community, comparing the term to an ecological community and asks '*who is top of the food chain*?' Using this analogy, Eraut questions the effect of power and agency among individuals in communities of practice. In Lave and Wenger's legitimate peripheral learning model (1991), the power imbalances are between the novice and the masters. In Brown and Duguid's theory (1991), the focus is on individuals all at the same status level. Later in Wenger's theory of 'communities of practice' (1998), there is some mention of conflict that might be caused by multi-membership of communities but not of conflict within the teacher's own community. In schools, as in any organisation, power and social equality are a large factor in the day-to-day running of the organisation; not all members of a school community are equal in status and influence. Teachers have performance targets set by the senior management teams that identify pedagogical and organisational areas for them to address. Failure to reach these targets can influence movement up the pay scale or not. Ofsted inspections, where an external judgement of a teacher's practice is made, can also influence the teacher's status and power within a school. Within external communities, there will also be hierarchies of power. In professional associations, for example, there are always some members with greater power and influence than others. Hodkinson and Hodkinson (2004) draw on the theories of Bourdieu (1999) to highlight the position of a new teacher, or a teacher new to an organisation, who may lack the cultural capital (including an understanding of the ways the organisation functions) to be able to gain equal access to learning. The authors also suggest there will be inequalities in social capital between workers and, therefore, bias in the provision of training; new teachers may be less likely to be picked for training opportunities as they have a lower status in the school than established teachers.

Whether these theoretical models are appropriate for my research is also determined by the nature of the situated learning within the teachers' school contexts. The learning described in Brown and Duguid (1991) is that of 'problem-solving', whereas the learning in Lave and Wenger represents an induction into established practices (1991). Wenger highlights further differences in learning communities by stating that, in some cases, communities can 'learn not to learn' (Wenger, 2000, p.6). Schools can become communities where disengagement with the learning is part of the culture and way of being. He discusses the ways that multi-membership of communities can extend the identity of the individual and the community even if some memberships are at the periphery. Perhaps it is in this way that communities can learn new practices and grow.

Eraut, (2002), identifies conditions in which a community of practice would be rendered an ineffective learning environment, including many temporary staff, a great number of individual tasks, over-prescriptive management and IT-mediated work-based tasks. Some of these factors are less evident in a school scenario but one relevant key factor Eraut suggests is time pressure, which may prevent teachers from being able to discuss and share their practice. Lack of time is certainly a factor identified by teachers as a key pressure in their roles in schools (Score, 2008). Time to share and develop a community of practice is difficult to find in schools and much of a teacher's working day is spent on their own with a class or, maybe, with one teaching assistant. Schools try to use staff meetings and INSET days to develop knowledge sharing and practice development, yet these are short periods of time in the life of a school and the meetings often have to fulfil many other purposes too (Harland and Kinder, 1997). While there is often some informal discussion of practice in staffrooms, and occasionally opportunities to teach together, time pressures certainly limit these interactions. (Roth, 2001).

One of the loudest criticisms of Lave and Wenger's work on community of practice and legitimate peripheral participation (1991; 1998), is that the authors neglect to consider the contribution of the individual; their experience and beliefs and what they bring to a workplace (Cobb and Yakel 1996; Hodkinson and Hodkinson, 2003; Hodkinson and Hodkinson 2004; Cox, 2005). As Hodkinson and Hodkinson state, '*there is a risk of seeing only the social, because the individual is subsumed within it'* (2003, p3). These authors argue the dispositions of individuals and the social and cultural capital brought to the workplace is undervalued in the work of Lave and Wenger (1991; 1998). This difference between individuals could also be an important factor when viewing the power relationships within a workplace and the varying degrees of influence that individuals may have in a community of practice.

In research on teachers' decisions on practice in the classroom, much is made of the complexity of the factors that influence their choice of methods and approaches. Such factors include not only the contextual and social, but also early life experiences with science, beliefs about scientific endeavour and even 'science capital' (Bianchini and Cavazos, 2007: Crawford, 2007). Bourdieu's social practice theory models (1999) provide a framework to consider the impact of the different experience and capital a teacher brings to a school. The effect this 'capital' has on the teacher and the school and will now be considered.

2.2.5 Bourdieu's Social Theory Model

Bourdieu's social practice theory model needs to be considered in its three constituent parts; habitus, capital and field (Maton, 2012). It is the relationship between these three aspects that makes the model useful.

Bourdieu's 'habitus' describes the social structures that shape a person's present and future practices (Maton, 2012). Bourdieu sees habitus as a property of individuals, groups or institutions, which act on a person to produce their views, values, tendencies and beliefs. Habitus is not static as a person's habitus is always changing in response to life events and the people around them. It is influenced by and in turn influences the present social space or 'field' that a person inhabits.

The field is a ‘social space’ where interactions, transactions and events occur (Bourdieu, 2004). A field could be a primary school, shop or a public house, however, on a bigger scale, it could also be a national political party. The nature of the field is described by Bourdieu as being inherently competitive. Thomson (2012) compares Bourdieu’s field to that of a football field, bounded by size and physical conditions that affect all players but unequally because of what each player brings to the game; the different skills, attributes and experiences that the players bring to the field are described as ‘capital’ by Bourdieu. He breaks down capital further into economic capital like money and possessions; cultural capital such as taste, knowledge and language; symbolic capital like qualifications and other credentials; and social capital such as social contacts and networks (Thomson, 2012).

Bourdieu also coins the term 'science capital’ (1999:2004). As part of his theory of habitus, he suggests that the elevated status of science in society can inevitably create economic, cultural and symbolic inequalities among individuals. Bourdieu (2004) describes how science capital can be built up and transferred into other sorts of capital within society through qualifications, interest and participation in science by family and friends, and through participating in science in the wider world. Although, in his original writings, he was referring to the situated science societies of industry and research, the theory has some resonance for teachers with science backgrounds operating in a world where very few teachers hold that science capital.

Thomson suggests a formula for how the aspects of habitus, capital and field interact:

[(habitus)(capital)] + field = practice (Thomson, 2012, p 50).

This social practice model recognises the differences in ‘capital’ a teacher brings to a school but also the influence of the school on the teacher’s views, beliefs and practice.

The argument above, proposes that the social-cultural theories of situated learning in communities of practice, located within the socio-constructivist theory of learning, may offer a useful framework for analysing the learning and especially the development of the teacher within the school environment. My use of this framework comes with an awareness that there are conditions within the school environment, such as time pressures, which make the theoretical model less applicable in some schools, which do not prioritise time for staff to work together. Bourdieu’s theories of ‘science capital’ (2004) also have relevance to the status of the science teacher in the school community and their beliefs and practices as science specialists. The lack of consideration of the beliefs, education and experience, the individual brings to the role of the teacher has been identified as a failing of the theories of situated learning and participatory communities of practice (Cobb and Yakel 1996; Hodkinson and Hodkinson, 2003; Hodkinson and Hodkinson 2004; Cox, 2005).

Bourdieu's model of social practice implies that a new teacher with strong science capital, joining a school with a community of practice consisting of other teachers also with strong science capital, will have less power and influence than if they had joined a school with members with little science capital. However, power within the field of the school may also be impacted by social and economic capital in other areas of expertise such as management and leadership.

The habitus feature of Bourdieu's social practice model (1999) suggests that beliefs and values are formed by a teacher's childhood and social contexts throughout their lives, with the resulting dispositions influencing their beliefs and practice. Consequently, the next section discusses theories on the nature of beliefs and how they are formed.

2.2.6 What are Beliefs and how are they Formed?

The conceptualisation of what a teacher's 'belief' is varies according to the author; indeed, there is some argument over the meaning of 'belief' itself. Enyedy et al. (2006) identifies a school of thought on beliefs, which defines them as:

> *.. psychological constructs that describe the structure and content of a person's thinking which in turn influence a person's interpretation of events and actions* (p.70).

Nespor (1987) tries to clarify the nature of belief further. He differentiates belief from knowledge by identifying their affective and evaluative elements. He believes that beliefs often arise from a judgement made about a situation, someone or something. He argues that because of their personal nature they do not need any internal consistency or logic. This means it is important that a teacher can hold opposing beliefs to an individual in a class, as well as views about what will benefit the whole class, which may disadvantage the individual. Pajares (1992) states that knowledge is different to belief as it is open to evaluation and critical analysis, whereas beliefs are not and are not expected to be. Beliefs can be intensely personal and can be considered beyond an individual's own control.

Pajares, (1992) also proposes that beliefs are not just a static set of ideas but a system with substructures and areas that may or may not agree with one another. He defines beliefs as:

> *an individual's judgment of the truth or falsity of a proposition, a judgment that can only be inferred from a collective understanding of what human beings say, intend, and do* (1992, p. 316).

He argues that confusion over the definition of beliefs comes from an unclear distinction between beliefs and knowledge. He states that belief systems are formed through life experiences, education, social influences and other aspects beyond the classroom and the immediate activity of teaching. They are also formed by ideas about the nature of science, how children learn, children's views in the classroom, and pedagogy learnt in training, as well as in response to the children's attitudes to science and their own academic aspirations (Fitzgerald, 2013). Turner-Bisset, (2001) helpfully reminds us that teacher perceptions will alter over time and that the process of teaching will likely affect the teacher's beliefs about themselves and their role in the classroom.

Nias (1989) is also aware of the role of personal identity and how this influences beliefs and practice in discussing teachers' sense of self:

> *The emotional reactions of individual teachers to their work are intimately connected to the view that they have of themselves and others. These perspectives are shaped by early influences, as well as by subsequent professional education and experience. All of these influences themselves have historical, social and cultural roots and contexts which transmit belief systems and perpetuate social and organisational structures* (1989. p.294).

She describes the intertwining of emotion, belief and experience and indicates her conception of how these factors influence teachers and how teachers subsequently affect society.

In 1986, Benson (cited in Hodson, 2009), found that across a school the views of science between pupils in the same class had a greater similarity than those in different science classes.

He also found that the longer the pupils spent with one teacher the more entrenched and similar those ideas became to those of the teacher. This gives us a glimpse into the potential influence a teacher can have on imparting messages about science within their own classroom. If this research is a true indicator of the spread of influence by teachers it would appear important to explore how these ideas are formed, what the children's views are and whether, in some cases, they can be changed.

2.2.7 Primary Science Teacher Identity

As discussed, and as Clark et al. (2012) state, a teacher's personal beliefs will mould the identity of that teacher, and/ or the identity will mould their beliefs and help to form the teacher of science, thereby directly influencing their practice

> *For each teacher, the way in which they used practical activities was linked to their beliefs and emotions about teaching science, rooted in their identity and history.* (p.472)

In this section I propose to look at the meaning of identity, some theories on the identity of primary science teachers, how identity is formed, and the influence of family science capital on the individual.

Identity is a contested construct. Shwartz et al. (2012) suggest that identity is not just the 'who are you' but the 'who you act as being' in interpersonal and group interactions, plus the recognition these groups or individuals give you in return. They also argue that the definition will change in emphasis depending on one's theoretical perspective and field of study. Wood and Jefferies (2002) however, divide the construct of identity into three distinct areas; social identities assigned by others to define people as a social object; personal identities assigned by oneself; and self-concept or the *'overarching view of oneself as a physical, social, spiritual, or moral being*' (p.90).

The identity of a primary science teacher may not even be one individual social identity. Clark (2012) suggests that the identity and emotions of a primary teacher cannot be separated from the primary science teacher identity, the teacher of children or the school leader, as these identities are all entwined and dynamic. The nature of primary teaching and the culture in primary schools can encourage an identity as a generalist, whose main role is to teach young children.

Identities will be formed by personal histories and will also be influenced by teaching experiences themselves. Nias (1989), in her work on primary teachers, suggests that personal investment, the amount of emotional energy and physical time involved in teaching, the role of the teacher and the historically constructed context of that role, combine to mould the person and their teacher identity. Teacher identities are not static entities, they change continually. Learning to teach can be seen as cognitive but also affective (Turner-Bisset, 2001). Turner-Bisset, (2001) theorises that the two-way relationship, emotions and personality, involved in teaching mean that a lesson can evoke a range of emotions in a teacher, sometimes joy as well as periods of frustration. They also produce a response in the children. The combination and learning that takes place between these aspects of the job shapes and teaches the teacher about teaching itself.

When discussing communities of practice, Wenger (1989) proposes that participation in communities is what shapes a person's identity; in this case becoming part of a school community, sharing the community's aims and practices. Wenger also argues that we form our identities in our non-participation in communities too. When a teacher is new to the school, although they participate fully in the classroom their participation in the whole school community will be peripheral or partial. This happens because NQTs seldom take on middle management roles in primary schools and can help define their identity as a new teacher.

According to Bourdieu (1999), family habitus, including attitudes to science and support of interests in science, can have an impact on primary science teacher identity later in life. They are, what can be viewed as, an early learning community. The identification with science as a subject early on in life or in school has been the focus of recent research due to concerns about the low uptake of science subjects by certain groups of the public. Using Bourdieu's habitus and science capital conceptual model (1999: 2004), the Aspires project (De Witt et al., 2013), surveyed UK primary school children and their parents to ascertain the factors which influence and support children's interest in science and scientific careers (Archer et al., 2012).

The Aspires project (2013) examines the influence of family habitus and capital on science aspirations. Its results indicate that these two factors do have an impact on children's consideration of science as an aspiration, either as qualifications or as a career. The research findings suggest that families play a vital role in the development of children's ideas about science careers and the likelihood of them being able to reach those aspirations. Although this was not self-deterministic, it was discovered that social class was a significant factor in such aspirations. According to the project classification, even in cases where there was little family science capital, relations in science careers or interest in sciences, middle-class families used a range of resources to support their children's interest in science fields. Meanwhile, many working-class families did not have the economic or cultural capital to access unfamiliar subject territories to support their children's interest and were disadvantaged when it came to science careers from primary school age onwards (Archer et al., 2012; Aspires Project, 2013).

Although it could be argued that not all children should want to aspire to a scientific career or qualification, the issue is whether all children can even consider science as an option in the first place. Described as '*thinkability*', this factor seems highly relevant here and applicable to the formation of identity (Aspires, 2013). If science capital is provided in a family their child can at least consider taking science qualifications and could eventually identify themselves as a primary science teacher rather than a primary teacher who teaches science (Sacka, 2013).

In considering whether it is science knowledge that influences the identity of teachers with a background in science subjects, Olsen (2003, cited in Smith 2007) theorises that there is no difference between the knowledge individuals hold and their identity. However, Smith (2007) sees identity growing alongside science knowledge and science pedagogy on an initial teacher education course. This implies a teacher's identity and subject knowledge will continue to grow throughout their career if they continue to teach science.

The beliefs of teachers of primary science will, therefore, not necessarily be consistent and will be subject to change throughout their careers as the socio-cultural influence of new environments, colleagues, experiences and roles shape their world view. The habitus and consequent dispositions of the family, previous experiences and beliefs about teaching science, may be influential but will be subject to change both through the act of being part of a school community and during the process of teaching.

2.3 Part 2. The Socio-Cultural World of Science Education

Lemke (2001) reminds us how the individual interactions between workers in a laboratory and individuals in a classroom are important for the social construction of ideas in science and science education but that it is the larger scale organisations such as universities and subject associations that give the people the scientific tools to make sense of the world through:

> *languages, pictorial conventions, belief systems, value systems, and specialized discourses and practices* (2001, p.1.).

These socio-culturally created values, discourses and practices of science education will now be considered by reviewing the current, key, pedagogic paradigms in teaching science, such as the view that beliefs about the nature of science and the children influences practice, practical work and enquiry and dialogic teaching. These values and practices influence teachers and schools in their own practice of science education. I will also be considering the mechanisms by which these pedagogies are shared with teachers in schools.

Science educationalists have developed their own community of practice from the science research community. Teachers have become part of the culture of science in schools and, through their initial teacher training, have received further values, beliefs and methods about science teaching that are not necessarily shared by the professional scientific community (Chalmers, 2013). Often the teachers are part of national or local primary science teachers' communities, a school community and sometimes their science initial teacher training community.

Part 2 of this chapter therefore explores the nature of science in the primary school and teachers' and science education theorists' views on this subject, the impact of teachers' beliefs about the children in their classes, science in their class, effective practice in science, including enquiry, dialogic teaching, linking what is observed in practical science work with scientific ideas, many described by the Education, Audio-visual and Culture Executive Agency of the EU to be '*successful policies and strategies'* to '*modernise'* science teaching (2011). There is an emphasis on practical science enquiry as this is a teaching and learning strategy, although not clearly defined, that has been ascribed as an effective strategy for teaching skills and knowledge in science as well as being motivational and appealing to girls (EACEA, 2011; Ofsted, 2013; Osborne and Dillon, 2008, Minner, 2010).

2.3.1 Teacher Beliefs about the Nature of Science

The formation of beliefs about teaching science is a complex process. The teachers' experiences of science in the world, as well as their own experiences of science within their own schooling, is likely to have had a profound impact on their beliefs about science, how scientific knowledge is formed and their ideas of what scientific activity looks like in practice. The views of teachers on the nature of science and enquiry appear to be particularly important influences on their approaches to practice in science (Lotter, 2007; Leonard, 2009). These views and teachers' science knowledge are acquired from wider societal views of science and possibly from their family habitus. The science education community has reflected on teachers' views of the nature of science and researched the effect of these ideas on pedagogical scientific practice. In one project, these views were found to exert a profound influence on the way teachers' approach teaching and learning in the classroom: Lotter (2007) found:

> *The teachers' conceptions of science, their students, effective teaching practices and the purpose of education influenced the type and amount of inquiry instruction performed in the high school classrooms* (p.1318).

Teachers need to believe that a pedagogical approach, that they perhaps have not experienced themselves, is an appropriate and effective teaching method for their pupils. This approach also needs to be congruent with their views on the purposes of education.

Kang and Wallace (2005) have developed a framework for teachers' epistemological beliefs, their science teaching and learning styles. They classify teachers' views and subsequent pedagogies into:

> Positivist view group. *The teachers in this group presented scientific knowledge as given facts instead of relating to students' ideas for engaging students cognitively in discussion..*.(p.1301).

Misconceptions view group. *The teachers in this group focused on students' misconceptions and tried to confront them through purposefully planned lessons*…(p.1304).

Systems view group. *The teachers in this group emphasised students' thinking processes and paid more attention to what students knew. They expected their students to progress from scientifically sound but naive ideas to scientific ones through a series of thought-provoking activities..*.(p.1306).

There has been much research on teachers' beliefs about the nature of science (NOS) and how this may or may not influence their chosen pedagogies in science (Koulaidis and Ogborn, 1989; Brickhouse, 1990; Lederman, 1992; Tobin and Mc Robbie, 1997). For example, it would seem reasonable to conject that a teacher with positivist ideas about science, one who believes that science has ultimate truths about the universe, might present science as a body of knowledge. However, the teacher who believes science is a hypothetico-deductive process, where they believe a hypothesis in science can only be disproved with observable data but that does not conclusively lead to new knowledge, may value the importance of practical testing of theory.

In research on teachers' beliefs about science, and the effects of their chosen scientific pedagogies, there have been many problems in identifying what those beliefs are, firstly in eliciting the teacher's ideas and then in classifying those beliefs (Osborne and Dillon, 2010). Lederman and Kouladaidis, (1987) have tried to explore the teachers' ideas in semi-structured interview sessions or by questionnaires. These methods have been criticised by Guerraramos et al. (2010), who believe:

..that there is much to be gained by a move away from research which investigates the (usually naive) ideas about the world of science displayed by teachers in response to direct questions, toward more detailed accounts of the ideas displayed by teachers in situations closely connected to classroom practices (p.299).

They assert that teachers need to verbalise the beliefs behind their chosen teaching pedagogies in the classroom to aid researchers understanding about beliefs and practices.

Despite the concern over data collection methods used in the above research, the results present some interesting views, implying that the pedagogy is more of an indicator of beliefs than declared beliefs. In looking at the views of elementary teacher education students in science, Gustafson and Rowell (1995) found students' teaching methods closely related to their views on science and that their training had little influence on their beliefs. They found that students cherry-picked activities and approaches from their course which were congruent with their original beliefs. Alternatively Lederman (1987), Brickhouse (1990) and Hodson (1993),, all proposed that teachers' beliefs about the NOS had little direct effect on their chosen teaching and learning methods in the classroom. However, these research projects were mainly undertaken in secondary schools, where teachers tend to hold higher educational qualifications in science and so may not be applicable to primary teachers, who often only have GCSEs in science at best. Tightly bound up with ideas about the teaching and learning strategies are beliefs about what the teachers think of their class, which will now be considered.

2.3.2 Teachers' Beliefs about the Children in their Science Lesson.

In studies on primary school age children, teachers' views of children were thought to be a self-fulfilling prophecy when it came to achievement; Brophy's seminal work (1970) put forward the idea that if a teacher thought the child was more able they would encourage and help them more than those they thought less able. More recent studies have been less conclusive and research in primary schools appears to have a different outcome. In New Zealand, for example, Rubie Davis (2006) appeared to find that teachers' expectations were influenced by the ethnicity of the child, specifically Maori children, but not consistently social class or gender. In the Netherlands, Timmermann et al. (2016), reviewed teacher expectations against teacher perceptions of student attributes in the first few years of schooling. They found patterns which indicated a child's gender and social skills had an impact on the teachers' expectations, with higher expectations of girls and socially adept pupils. However, they found that teacher expectations had a greater impact on some children than others, with those most affected coming from low-income families and minority ethnic boys.

These studies are not science specific. One study that looked at teacher attitudes and gender found that teachers did not disadvantage girls or boys in science. However, there was evidence that teachers tended not to encourage girls into sciences as they were concerned about obstacles that girls might encounter in male dominated subject areas (Bank, Delmont and Marshall, 2007).

However, it should be noted that Hattie's quantitative impact study (2012) found that teacher expectation had a limited impact on achievement compared to other identified practices. This may mean that although teacher expectation has an impact it has a lesser impact than other factors at work in the classroom such as students' own expectations and feedback from teachers.

2.3.3 What is Effective Teaching in Science?

In discussing the beliefs of teachers about effective science teaching there should be consideration of what the science education community considers effective science teaching from the perspectives of researchers and policy makers. Much of the research discusses general teaching effectiveness rather than science teaching effectiveness. Many of the features of effective teachers will be shared by science teachers and so the research is worth some scrutiny. Those who have attempted to define what makes an effective teacher differ in the value they put on innate teacher characteristics and learnt skills.

Turner-Bisset observes that we judge effective teaching by the '*response of the children*' (2001, p.xi). This describes a focus on the result of the teaching pedagogy and subject knowledge. She also points out this can be a very subjective process interpreted by the beliefs and experiences of the observer.

McBer commissioned by the DfEE to identify the characteristics of effective teachers (2000), divided the attributes he identified into professional characteristics, teaching skills and the classroom climate. He concluded that neither age, experience nor qualification had a significant impact on who was an effective teacher, neither did their school context. He stated that effective teachers did not necessarily have different characteristics than others but they had them at:

> *higher levels of sophistication within a structured learning environment* (2000, p.9).

He identified 'micro-behaviours' more prevalent in effective teachers: effective questioning, differentiation of the curriculum, variety of appropriate teaching methods and inclusion.

Hattie's (2012) research on 'visible learning', a meta-study of 1000-plus research projects on raising achievement in schools, has received a great deal of attention. He identified that the teacher has the greatest influence in the school on children's achievement but focused on the effective behaviour of teachers and its subsequent impact on children, describing teaching as a practice and not a science. In his view, therefore, the effective teachers were those who drew on more of the practices that have the greatest impact. Interestingly in his quantitative research, teaching practices such as effective questioning, enquiry-based learning, as well as other practices identified by others, such as Alexander (2000;2008) do not appear to have as much impact on achievement as an atmosphere of trust or feedback to individuals on their progress against learning objectives. Some of these identified practices confirmed the work by Black and Wiliam~~s~~, (1998), who in their meta-study of practices which made a difference to learning, in which they identified feedback on current performance, clear guidance on what to do to move towards the learning goals and an explanation of those learning goals. The latter started the assessment for learning focus still present in schools today. However, they also identified teacher questioning as a vital element for children's progress, an aspect of their research often forgotten, which counters Hattie's finding that questioning practice has a much lesser impact on pupils.

Critics of Hattie's work, such as Terhart (2011), point out that Hattie admits he does not cover variables affecting achievement outside the school environment and that he only draws on quantitative studies and can only use studies with measurable student performance indicators. Indeed, this gives a restricted view of the outcomes of schooling and teaching.

In the present educational climate, the government has a set of teaching 'Standards' (DfE, 2014) that divide the skills and attitudes of teaching into a number of measurable elements that teachers are judged against when training and in a teaching post. The Standards include expectations of children's achievements, planning, teaching and assessing skills, as well as ensuring individual and class progress in the curriculum. Added to these is a set of professional attributes such as upholding '*public trust in the profession and maintain high standards of ethics and behaviour'* (DfE 2011, p.14).

Ofsted clarifies some of what they are looking for in effective science teaching in their subject reports on science. In 'Success in Science' (2011) they express concern at the lack of relevant subject knowledge of the teachers observed and question whether the teachers are able to draw on appropriate pedagogies to meet the needs of all pupils (Ofsted, 2011). In examples of outstanding practice, they identify features of effective questioning, mentioning sequenced conceptual development several times in their published example, presumably because they think these are important features of effective teaching in science.

A common feature of the three afore mentioned publications by Hattie, McBer and Ofsted, is their focus on the teacher reflecting on the evidence for what makes an impact and what does not and then learning from this information e.g. *'reflect systematically on the effectiveness of lessons and approaches to teaching'* (DfE, 2015, p.11). McBer describes this as '*analytical thinking'* (McBer, 2000) and Hattie describes teachers as '*evaluators and activators*' (Hattie 2012, p14). This focused reflection on outcomes appears to be an important element in developing effective science teaching.

Views on what makes effective science teachers set a context for the research in this thesis, but my focus is on what those teachers themselves <u>believe</u> is effective for children's learning. The next section reviews current pedagogies considered to be effective practice in primary science education by educational researchers and policy makers. The discussion starts with socio-constructivist approaches in science education.

2.3.4 Socio-Constructivist Pedagogy in Primary Science

In considering paradigms of science teaching theory and practice, socio- constructivist approaches in science education are still dominant in primary science teaching (Solomon, 1994; Osborne, 1996; Skamp. 2008 Garbitt, 2011). This paradigm will impact primary teachers through exposure to the socio-constructivist theories in their training and from other teachers. This paradigm shift started with a group of science educationalists, principally Rosalind Driver, from King's College London and Liverpool University, meeting in Paris in 1978, who had concerns with the science curricula and pedagogical methods on offer at the time. They considered there was a conceptual mismatch with the science curriculum and the level of understanding of the pupils. They produced a series of research projects to explore children's thinking in science; CLIS, a secondary research project (Children's Learning in Science, 1980's), and then SPACE (Science, Processes and Concept Exploration, 1990's), a primary age-range research project on children's alternative frameworks in science.

Most of their research found that ‘common sense’ alternative frameworks that pupils held to explain the natural and physical world were resistant to change through teaching (Novak, 2002). In fact, the CLIS and Space research recognised that most teaching appeared to undermine children’s understanding (Driver, 1985), perhaps by destabilising their existing beliefs.

The research on children’s misconceptions and the work of the CLIS project in secondary schools led to a pedagogical approach that consisted of different stages of eliciting children’s ideas about a science concept and providing practical science activities that challenged their existing ideas. Curriculum projects such as Nuffield Primary Science curriculum materials (Nuffield, 1997) and Concept Cartoons (1999) were used to establish children’s understanding and misconceptions in science and activities were suggested to challenge these ideas. These are still seen in primary classrooms despite the original assertion of the SPACE research that ‘misconceptions’ or alternative frameworks’ are persistent and unlikely to change as the result of a couple of activities in the classroom. Anderson (2007) finds that the use of socio-constructivist approaches, such as the Nuffield Primary Science materials, had little impact on the differences in science achievement between high and low achievers. Transferring a theory to a pedagogical approach can be problematic. Osborne reminds the teacher that a theory and the practices originating from it are not always the same; aspects of the theory can be lost (Osborne, 1996).

2.3.5 Practical Work and Scientific Enquiry

Practical work, and specifically, scientific enquiry in science education, have been an important pedagogy through which to share the skills and knowledge of scientists. They are a pervasive paradigm of the primary science education community. This paradigm is evidenced by a UK survey of primary and secondary school science teachers, where 99% of the teachers believed practical activity to be beneficial to children’s development in science (Score, 2008). This section considers the contribution and effectiveness of the pedagogies of practical scientific activity and science enquiry to children’s learning in science.

Practical work has been defined by Millar as:

> *Any science teaching and learning activity in which the students, working individually or in small groups observe and/or manipulate the objects or materials they are studying* (Millar, 2010, p.109).

This is a broad description of the kind of activity that happens in primary school science and could even include watching a demonstration by the teacher. In research on UK teachers' views of what 'practical work' means in science, Score (2008), suggests complementary activities such as investigations/enquiries, laboratory work and field work but also tasks such as analysing data and complimentary activities such as surveys. Primary teachers were found to be willing to include a wider range of science activities into the bracket of practical work than secondary teachers (Score, 2008). Perhaps secondary teachers, often with degree level science, have had a longer enculturation into the world and culture of science and, therefore, more fixed ideas about what constitutes practical and non- practical science activity (Score, 2008).

Practical work is often ascribed to the aim of developing pupils' range of knowledge and skills. Practical activities aim to address the substantive knowledge of science, syntactic, procedural skills, as well as communicating the nature of scientific activity and motivating pupils. It would seem inevitable that with such a diverse range of aims for practical work some are addressed better than others (Score, 2008). From the primary teachers' perspective, it was generally felt to be a beneficial activity for pupils (NESTA, 2005). However, in a survey of pupil opinion, 71% found practical work to be enjoyable but 48% of pupils identified '*having a discussion/debate in class',* or 45% '*taking notes from the teacher*', as more helpful strategies to aid learning in science (Cerini, 2003). Teachers believed the purpose of practical work is to teach scientific skills and to motivate pupils, but only 37% stated it was to teach concepts in science (Score, 2008). This may indicate some congruence between the views of teachers and pupils over the separation of practical ideas from conceptual learning in science education.

2.3.6 Enquiry as a Type of Practical Work in Science

Enquiries in science lie within the range of activities considered practical. The idea of an enquiry can be traced back to the theories of Dewey (1938), who described the process of learning knowledge as a process of discovery. This process of discovery, combined with socio-constructivist and socio-cultural perspectives on learning, has resulted in a focus on enquiry across the curriculum but especially in maths and science education (Osborne, 1996; Tobin, 1993).

There is disagreement about the definition of enquiry as a type of practical work (Grandy and Dusch, 2007). In fact, at an international symposium on scientific enquiry, Abd-El-Khalick described an '*international proliferation'* in the meaning of the term inquiry/ enquiry (2004). Enquiry is seen as more than the traditional positivist scientific method; gaining knowledge only from first-hand observation. It requires the pupil to '*formulate driving questions, make predictions, conduct investigations, and communicate science findings'* (Lui, Lee and Lin, 2010). There is a sense of the child's agency in the process of enquiry not always evident in practical work where a child can be following a teacher's instructions. The international symposium identified a range of activities that would characterise enquiry, such as hypothesis, methodology and analysis of the positivist scientific model, problem-solving, designing experiments, deriving conceptual understanding, knowledge as temporary truths and creative inventive activities (Abd-El-Khalick, 2004 p.2).

Enquiry in science, as a pedagogical approach, has received much attention especially in the US where it was identified as an important pedagogy for science by the National Science Foundation (NSF) in 1996, and has permeated much curriculum design and research ever since. This focus on enquiry in science has had an impact on our own curricula across England and in science education policy across Europe (Rocard, 2007). In England, enquiry is identified in the previous and most recent National Curriculum for Science publications (DCSF, 1999; DfE, 2013), but is often referred to as 'investigation' in the context of primary science (Harlen, 2005). The 2013 curriculum states:

> *These types of scientific enquiry should include: observing over time; pattern seeking; identifying, classifying and grouping; comparative and fair testing (controlled investigations); and researching using secondary sources. Pupils should seek answers to questions through collecting, analysing and presenting data.* (DfE, 2013).

The different rhetoric around the use of enquiry would certainly indicate that it covers a range of views of activity located within the remit of scientist, pupils and teachers

Scientific enquiry has its roots in socio-constructive theory (Osborne, 1996) and the teaching and learning methods arise from an interpretation of these theories. Enquiry can be seen as congruent with Vygotskian socio-constructivist learning theory which suggests that pupils are active assimilators or rejecters of concepts and that they hold a range of alternative frameworks in science that help them to explain their world (Driver, 1985). The role of the socio-constructivist teacher is to help pupils explore and challenge these ideas through experience with their physical world by testing out their ideas and challenging their explanations e.g. enquiry. In this way, an enquiry as Abd-El-Khalic's (2004) 'enquiry as a means', as the methods for helping pupils to develop their thinking and ideas.

2.3.7 Are Practical Activity and Science Enquiry Effective Pedagogies to Teach Science?

Practical activity and science enquiry have been prominent in science education rhetoric for over half a century. They are cited as effective pedagogies to raise standards in science teaching (NRC, 2000; POST, 2003; OFSTED, 2007; Rocard, 2007). Yet enquiry's prominence in literature may not be a measure of its effectiveness as a teaching pedagogy (Anderson, 2007).

In England, schools do more practical activities than most other countries, identified by the International Maths and Science Survey (Martin et al., 2012). In a NESTA survey, an extraordinary 99% of teachers felt that enquiry learning in science, rather than practical work, had a positive impact (NESTA, 2005). There are disputes as to whether this enthusiasm for practical work is born out of the achievements of pupils (Anderson, 2002). A science teaching programme can be a complex combination of social, pedagogical and environmental factors and therefore, it is hard to demonstrate the impact of learning using practical science pedagogies rather than non-practical ones. Hewson and Hewson, (1983) reported a significant increase in scientific understanding in their research on practical work and yet many others have been unable to detect more than marginal effect (Hofstein & Lunetta, 1982; Mulopo and Fowler, 1987; Watson et al., 1995).

However, there are reported noticeable effects in scientific attitudes, skills and logic through scientific enquiry activity rather than just practical activity (Anderson, 2002: Lachapelle, 2010). In a more recent meta-study of scientific enquiry in primary and secondary schools from 1984-

2002, Minner (2010) summarised that in over 138 analysed studies there is a positive effect on conceptual learning, particularly in interventions where there is a targeted instruction that emphasises student active thinking and drawing conclusions from data (Minner, 2010).

The impact on learning seems to be greater therefore for enquiry versus practical science activity, but also for scaffolded scientific enquiry compared to un-scaffolded. This would imply that pupils need structures and support to get the best from enquiry teaching rather than it simply being an unfocussed exploration. They also require scaffolding to enable the construction of concepts (Lachapelle, 2010). In addition, different teachers have an impact on learning; a survey of middle school pupils showed achievement was greater in classes where the pupils had practical experiences compared to those watching demonstrations, however even greater differentials could be ascribed to the teachers in each class (Lotter et al., 2007).

If, as Grandy and Dusch, (2007) and Abd-El-Khalic (2004) suggest, there is a lack of clarity over the definition of enquiry in science teaching, it is understandable little definitive work exists on whether enquiry teaching and learning methods have an impact on conceptual understanding.

2.3.8 Linking Scientific Concepts to Observable Features in Practical Work

As a result of this less than conclusive research on the effectiveness of practical science activity including science enquiry, a number of UK science educators (Hodson, 1991; Osborne, 1996; Wellington, 1998; Abrahams & Millar, 2008) have attempted to look more closely into what goes on in the classroom during practical science lessons. They suggest the apparently low impact of conceptual learning arises from the poor design of investigative activities and the nature of teacher interaction with children in the classroom.

Millar (1994) provides some useful theories of the processes involved in pupils' understanding of Inquiry-Based Science Education (IBSE) lessons. He states children have to make the links between two domains of 'objects and observables' and 'ideas'. He is critical that most 'inquiry-based science education' (IBSE) does not achieve the aims of the teacher and that while procedural knowledge is often developed, substantive knowledge of science concepts is not. Hodson and Osborne raise similar concerns as to the effectiveness of practical activities (Hodson; 1993; Osborne, 1996). Al-Naqbi, (2010) identifies that teachers seldom allow primary students enough independence in their enquiry practices, which consequently hampers the pupils' development.

Abrahams and Millar (2008) devised a more structured analytical framework useful for critical evaluation of science tasks and their effectiveness in developing different types of knowledge. This framework is summarised in Figure 1, below. The cells in the table are not independent of each other as they state it would be unlikely that a task would be effective at the 2.i level if it were not effective at the 1.i level

Effectiveness	**Domain of observables (0)** (objects, materials and phenomena)	**Domain of ideas (i)**
A practical task is effective at Level 1 (the 'doing' level) if …	… the students do with the objects and materials provided what the teacher intended them to do, and generate the kind of data the teacher intended	… whilst carrying out the task, the students think about their actions and observations using the ideas that the teacher intended them to use
A practical task is effective at Level 2 (the 'learning' level) if …	… the students can later recall things they did with objects or materials, or observed when carrying out the task, and key features of the data they collected.	… the students can later show understanding of the ideas the task was designed to help them learn

Figure 1. Analytical Framework for Considering the Effectiveness of a Practical Task (Adapted from Abraham and Miller, 2008, p.1949). Reproduced with Permission from Taylor and Francis.

In their observations of science lessons for 11-16-year-olds, Abrahams and Miller found practical activity was successful in the domain of observables, with pupils remembering these after the task; in contrast, the scientific ideas were not recalled even during the task itself

(Abraham and Miller, 2008). The researchers are aware they observed one-off lessons with no recap and feedback lessons, so acknowledge they may have missed the integration of the theory and practice. In light of what Hofstein, Lunetta (2004) and Hodson (1990), identified as some of the aims of practical activity in science, the Abraham and Miller research focused on the skills and knowledge of science as well as an understanding of scientific activity but did not research teaching on the nature of science.

With a similar focus on the experience of children within science lessons, a meta-study of science classrooms in primary and secondary schools in the US, by Schroeder (2007), identified correlations between certain teaching strategies and achievement in science. Ranking teaching strategies in order of their effectiveness on science achievement, he found that providing an enhanced context had the most beneficial impact. Schroeder described such a context as '*teachers relate learning to students' previous experiences*' or knowledge, and/or engage students' interest through relating learning to the students'/ schools' environment or setting (2007, p.1446). However, his study did not separate the conceptual learning from the skills and learning about the nature of science. Schroeder's research, like the work of Abrahams and Reiss, (2012) suggests that it is the responsibility of the teacher to make the connections between parts of the learning experience in science, whether those links are to previous work or to features of practical activity in science.

In a UK study of both primary and secondary science classes using the same analytical tool, Abrahams and Reiss (2012) suggest that primary teachers spend more time on the 'ideas in science' than their secondary counterparts, whereas the secondary teachers spend longer on the actual doing of science activity; this allows the primary pupils to experience more conceptual scaffolding than the secondary pupils. The researchers argue this is important as ideas do not 'jump out of data'. However, there is evidence in this research that the teachers had not explicitly planned how they were going to teach conceptual ideas to the pupils. As Anderson (2007) and Miller (2010) suggested, there was more guidance on *what* to teach in science than *how* to teach the content. It could also be synthesised from the research by Abrahams and Miller, and Schroeder, that it is the interaction between the teacher and pupil, or between the pupil and fellow pupil(s), that has a more significant impact on the achievement of learning aims in science education than the type of pedagogy.

2.4 How Do Teachers Learn Science Education Pedagogies?

This section considers some of the ways that teachers develop their beliefs and practices once in-post in school, from being a newly qualified teacher to a more experienced teacher of over five years standing.

Huberman's model of teacher career development, as reported by Richter et al., (2011) is a useful model for the definition of a teacher's career stages. He defines five stages; 0-3 years as a time of 'survival and discovery' where new teachers are concerned with behaviour management, express emotions of feeling swamped and tired by the remit of teaching but also a sense of discovery and achievement. In the 'stabilisation' phase, that is said to occur in years 4-6, teachers refine their skills. The third stage can be seen in the middle years from 7-18 years when "experimentation and activism" or "reassessment and self-doubts" take place. The final two stages, from 18 years to retirement, are characterised by stocktaking, serenity and conservatism (Huberman, 1989 cited in Richter et al., 2011).

As an alternative, Richter et al. (2011) add teachers' ages, to Huberman's model, in order to analyse the type of professional learning activity in which they take part. However, they only compare in-service training, teacher collaboration and the use of professional literature. They surmise from their research that younger teachers are the most likely to undertake formal training, peaking at 42 years of age, while older teachers are more likely to use professional literature to inform their practice. Teacher collaboration with peers seems to decrease with age.

In researching the types of activity that teachers use to learn pedagogy, Grosemans et al. (2015), in Belgium, consider the types of professional learning opportunities that primary teachers undertake at different stages of their careers. They differentiate between informal and formal learning opportunities that teachers use; formal being defined as courses, in-service days and arranged training in a structured learning environment; informal learning might include collaboration, reading, observation, discussion and using the internet. While informal learning does not take necessarily take place in one environment (Richter, 2011), and can include the classroom, formal activities are commonly removed from the classroom. Grosemans et al.'s findings concur with that of Richter in that more experienced teachers use less formal activity and less collaborative activity but still use a range of informal learning methods. In the novice teachers, they found experimentation is an important learning activity but is less-used in core subjects where there is a greater national accountability on standards of achievement. Reflection is declared as an important activity by all teachers.

Although these studies look at the types of learning activity that teachers take part in they do not explore the extent to which those activities impact on their practice. Likewise, they do not consider the impact of the complexities of workplace relationships, particularly in schools. Melville and Wallace (2007) researched the workplace community in a secondary science department and theorised that there were conditions that facilitated effective professional learning, such as: engagement, which required trust between colleagues; confidence in their convictions, rather than measuring the value of relationships between themselves; allowing a common identity to develop; and the exploration of new areas to expand the learning and commitment to science education. This theory draws on the work of Wenger’s communities of practice (1998) but appears to be a living example of his theory. If it is recognised that this research occurred in a department where the teachers were likely to have a secure background in the sciences, it might be reasonable to conjecture that the need for trust would be greater among primary teachers, who most often possess only a basic science knowledge. Commitment to science education is harder in a primary school, where teachers are required to demonstrate a commitment to a far larger number of subjects.

In a review of 111 articles on research into the professional development of teachers in primary and secondary teachers across the world, Avalos (2011) contends that there has been a move away from standard CPD courses. She suggests there is a greater recognition of the personal and contextual aspects that influence teachers’ learning, the influence of striving for higher standards, standards-based training and accountability on learning in schools. She reports that co-learning, socio-constructivist approaches among teachers, appear to be having a greater impact on teachers’ effectiveness in the classroom than traditional CPD courses, but that there is little research on the sustainability of these methods.

The above research indicates that teachers prefer different types of CPD activity at different stages in their careers. There appears to be a window early in a teacher’s career where they are more open to experimenting and new initiatives than at other times. Avalos' work indicates an international move towards more situated CPD learning within schools (2000). Yet, the pressures of national accountability and school budgetary constraints, described in Chapter 1, appear to impact on teacher experimentation and access to CPD within core subjects. The current pedagogies and new initiatives supported by the national science education communities, described above, will only impact on a teacher's practice through communication of those initiatives through CPD or communities of practice.

2.5 Chapter Summary

This chapter has presented my theoretical framework for the research. It has drawn on theories of learning and within that has placed socio-constructivist learning such as those described by Vygotsky (1986), and by Lave and Wenger (1991), alongside the participatory socio-cultural theories of learning advocated by Brown and Duguid, (1991), Lave (1996) and Wenger (2000). The socio-cultural theories of situated learning and communities of practices can be helpful models to analyse the agency and status of the teacher within the school community and to analyse the potential for situated learning in the classroom. Unusually for science education, these interpretations are augmented using the social theory of Bourdieu, who, through his social theory, describes the impact of science capital on an individual's workplace and their success within that workplace (1999:2004). Recognition of the beliefs and capital a person brings to a role has been identified as a weakness in the communities of practice models of learning (Cobb and Yakel, 1996; Hodkinson and Hodkinson, 2004; Hodkinson and Hodkinson, 2005). This thesis considers the habitus and capital a teacher brings to a school and how that helps or hinders their development as a primary science teacher. Bourdieu argues in his social theory (2004) that the science capital: economic, social, symbolic and cultural that a teacher gains from their 'habitus', will impact on their position and interaction with the 'field' or school they join. These elements of science capital will have a different value in different schools depending on the existing staff's science capital e.g. a school with graduate scientist staff will value a new staff member with 'A' level sciences more than a school with staff with no science qualifications. A teacher's science capital will influence the way he/she sees themselves as a teacher of science and their beliefs and practices as well as their ability to share their own practice and to learn from others.

The second part of the chapter reviewed current influences on features of effective science activity by the science education community and policy makers. Practical activity and science enquiry feature as the main pedagogical paradigms of primary science education in current practice. This chapter examined the definitions of practical activity in science enquiry and the effects of this activity on pupils' achievement in the classroom of different science education goals, as well as looking closely at what really goes on in enquiry practical work in school. It has suggested that enquiry is effective in raising the motivation of pupils and teaching them about the skills and nature of scientific activity. It has also provided some evidence that enquiry can support pupils' learning of primary science concepts. Within practical enquiry activity, research has been shown to reveal that teachers pay attention to the practical nature of the activity and place less emphasis on linking practical activity to substantive knowledge. If, as Abrahams and Miller (2008) suggest, the interaction between the teacher and pupil is an important aspect of the conceptual learning in science, then what is the nature of this interaction and do teachers' beliefs about science and science education have an impact on that interaction?

My own research therefore primarily focuses on three English primary teachers' beliefs about effective science teaching practices. It will also explore features of these teachers' experience and beliefs examined in this chapter, which are likely to have an impact on their beliefs and practices, namely;

- The teachers' background and qualifications in science
- Their beliefs about the nature of science and purposes of science
- Their beliefs about effective practice in primary science

To explore the process involved in the development of effective practices my research will explore the teachers' experience of developing their own practices through CPD, the school's community of practice in science and the influence of external agencies.

The next chapter discusses the rationale behind the research design, research tools and the chronological order of the research process.

Chapter 3 Research Methodology and Methods

3.1 Introduction

In this chapter, I will describe the rationale behind my chosen research methodology and tools for collecting data, referring to Chapter 2 on my theoretical framework, which informs and underpins my choice of methodology. I will argue for my use of three case studies using interviews, participant observations and analysis of planning materials and discussions over email. Firstly, it may be helpful to be reminded of my research question and sub-questions:

> What are the beliefs about effective teaching practices in three primary science teachers and how are these developed?
>
> 1. What impacts on the three teachers' beliefs and practices?
>
> 2. What are the primary teachers in the case studies' views and beliefs about effective science teaching?
>
> 3. What are the three teachers' views of barriers to using effective practice in primary science?
>
> 4. How do the three teachers develop their pedagogy in the current educational climate?

Research method/collection	Subjects	Data Content	Question addressed
A. Semi-structured interviews	Teachers Shamah, Nathan and Karen.	Historical context, values and beliefs Ideals / definitions/values/views of actions/goals/barriers in science	Identification of views on science/ historical context which may help to explain actions/beliefs Teachers' ideas/ views on effective science teaching

B. Planning/ written plans/ notes on co-planning meeting	Teachers Shamah, Nathan and Karen Researcher	Thoughts behind planned actions Preferred practice modes	What happens in practice?
C. Informal comments noted after teaching in field notes	Teachers Shamah, Nathan and Karen Researcher	Teacher responses/ views of action/ reflection in action/reflection on action	What happens in practice? / Teacher responses
D. Review of practice	Teachers Shamah, Nathan and Karen Researcher	Reflection on actions/questioning on actions	What happens in practice? / Teacher responses
E. Post-practice interview. Transcriptions	Teachers Shamah, Nathan and Karen	Review of actions in practice/ Definitions/views on practice Barriers to practice	Barriers to practice. Teachers' ideals/ views How teachers develop their pedagogy

Figure 2. Research Methods and Data.

There follows a discussion on my chosen qualitative interpretive approaches. I will examine my rationale for using case studies, the advantages and disadvantages of using a case study methodology, its validity and the transferability of the findings from case studies to other contexts. I also discuss the tools used to gather the data in the case studies, participant observation, semi-structured interview and artefacts of teacher's practice such as the co-planning sheets.

3.2 Research methodology

The social constructivist and socio-cultural nature of the research literature presented in the previous chapter would indicate that qualitative interpretivist research has the potential to provide data to answer the research questions. However, I had concerns arising from my background in sciences to the research methods of social science; as Crotty (2010) reflects:

> *On some understandings of research (and of truth), this will mean we are after objective, valid and generalisable conclusions for our research. On other understandings, this is never realisable. Human knowledge is not like that. At best, our outcomes will be suggestive rather than conclusive* (p13).

3.2.1 Qualitative research

My perspectives may be influenced by my working within the field of science education and science where a positivist approach still predominates; this view owes much to the inductivists of the 18th century. However, my views are tempered by the philosophical and methodological approaches of social scientists, who tend to reject the positivist approach used in quantitative methods (Denzin and Lincoln, 2008).

Flick (2014), drawing on the work of Maxwell (1992), describes how interpretive methodology gains its validity from descriptive accuracy by the researcher as well as how interviews and observations are used to describe the participant's perspective. The need to report the observations accurately and objectively is emphasised but the influence of the researcher analysing the work is acknowledged. In this vein, the data was reviewed in an interpretivist manner acknowledging that the co-planning and participation gives access and created a trust that provided rich data.

My own life experience as an advisory teacher of science, as well as a teacher educator, means I have spent many hours observing and talking to pre-service teachers. In these roles, I have acted as a judge and a consultant on teaching practices. This experience has contributed to the formation of my ideas and beliefs about teaching generally and science teaching specifically.

Keeping an open mind and not making judgements about practice is important to the validity of the data collected as well as an awareness of the co-constructive nature of research.

3.2.2 Validity of Qualitative Approaches

Denzin and Lincoln (2008) define qualitative research as:

> *A situated activity that locates the researcher in the world. It is a set of interpretive material practices that make the world visible* (p.4).

In this way, they are positioning the term within the methods and processes of the research. Others, however, define the term by the researcher's approach and mind-set; Erickson (1985), considers that qualitative research is a '*matter of substantive focus and intent, rather than of procedure in data collection*' (p. 12). Berg's definition seems to define qualitative approaches by the data or outcomes of the research. In separating qualitative and quantitative research, he talks about qualitative research referring to the '*meanings, concepts, characteristics, metaphors and symbols of things*' as opposed to '*the counts and measures of things*' used in quantitative research (Berg, 2004, p.4). In the case of my research project, I believed the methods, intention and data are of a qualitative nature in trying to explore the teachers' thinking and practices. Like Creswell (2013), I was not convinced that the two approaches of qualitative and quantitative data collection are absolute opposites. My own scientific background led me to believe that numerical descriptions are just one type of observation.

Humans are well practised in numerical observations from one to one matching in early schooling to the use of percentages in everyday life. In fact, without taking a positivist stance, one could argue that there is a greater shared understanding of quantitative values than qualitative statements where there may not be an agreed understanding of vocabulary between reader and writer (Creswell, 2013). Both qualitative and quantitative research methods seem to be positioned on a continuum. The theoretical perspectives emerge when analysing project design and the value data is given in interpretation.

Qualitative interpretive research has a resonance with socio-constructivist theory. If knowledge is socially constructed, then surely the researcher and participants' interaction and creation of the research data is synonymous with the theory. If the researcher and subject are part of the process the research knowledge must be socially constructed (Crotty, 2010; Flick, 2011).

The critique of qualitative interpretive research could also be an asset to answering the research question in this thesis. The approach allows the researcher to understand the world from the view of subjects in their natural location (Hitchcock and Hughes, 1995; Flick, 2011). Although qualitative research covers a broad range of practices, Flick (2011) identifies commonalities between approaches, including the choice of appropriate research methodologies for an object of study, the reflexivity of the researcher, the reflection of the participants and their diversity, the variety of methods, 'verstehen' (the meanings of actions from the participants' perspectives) as an epistemology, the reconstruction of cases as a starting point, construction of reality and texts as empirical sources (2011). My research design has chosen methods to suit its intentions to explore the experience of the teacher from the teacher's point of view through using case studies using participant observation, semi- structured interview and the co-planning documents.

3.2.3 Case Study

The case study approach for this thesis was a qualitative research methodology which could draw on a range of data collection strategies to look at a particular situation or person, as Stake defines:

> "*Case study is a study of the particularity and complexity of a single case coming to understand its activity within certain circumstances."* (Stake, 1995, p.xi).

Yin, furthers this definition by stating how case studies are a form of empirical enquiry where the case is researched in its real-life context and '*the boundaries between phenomenon and context are not clearly evident'* (Yin, 2014, p.16). In these definitions, Stake is emphasising the data-rich and distinctive nature of a case study, whereas Yin focuses on the blurred nature of the case and its situation. Yin also argues that although a case will be affected by its context, its boundaries are important - Where do the cases begin and end?

The cases in my study were three primary science specialists in Bristol primary schools in the year 2015. Although the cases were all general primary teachers their boundaries were drawn from the fact they all considered themselves to be primary science specialists. This may have been a role assigned in school or by self-election on their initial training course. This was also bounded by researching their teaching in primary science, at a point in time, although this may have been a minor part of their role as a teacher in a primary school (Hitchcock and Hughes, 1995).

Yin, (2014) highlights that there may be more variables acting on case studies than data points reported; each case study is itself a data point. Human behaviour can be influenced by a vast range of factors in and out of the context in which the research takes place and even before the research occurs. Although a researcher can try to report on these factors it is inevitable that they will not be aware of all the factors influencing beliefs and practices in schools. Cohen and Manion (2011) argue that case studies are useful for considering the impact of the context in a research situation as this is an important determinant in cause and effect, rather variables external to the setting. They propose that the careful study of the research context is helpful for an understanding of the range of factors influencing the setting. While it is not inevitable that a researcher will be able to separate the impact of the context on the participant from their beliefs, because human behaviour is complex, use of the case studies does potentially allow for detailed study of that teacher's personal and professional context.

My research methodology drew on three cases of primary teachers of science. It presented intentionally contrasting experiences from three teachers at different stages of their careers and each with different backgrounds in science. The choice of case studies resonates with the theoretical models of Lave and Wenger (1998), who present the experience of workers at different stages of their careers, and Bourdieu (1999) who presents the model of individuals with differing economic capital, in this case science capital.

Hyett et al. (2014) make the distinction between case study reports and case study as a methodology. They propose that the boundaries and methods for selection and detailed contextual data are defining features of the case study as a methodology. They also suggest that a case study methodology can be socio-constructivist, as described in the approaches of Stake (1995) and Bassey (1999), or post-positivist as described in the approaches of Yin (2014) and Flyvberg (2006). Meanwhile, the socio-constructivist approach accepts that the relationship between the researcher and the participant is an inherent factor in the data, creating 'fuzzy generalisations', (see section 3.2.1) or 'naturalistic generalisations' (Stake, 1978). The post-positivists follow protocols and procedures, such as being aware of subjectivity, to enhance the validity and ability to generalise the findings of their data. I recognised the socio-constructive factors at play in case study research as suggested by Stake (1995) but also intended to follow some processes and guidance suggested by Yin (2014) to enhance the validity of the findings as Hyett et al., (2014) state

> *Qualitative case study research is a pliable approach.....that is on the borderline between post-positivist and constructionist interpretations* (p.3).

Yin suggests scrutiny of the case study design during the planning phases in order to construct validity, internal validity, external validity, and reliability. These aspects of the design were considered but with the recognition that there will always be an element of social construction involved in research. This 'borderline' perspective is congruent with my own views on case study research.

3.2.3.1 Advantages of the Case Study

I chose case studies to provide rich, detailed data about 'why' and 'how' the primary teachers form and develop their practice. The data collection, in these cases, was also situated in the place where teachers teach and learn about teaching, in the school and classroom. Flyvberg (2006) argues that case studies are important tool for providing the 'depth' rather than breadth of a researched process or situation. The use of the case studies in this situation were likely to produce in-depth data for looking at the three teachers' beliefs, practices and continual professional development opportunities in their context.

Case studies also allow for the flexible use of a range of data to triangulate and inform analysis (Wellington, 2015). This was important in my own situation where the research data was made up of accounts of everyday teaching actions and co-planning, interview transcripts, planning documentation and e-mails. The actions of the teachers may have been different from their professed beliefs, but this was important data.

Case studies also can have the advantage of providing a sample of the world at the time of the research, although it will always be selected and reported through the eyes of the researcher. The case studies can also capture detail that other research might miss.

3.2.3.2 Generalisability and Validity in Case Study Research

Bassey (1999) and Schofield, (2009) report some of the criticisms that have been levelled at case study research; that the cases are not bounded, that researchers are more concerned with ethics than methods and analysis, or that such research distorts our view of the world. One theme that commonly recurs in criticism of case study research is its application in generalising knowledge to other situations; how one instance can be used to inform a class of instances (Cohen and Manion, 2011). Flick, (2014) expresses concern that the focus on one case can lead to a problem when generalising knowledge from that case. Flyvberg counters this with his view that knowledge is generated from individual cases and argues that generalisation is often over-rated in importance and that '*the force of example'* is often under-rated. 2006, p.228). Schofield (2009) also questions why some interpretivists reject generalisation as a goal as they are trying to show a snapshot of the world we live in; the idea of replication for external validity embraced by positivist researchers seems to counter the approach of presenting a unique sample of life. Atkinson and Delamont (cited in Bassey, 1999) argue this would leave case study research as one-off instances with little relevance to other individuals or institutions. Stake (1978) asserts a type of generalisation where the researcher can apply knowledge to a different situation if the situation was similar. He suggests this process of application is the role of the reader not the writer (2013). This necessitates a detailed description of the research context to allow comparison between contexts to take place. I considered that the detail of case studies could bring information and issues that were applicable to another situation; although teachers are unique individuals, their situations in school may have similarities.

Bassey (1999) proposes his own theory that case studies can produce 'fuzzy' generalisations; that is, generalisation with an element of uncertainty. Such fuzzy generalisation added to a report of findings, he argues, can present a credible proposition to inform other researchers. Flyvberg (2006) meanwhile, draws on the theories of Popper to justify the use of case studies; Popper's falsificationist theories of knowledge state that we cannot know what is true only prove what is not true (1979). Flyvberg thus argues that the case study is an important part of the falsificationist process of creating knowledge by demonstrating what is not true.

Schofield (2009) proposes that features of research design can enhance the generalisability of a case study; she suggests that using multi-site studies increases the likelihood of one of the cases being comparable to another's situation, thereby avoiding the particularity of the sample context. She also counsels that the generalisability can be enhanced by choosing heterogeneous sites for the research. Although Schofield's argument may appear logical, it is not guaranteed that any of the sites in a multi-site research project are representative of other sites where the knowledge may be applied. Cohen and Manion (2011) suggest that the cases need to be carefully chosen to enhance generalisability, either as critical cases or typical cases, or as a mixture of both features. They also argue for detailed checking of the internal validity between the reported data sources to enhance the credibility of the findings. The research in my thesis uses multi-site research, where the case studies are heterogeneous, carefully chosen and internally validated, as are the schools in which they are based. Yin (2014) describes this approach as a traceable chain of evidence where the reader can look back at the raw data and then match that evidence to the interpretation and conclusions. In chapters 4, 5 and 6 the data is reported from the interview transcripts and evidence from field notes and other documents used in teaching are identified and are used to check details of validity across the data.

Researcher bias in the selection and interpretation of data, and drawing conclusions arising from these, can be a threat to the validity of case study research. A researcher with set ideas of the outcomes of research can make theory-led observations, for example by only selecting data that agrees with their perceived outcomes, even unconsciously. Yin (2014) suggest that case study researchers are particularly prone to bias as they have detailed understanding of the themes surrounding research even before the field research takes place. In considering bias, it must be recognised that all humans have some bias in the way they perceive the world, built on their previous experiences and beliefs. However, steps can be taken to reduce researcher bias. Yin (2014) and Bassey (1999) both propose that case study researchers monitor how open they are to different interpretations of their findings. They argue that the researcher needs to make sure they have considered alternate interpretations of their data and provided compelling evidence for their chosen interpretation. I endeavoured to take this approach in my thesis, where appropriate in

Chapters 4-6. The issue of my position as an insider researcher or as an outsider is discussed further in section 3.3.2

3.3 Research methods

In these three case studies, I gathered my data using participant observation, semi-structured interviews and analysis of artefacts of the teachers' practice such as classroom posters to support children's work, questions matrices, planning from the co-planning meetings, emails and handouts to children. Firstly, I will define and put the case for my use of participant observation as well as discuss the disadvantages of this method.

3.3.1 Research Design and Sample

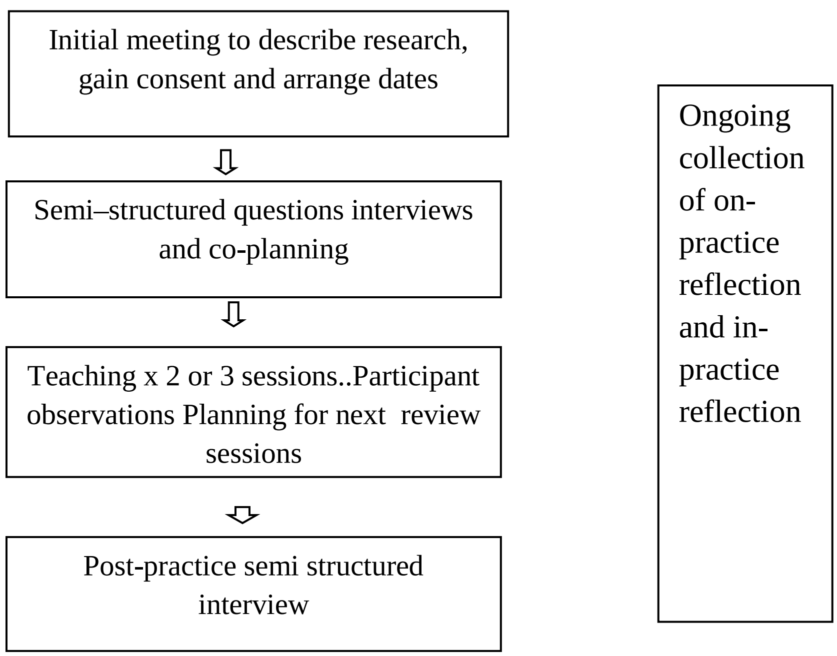

Figure 3. Sequence of Research for each School Context.

Teacher	Pre- interview and Planning	Field Research	Post Interview
Nathan	29.01.2015- Interview and Planning	23.02.2015. 2.03.2015	23.03.2015

		9.03.2015	
Shamah	5.02.2015-Interview 9.02.2015-Planning	27.04.2015 11.05.2015 18.05.2015	15.07.2015
Karen	8.06.2015-Interview and Planning	22.06.2015 23.06.2015	22.09.2015

Figure 4. Timings of Research

3.3.2 Participant Observation

Participant observation was my chosen method used to gather information for the case studies. It can be defined as a mode of observation where the researcher takes on different roles within the field and may contribute to the activity taking place (Yin, 2014). It has the advantage of being a more naturalistic method of research as the participant is often within their own field, engaged in activity with which they are familiar. In addition, it covers actions in real time within the case studies context and provides an insight into interpersonal behaviour and motivations. Wellington (2015) discusses how the degree of participation can be seen on a spectrum from complete observer, through observer as participant, participant as observer, to complete participant. In my research, I oscillated from being an observer as a participant to a participant as observer, because I taught in the classroom as well as watched the teachers teach and co-planned the activities with them. The observations were recorded in my field notes after the teaching. These filed notes provided data that allowed cross referencing with interviews and therefore a triangulation of the data.

The participant observation sessions took place in normal scheduled science teaching sessions in the classroom. I will now describe a typical scenario from the participant to observation sessions as an illustration. The teacher and I had planned different parts of the lesson to lead in approximately 10-15-minute sections. The class teacher would introduce the lesson and learning intentions and recap what had been covered before. I might then have led a section on a part of subject knowledge or a skill we were going to use. The teacher might then relate that to other learning the class had been doing. The children could then be involved in a small practical activity e.g. investigating the parts of a snowdrop. The teacher would bring the class together and consolidate the findings of the class. We would alternate leading and supporting unless the children were all involved in a whole class activity when we would both circulate to support and extend children's thinking. The teacher would often do a plenary at the end of the lesson to recap on the learning. I would have a brief discussion with the teacher on the lesson and success of the teaching strategies. If there were planning sheets for the sessions or support materials issued by the teacher I would endeavour to take a copy away with me. As soon as was practical, I would make detailed field notes of the organisation, teaching strategies and comments by the teacher. Occasionally the discussion afterwards was not possible and took place by email. Further details about the individual co-planning and teaching are in Chapters 4, 5 and 6.

Atkinson and Hammersley (1994) argue that all research, even that at the extremes of positivist research, is participatory; that we cannot study our world without being a part of it. One of the underlying beliefs central to participative research, which differs from positivist research approaches, is the belief that knowledge is constructed in social situations. Mitchell et al. (2009) state that other forms of research can only be representational rather than participatory within the research field as researchers observe and interrogate the field but are not embedded in it.

Participative observation allowed me to be present during times of 'reflection in action' that are not always experienced by researchers (Schön, 1987). It provided a shared understanding of the context for Schön's 'reflection on action', both after the session had finished and after the project. Yet was it reflection? Dewey (1938) questions whether all thought is a reflection and warns against jumping to conclusions through lack of time or effort or through an impatience to complete tasks. The current workload on primary teachers, reported by the DfE to be 59.5 hours a week (DfE, 2014), would certainly put pressure on teacher participants, perhaps reducing the time they have for deep reflection or as Dewey states:

> *sustain and protract that state of doubt which is the stimulus for inquiry* (1938, p.15-16).

I believed that participative observation is one of the most fitting research methods to use, because it gave me access to the ideas and practices of the primary teachers without exacerbating any power imbalances between me and the participants. I also believed, ethically, that putting myself and my own teaching up for scrutiny, was a more democratic situation than just observing and making judgements on the practice of others. There are, however, criticisms of participatory observation methods and an ongoing academic debate about the advantages and disadvantages of insider or outsider positioning of researchers that I will now consider.

The concept of an insider and outsider position of a researcher may appear artificial on first encounter, as it did to me, but as Hellawell (2006) describes these can be useful concepts for presenting and analysing power, knowledge and possible access to data within a research setting. They can also make the researcher aware of the assumptions and bias they may use to interpret the context they are researching. Hellawell draws on original thinking by Merton (1949) to state that a researcher with a view of themselves as an insider to the research context is one who has some previous knowledge of that setting or the individuals within it. An outsider comes from the opposite perspective; possessing no knowledge of the research field or participants.

Mercer (2007) argues that this dichotomous distinction of insider and outsider can be applied to features such as gender, ethnicity and personality but that the distinction does not lend itself to less clearly defined features such as culture or beliefs. Hellawell (2006) proposes that these features are more of a continuum than a dichotomy. Wegener (2014) makes a further proposal that the position of a researcher fluctuates as the research progresses and as activity changes.

These distinctions in researcher positioning are meaningless without considering what these differing positions contribute or how they may detract from the research. The researcher in the position of an insider can be aware of contexts quickly and be aware of sub-contexts that might exist in a field. The researcher may be able to establish a quicker rapport knowing and empathising with the participants' situations. The researcher, being familiar with the context, may also be able to make reasoned judgements about honesty and responses as an insider.

Outsider researchers are often considered to make more objective analyses of the data as they come to the context without expectations and less of a tendency to ‘go native’ (Fontana and Frey, 2008), or be over-empathetic to the participants. However, as Hammersley and Atkinson (1983) conclude, there is no guarantee of valid knowledge by being in either position. In either position, researchers are still susceptible to general observations and bad judgements. He argues for a mixture of empathy and alienation to give a humane and more subjective perspective to data collection and interpretation.

My own position as a researcher in the three participants' schools was complex and fluid. I am a former primary teacher, who has spent most of her working life focusing on primary education. This makes the primary school context familiar to me, but I needed to ensure that because I felt it was familiar I did not reach premature conclusions about how the world of every school functions. To one of the participants, Nathan, I was his ex-tutor, to Shamah I was a former project co-researcher, and to Karen I was a PGCE tutor, who sometimes visited her school. In addition, they all knew I was a primary science academic whose main interest was developing primary science practice at their local university. The participants' knowledge of my role in the university may have created a power imbalance as I could have been seen as an 'expert'; I mitigated this by being clear that my skills in teaching were out-of-date and lacking in practice compared to their own expertise. The teachers were also 'experts' in their knowledge of the children whom I had just met. I made it clear to the case study teachers that my expertise was in teaching initial teacher education students and that they had the expertise in the classroom. I was careful to discuss the sessions we ran together and not to make judgements on the science teaching. I recognised that I had expertise in the range of activities we could use in the classroom and the types of equipment we could use. These knowledges I contributed to the teacher researcher relationship. I made efforts not to influence the teachers to pick the pedagogies they wanted to use. This was harder to achieve with Nathan as he had a recent memory of my role as a lecturer in science education. However, by the time of my last visit he was willing to take the lead.

I was an insider in the classroom in that I have personal experience of their role within school as a teacher and science leader. However, I was an outsider to their schools' organisation. I had supervised students within their school but not in their classes. I had some public knowledge of their schools' reputation from colleagues, the press and students' comments, as well as the school's socio-economic catchment area. Yet, I had little or no knowledge of the ways their school functions every day or of their leadership team, ethos or collective values. I did not know the children in their classes or the local area in which the school is located. It appeared to me that the advantages of participant observation and my position as part insider and outsider outweighed the disadvantages of the possible abuse of trust of the participants. My awareness of the importance of trust would help to prevent misuse of my position.

3.3.3 Semi-Structured Interviews

This section explains my rationale for choosing to use semi-structured interviewing. The research plan was to have an interview at the beginning and the end of the teaching sequence see Figure 3. The first semi-structured interviewing stage can be considered as a reconnaissance for the participative observation (Elliot, 1991). The main purpose of the interviews in my research was to explore the backgrounds of the three teachers and explore the factors in their lives and experiences which may have an influence on their beliefs and practices in teaching primary science. Interviewing is a commonly used method of data collection or perhaps ‘a conversation with a purpose’ (Berg, 2004 p.75). Yet as with any activity, and in particular human interaction, it was much more complex than that. It is influenced historically, politically and contextually (Fontana and Frey, 2008). Human interactions, in general, are influenced by the location, previous experiences between the participants and content of the conversation. The interview is an uncommon type of interaction that brings hierarchies of power to the interaction, expectations about interviews and emotions about personal agency and identity in the situation. It is an artificially created interaction which often ignores normal social practices to gain the data, such as not enquiring about personal views on matters when you do not know a person well, (Hitchcock and Hughes, 1995). Others, such as Chase (2008), describe how interviewing is ‘retrospective meaning making’ which can only be a representation of the past influenced by subsequent experiences and memory.

I chose to use a semi-structured interview approach as it offered a less formal, more naturalistic method which was likely to be more productive in exploring the narrative of the participants as well as ascertaining their ‘subjective theories’ (Flick, 2011). This approach allowed me to alter questions, the language used and follow up themes and ideas, enabling me to clarify aspects and to question further where the subject matter seems relevant (Berg, 2004). It also encouraged the establishment of rapport and empathy between the interviewer and interviewee by becoming more sensitive to the social contexts of the interview (Hitchcock and Hughes, 1995). However, the issue of rapport can be contentious. Duncombe and Jessop (2002) discuss how often we ‘do rapport to’ rather than ‘with’ our interviewees to gain their trust and confidence. They suggest this can raise ethical issues as rapport in their view is ‘tantamount to trust’. I endeavoured to address this concern in my research by being very clear about what I would do with the data and the teachers’ role in the research process. This transparency was important to develop trust and rapport. Fontana and Frey warn that although it is vital to form a good rapport with interviewees to gain informed data, being misled by the rapport between subject and interviewer, in a type of false friendship, can result in a trade-off in the distance and objectivity required (2008).

The interview, and even the information gathered informally about the case, was representative of a snapshot in time. The interviewee could give a different response on a different day and my interpretation could also be altered by subsequent events. We could play different roles on different days all leading to a different outcome. As Stake proposes, case studies are not irreproducible (1995). It is important to recognise that this variation can occur but also that different situations in life occur through the factors that affect each day’s activities. Flyvberg (2006) argues that to suggest case studies have less reliability than other research methods could be to underestimate the care in which a case study is planned. Participants are usually chosen carefully, according to certain criteria, researchers are highly aware of the possibility of subjectivity and variation, and they plan to reduce the effect of variables on the final data. He gives examples where the hypothesis in a case study is refuted by the evidence collected. Flyvberg argues that:

> *The proximity to reality, which the case study entails, and the learning process that it generates for the researcher will often constitute a prerequisite for advanced understanding* (2006, p.236).

In this way, I contend he accentuates the increase in validity of the interview approach rather than its possible disadvantages. In the first stage of my research, I chose to use semi-structured interview questions to follow up the prompts for specific beliefs and opinions as well as descriptions of practice. Opinions and views were likely to be expressed, enhanced and expanded, and possibly contradicted throughout the participative observation phase of the project while planning, teaching and reflecting on actions.

The guiding questions were developed through my research on question design, previous research models and adaptations. Flick (2011) advises that interview questions should be open-ended, theory-driven, and then confrontational (i.e. in opposition to the already expressed views of the participants) to challenge the interviewees' subjective theories. I designed my questions to be open ended in form, while many were theory led; for example, there was an open question on how each teacher thought they linked objects and ideas in science based on the work of Abrahams and Miller (2008). I chose not to use 'confrontational' questions, partly because that was not a natural approach with unknown people, but mainly because, through working with each teacher in planning and teaching, inconsistencies in their personal theories and practices would become evident.

I used 12 initial guiding questions in total, with the potential for follow up questions, to provide a discussion of about 30-40 minutes. The first three questions were designed to stimulate a discussion on experiences of science within the family. The middle section of questions were 'semantic' questions to encourage the teachers to state their goals and beliefs about science education: these were adapted and altered from the research of Crawford, (2007), from their research on learning to teach inquiry. The final set of questions were 'procedural' questions which asked the teacher how they carried out teaching and planning for science teaching. As stated previously, these guiding questions formed part of a semi-structured interview approach which employed conversations and follow-up questions to elicit more information and to provide greater clarity. Appendix 1 gives the full list of my pre-designed guiding questions.

I piloted the guide questions on a teacher, not part of the research project, who was a science specialist. I was struck by some of the repetitions in responses and consequently streamlined and differentiated the questions. Other questions, such as one about an analogy of scientific inquiry seemed to cause the respondent difficulties. These questions were adapted or removed as there was sufficient coverage in other questions to give data on the areas of interest concerned. The pilot enabled me to create greater clarity in the questions and how I would phrase them, as well as some indication of the data they would produce. I am aware that every interviewee is different, but the pilot certainly highlighted some flaws in advance.

3.3.4 The Selection of the Case Studies

The case studies were selected from a group of eight science leaders whom I have worked with in my capacity as a teacher educator, as well as a PGCE supervisor, within schools around Bristol over the last 13 years. In considering possible cases for my research, I tried to choose participants at different stages in their careers. I suspect, in retrospect, I initially unconsciously chose individuals who valued educational research as a vehicle for improving practice. This may have been a strategy for ensuring greater success when approaching teachers.

The purposeful selection of case studies aimed to find teachers to represent differing career stages and science backgrounds. In considering the eight teachers first identified I excluded three using local knowledge about school stability. For example, if a school was on a local authority improvement plan I did not want to burden the teachers further with my research. I wrote emails outlining my research to a selection of 5 classroom teachers. The first two, who I had chosen for their contrasting experiences and backgrounds in science, responded to my request. This encouraged me to seek out the next case who had a different profile in terms of experience and background in science. Flyvberg (2006 p.12) describes the differing stages in their careers as a '*maximum variation case',* where he suggests the case selection has the intention of gathering data about the significance of circumstances on a process or outcomes. Although I knew little about the third teacher's science background or experience, I had other possible teachers to approach if this teacher's profile was too similar to my other case studies. I had not seen any of the three case studies teach before I started the study or elicited their views on science education. I was prepared to find a fourth teacher if I felt that I did not have enough data at the end of the first stage of research.

The choice of participants resulted in three teachers; one of over 5 years' experience, a teacher with 2-3 years' teaching experience and a newly qualified teacher in his first appointment. The teachers had differing amounts of science capital. All taught within primary schools in the

Bristol city area, teaching in lower Key Stage 2 classes. The phase they taught in was not criteria for inclusion.

3.3.5 The First Visit and Interview

As a first stage, I visited each of the three teachers in their own schools and described my research, answered any questions about the research and asked them to complete a consent form for the field research, use and storage of data. These visits lasted about 15 minutes and the teachers appeared to be enthusiastic about the research. I checked they had requested permission from their senior management, gained the necessary written permissions for the data and arranged dates for the first interviews and sessions in the classrooms.

From this first meeting, the participants will have decided whether they trusted me to be in their classrooms and to report on their beliefs and practices. Williamse et al., (2008) describe this as the assessment of whether the researcher has moral values of honesty, courage, concern for the participants' well-being and ability to accept criticism. In my role as an advisory teacher I would be sent to schools I did not know to support and work with science leaders. In this context, I developed skills in gaining the trust of the school science leaders in a short space of time and have always aspired to the moral qualities described by Williamse. I have also been in previous situations with the three participants where I have demonstrated these moral values; in bringing groups of students to their schools, as in Karen's and Shamah's case, I have had to ensure the well-being of the teachers during the process as well as that of the children. Nathan too had previously seen me ensuring the well-being of students in a position as an Initial Teacher Education (ITE) tutor. In addition, I was careful to arrange times that would not put the teachers under more stress as I was aware of their heavy workload.

During the research, I made efforts to reduce the burden on the teachers. I was flexible about the times and duration of meetings and teaching sessions, I altered my schedule and plans, sometimes with little, notice to fit in with the schedule of the classroom; there was only one occasion when I could not teach alongside Karen due to a timetable change. I did not demand any special science topics or pedagogy, I observed whatever was going on at that point in the term for science.

The first interviews were arranged in the participants' own schools at their convenience. The interviews took place in an empty classroom or the staff room. They took about half an hour with, in Karen and Nathan's case, another half an hour to discuss planning. I revisited Shamah's class for another half an hour after school to plan the science teaching. All three teachers were keen to show me their classroom and science displays. Shamah introduced me to some of her student science ambassadors: children assigned to promote STEM subjects in school. The teachers' actions might have been a strategy to emphasise their credibility as teachers interested in science or they might have imagined that this is what I wanted to see. These interactions, however, gave me an opportunity to demonstrate my interest in their professional lives, which helped to build trust and rapport. These interactions were recorded as part of my field notes.

3.3.6 Planning Meetings

The planning meetings were a delicate balance between accepting the ideas the teachers had about the science activity yet being able personally to contribute something to the planning. I tended to take on leading parts of the lesson that the teacher had already stated they wanted to do as well as being the provider of university equipment that would enable them to run an activity it would otherwise be difficult to resource in school. This strategy helped me to avoid giving my own views on what should or should not happen in the science lessons.

Having access to the process of teachers' planning and co-planning with the teachers gave me a privileged insight into the teaching strategies that they used and the reasoning behind their choices. They talked, during the planning, about why they chose teaching strategies and the reasons why they avoided others if they had completed some of the planning in advance, they explained the plans to me and justified their choices. This was time where they expressed their beliefs about teaching methods, activities they had done in the past and organisational structures. This data was recorded in the field notes after the meetings.

Shamah had most of her planning already in place using her school planning format, see Appendix 11. I led on parts of the teaching she had already planned. Nathan went to the school's commercial scheme of work and drew out parts he thought we had to cover. However, when he discussed this with his year group teachers, it transpired these were the wrong topics. He copied me the scheme and we then allocated sections of the programme of study to plan individually. We communicated our planning by email. Karen knew she was teaching the topic of 'sound' and had clear ideas of how she wanted to approach the teaching. She stated she wanted to do some data logging so together we developed the idea of the data-logging activity around school using university data loggers. She gave me the role of providing the data loggers and explaining to the children how they work along with doing some skills practice with the equipment. Some final arrangements were carried out jointly using e-mail.

I admit to feeling at times that I should contribute more to the planning and teaching as I had asked the teachers for access to their world and their time and felt pressure to give something in return. Additionally, in my role as a teacher educator, I am used to helping students reflect on their own practice and develop its effectiveness at the time. I did this using teaching strategies already mentioned in the interviews in my planning. Consequently, I had to make efforts to ensure I did not take this line with the participants as I was researching their beliefs and practices, not ones I had helped to shape. Yet in another sense we were acting like professional teachers, reflecting on the success of a lesson and planning for the next lesson. My multiple roles within life and in research were areas I had to monitor closely. I have no doubt I influenced the teachers to a minimal extent through my endorsement of teaching strategies I used making an impact on beliefs but hope that my vigilance kept any such influence to a minimum.

3.3.7 Teaching

The teachers and I planned discrete parts of the lesson, so it was clear who would lead and support each element. At times, this meant I was perhaps introducing a video clip to stimulate discussion amongst the class or, at others observing the teacher employ a particular teaching and learning strategy. When the children were working individually or in groups, the teacher and I would circulate to support and question the children. This process was surprisingly uniform across all the teachers' classrooms. My individual experience of teaching alongside each of the three teachers is reported in more detail in the next chapters from my field notes.

I was sensitive to the demands made on the teachers at the end of the school day. I wanted to discuss their views of the lesson and reflect together. I often had to make this brief as a parent would want to see the teacher or the teacher was involved in a school meeting. To reduce the demand on the teacher I kept these discussions to a minimum and put a ranking task into the second interview to allow for further reflection on teaching pedagogies.

3.3.8 Second Interviews and Ranking Activity

There was time between the first interviews and my field research to transcribe the first interview and start to analyse the field notes from the teaching I observed. In Karen's case, the second interview took place in the following school year, 2016-17. Using emergent and directive thematic analysis from the literature, discussed further in Chapter 4, I recognised that the field research or the first interview did not provide enough data on the beliefs that the teachers had about using different strategies to teach different parts of the science national curriculum or sufficient data on their professional development. As stated above, the demands of the classroom did not allow time for much discussion on the teachers' beliefs about teaching pedagogies in science after the lessons.

To gather more data on the teachers' beliefs about the practice, I devised a ranking activity as a tool for eliciting teachers' perspective on pedagogy. This entailed listing the teaching and learning strategies used by us in our teaching. I proposed to ask the teachers which of the strategies they believed, in turn, were most effective at teaching about: the skills and processes of science; the substantive knowledge in science and about the nature of scientific activity. I was interested in their choice of preferred strategies and why. The order of preference was not as important as their thoughts about why the strategies were useful. This activity also gave me another opportunity to make sure that I could record their ideas about teaching strategies and avoid my perspectives.

The second interviews took place in the teachers' classrooms and took about 30-40 minutes each. Shamah had prepared her ranking task before the interview, while Nathan and Karen did their ranking during the interview. These interviews were more relaxed than the first as trust and confidence in each other had built up through the shared experiences of teaching and planning together. I believe this trust encouraged the participants to be more candid about their own experiences and development. There could be an issue in a more candid atmosphere of the participants revealing something they would later regret; data that could reflect on their professionalism. However, the participants still had the cloak of anonymity and my own integrity to protect them.

Duncombe and Jessop (2002) warn of the perils of faking friendship within an interview or research setting. In the interview with Karen (Appendix 12), there is evidence of both of us forming a rapport; we both mirror each other beginning sentences with the word 'so'. I also volunteered my own less successful experiences in primary science in an effort to be collegiate and to reduce the power differential. This may have had an impact on the interviewee's views. Karen starts one response with the statement '*Like you said…*' (C1/5/20) in response to a comment I had made about her recount. I became more aware of this when reading through the transcripts and became more careful not to express my views during the interviews. When I found myself caring about the development and futures of the participant teachers, I was very aware I needed to be guarded in my interactions during the interviews. This was not a problem after the second interview as my research ended with the final interview question, apart from a couple of clarification e-mails. Following completion of the second interviews, I therefore felt able to suggest contacts or routes to developing and supporting their practice without fear of influencing the research outcomes. Once again, this is an example of the many roles that an individual researcher can find themselves in and of one's reluctance to give up a role that makes up their identity, from researcher to advisory teacher to colleague.

The post-practice second interview questions were formulated in response to the field research in the classroom (See Appendix 2). The focus of the questions was on:

- what the three teachers thought were effective teaching and learning strategies in primary science, after I had shared some of their teaching with them
- how they find out about teaching and learning strategies, and
- how they develop their own practice in science.

Some of the semi-structured questions were designed to explore areas not covered in the first interviews, such as the influences and communities the three teachers felt influenced their practice. Other questions were raised on areas in which I had become interested during the research itself, such as the kind of online support the teachers in the case studies used or whether they used the internet as an ideas bank for planning purposes. I surmised that I needed to analyse the influence of internet teaching support on beliefs and practices.

I found the teachers were reluctant, or did not have enough time, to discuss and evaluate their teaching strategies at the time of the lesson. To gain their ideas and reflections on of the effectiveness of the teaching and learning strategies used in the lessons, I listed the strategies used, whether initiated by me, the teacher or jointly, and asked them to rank the strategies three times: for effectiveness in teaching subject knowledge, for teaching skills and processes (the 'working scientifically' element), and for teaching children about the nature of scientific activity. I sent the list of strategies and the ranking task to the three teachers in advance of the interviews but only one teacher ranked the strategies before our meeting. All the teachers in the case studies added their own ideas about effective teaching and learning strategies to the lists I had provided.

3.4 Data Collection and Recording

The post-practice interviews were recorded on a Dictaphone and then transcribed. The transcripts were sent to the participants for amendment or comment after each round of interviews, on their inherent accuracy and to ensure an accurate representation of their views. I encouraged them to question or add data to the transcripts to be part of a democratic research process rather than having the research 'done' to them. None of the teachers in the case studies ever came back to me with amendments or additions even though I encouraged them to do so again when I next saw them. Only Nathan commented, saying he felt a bit embarrassed at his own self-consciousness in the interview. It may be the others considered the transcripts as a fair representation of their views or it maybe they did not have time to review the text.

My own reflections, and any by the teachers, were also recorded as written field notes after the teaching sessions worksheets, if used in lessons, were gathered and kept alongside emails containing details of our joint or individual plans, PowerPoint slides and other teaching materials given to the children.

3.5 Data Analysis Process

The data set I collected for my research consisted of interviews, field notes (including photos of classroom displays see Appendix 3), planning sheets, ranking task examples, and e-mail communications. I used thematic analysis to scrutinise my data set, as described by Braun and Clarke (2006; Clarke and Braun, 2013; 2017). I chose this method due to its flexibility in being able to draw on a range of data sources as well as its potential to reflect the socio-cultural mechanisms in the themes, for example the beliefs about the nature of science. Thematic analysis can elaborate correspondences and differences between cases (Flick, 2014). The analysis can be used for latent, underlying assumption and conceptualisations, as well as semantic, surface or explicit themes; therefore, it was well suited to exploring beliefs in the three teachers. Although thematic analysis is a flexible method of analysing data, Braun and Clarke (2006) advocate a set of processes to ensure its credibility. I shall explain how I followed these processes and how the themes for analysis are finally arranged.

Braun and Clark (2006) recommend that the transcription of interviews is carried out by the researcher as a first stage to become familiar with the data set, making notes on aspects of the data. I followed their advice and having read the whole data set several times I started to code responses or aspects of the data. I collected the coded data under a number of themes and then the themes were revisited and revised to avoid overlap and to exclude weak themes. The themes were both inductive; data-driven, and deductive; in response to the research questions and theory covered in Chapter 2. As Clarke and Braun (2017) and Fugard and Potts (2016) warn, themes do not just emerge from data; there is a recognition of patterns in the coding by the researcher. The researcher also makes an interpretation of the importance of data segments from experience, reading and personal perspective. I was aware of this process and tried to exclude themes that I had predicted would appear but that had little support for the prediction in the data, for example formative assessment.

Analytical themes were as stated above inductive such as the teachers' attitudes to their own school science, views on their own identity as a primary science teacher and differentiation which was notable by its absence. Deductive themes included the ways teachers linked practical ideas to science concepts, their science cultural capital in its various forms, their views on the nature of science, see Appendices 8-10.

Although all types of data can be used in thematic analysis, the differences between data can then made less distinct during the process. Data from interviews gives the researcher information from the choice of language, intonation and pace of speech as well as the context in which the statements are said. Other data, such as a poster on the wall, can contain useful data as part of a set of field notes, but the context of when the poster was created, by whom and for what purpose can be lost. I have been aware of this effect of the analysis and given prominence to the data where I have fuller information on its meaning and context.

As the research had a focus on beliefs and beliefs about effective practice, their formation and development in the three teachers, this meant some of the research required an element of semantic interpretation; taking what the teachers said as representing their practice and beliefs, but also an element of latent analysis; where their actions were interpreted as representing belief (Clarke and Braun, 2013). Some themes, such as the three teachers' beliefs about the nature of science were analysed from both semantic and latent data. See Chapters 4, 5 and 6 and Appendix 9, 10 and 11 for list of themes and codes.

The themes are reported in sections within the following chapter, for example, the reporting and interpretation of the data on beliefs is informed by the themes of types of science capital, beliefs about the nature of science and views of the purpose of science. The themes are reported for the individual case studies and then together to identify common and uncommon features of the data.

3.6 Reflections on my Experience of Research and my Role in the Process

In carrying out this research, I experienced areas of tension that were unexpected. One of the tensions was between attempting to reduce the power differential between researcher and participant and striving for objectivity. On reflection, some of the strategies I used to make people feel at ease is to be self-deprecatory and to make others feel good about themselves through positive feedback. This has benefits and I believe the level of trust between me and the teachers in the case studies was high, perhaps leading to the honest remarks about their own practice. However, my positive comments might have been interpreted as signalling the 'right' answers or actions and distorting the data.

The participatory approach of teaching together, for data collection, also had its tensions. I was reluctant to contribute my ideas in planning lessons as the research was an exploration of the teacher's beliefs about effective practice. It is inevitable that some of the teaching I planned and taught had an impact on the declared beliefs about effective teaching. On the other hand, I found it difficult to plan with another person's set of teaching strategies. However, the participatory research also increased the trust between myself and the teachers in the case studies and usefully shared experiences that we could jointly reflect on.

I chose participatory observation as a data collection tool within the case studies as I was attempting to make my research as democratic as possible. My rationale was that I was uncomfortable making judgements on teachers when I was no longer based in the primary classroom. However, I easily fell back into my teacher educator role of making judgements about what I thought was effective practice, which was not the aim of the research. I also took a nurturing role offering the teachers links to resources for their own professional development. This is unsurprising as I have been in teacher education for twenty years, yet I was surprised how difficult it is to separate your own beliefs from what you observe.

Lastly, some of my own ideas about teaching science were challenged. Shamah's skilful use of a range of activities all with the same clear learning outcome but with skilful linking between the activities and ideas appeared more effective at teaching abstract scientific concepts and skills than lengthy investigations. It has made me reconsider the teaching and learning strategies for concrete and abstract concepts in science and how best to teach them. This has changed my own provision and discussion with the students in science education sessions in the University.

3.7 Ethical Considerations

Written ethical consent was obtained from the research participants and their schools. Details of the research was also scrutinised by the University Ethics panel (UWE Rec. ref no: ACE/15/05/25). Participants were informed that all their names and the schools' names would be changed and that no details would be included that might expose their identities. It was stated the raw data would be for academic purposes only and would be destroyed after use. The participants were informed that the data would be stored at my home, while the research was ongoing, and that they could withdraw their data on request up to a cut-off date following the BERA ethical guidelines (BERA, 2011). Yet, while codes provide us with principles, the critical factor is the judgment of the researcher on when those guidelines are in danger of being breached, and this relies on the researcher's own integrity.

In protecting the participants, I considered the risk of the teachers' reputation and potential damage to their self-esteem (BERA, 2011), which might arise through my reporting on their lessons and the interviews. I mitigated these risks by making my reporting anonymous. I was also careful not to discuss the teachers' teaching with my colleagues or their peers. As previously mentioned, Nathan reported that he was embarrassed at reading his interview scripts; he stated he was concerned with his lack of fluency in discussing his beliefs and teaching rather than concern as to how his practice appeared to others. I reassured him that talking about beliefs and pedagogy was not common in primary schools and that few teachers were practiced at discussing these themes. The lessons involving participant observation did not include any recording of data from or about the children so did not require their or their parents' consent. From the children's point of view, the science lessons were part of their normal classroom activity.

My main ethical concern in the research was the protection of each participant teacher. Teaching in front of another professional can be an exposing experience and I did not want to cause the teachers any undue stress. I stated clearly in advance that the research was about ideas not performance and was explicit about also exposing my own practice, which I hoped would have the effect of reducing the power differential in the research. I also endeavoured to reduce anxiety levels among the participants by basing the research in the three teachers' own classrooms, an environment familiar to them along with their own classes of children.

To develop trust between myself and the teachers, I thought carefully about my interactions with them and how I could support them during the research process. I supplied science equipment to make their lessons easier to resource. I sent them resources to support their planning. I found myself expressing positive comments about their responses in the interview, which I hope would improve their confidence. I also supported their professional development, for example, by suggesting other teachers I could put the case study teacher in touch with to observe their practice (C2/6/6-10) or suggesting planning resources (B2/12/28). Pendlebury and Enslin, (2001) state that educational research can never be totally ethical as it always misrepresents and misidentifies but they argue these aspects can be reduced by considering:

> *the goal is not to push people into functioning in ways deemed desirable by the researcher or the policy makers or research funders, but to put them in a stronger position to exercise their agency in the light of their circumstances and professional obligations (p369).*

My support of the teachers' development could have put them in stronger positions to carry out their professional obligations.

I was particularly aware of the bureaucratic burden on the teachers, especially time pressures, that could arise from the differences in daily vocational activities between schools and university staff. Schools are unpredictable places where illness and seasonal activities can play havoc with the timetable. University staff may also be restricted by their own schedules and working days (Griffith and Davies, 1993). Some flexibility in the research design was therefore needed across the timetable of events as well as judicious use of each teacher's time for interviews and planning. I restricted the time spent in interviews and in reviewing lessons and was sensitive to times when teachers were stressed through time pressures. I recognised this might mean a compromise in the data my research would gain but my main concern was the participants' well-being.

In addition, I felt my own reputation could have been at risk during the research. I have not been a classroom teacher in a primary school for over 15 years and there is an image of lecturers in teacher education holding themselves up as experts. I therefore decided the best policy was honesty. I admitted to being out of practice at primary teaching and having developed practices more relevant to higher education than for a Year 4 class. My open reflections on my own practice seemed to have encouraged the teachers to reflect on their own or given them permission to admit to practices they may not have seen as 'good'.

Any participant research in education will have some impact on the life of a classroom and of the teachers involved. The measures I put in place, which have been described here, reduced that impact and protected the participants from overt harm in the context of the research.

3.8 Chapter Summary

In this chapter, I have provided a rationale for my methodology and research methods and tools. I believe the qualitative interpretive case studies approach is an appropriate approach to gather data from individuals about their beliefs and practices. Participant observation is a way of working alongside teachers in the case studies in a more equal, non-hierarchical capacity to co-create the data that is congruent with my own experience as an advisory teacher and also my own beliefs about research and the role of researcher.

I have recognised the difficulties of bias and subjectivity in this research design and although I believe all research is interpreted through our own experiential and critical lenses (Chase, 2008), I consider that my chosen approach will embed me in the teaching context and allow me to get as near to individual's approaches and beliefs as possible. I am aware I need to separate myself from my third person critical persona to evaluate and learn from the data I gather (Hitchcock and Hughes, 1989). I am also aware that there will always exist an 'otherness', in the form of a power differential between researcher and research participant (Fine, 1994; Katsiaficas et al., 2011), yet compared to other research approaches in education this seems most likely to be reduced through the co-teaching scenario I intend to adopt.

The research approaches I have outlined in Chapter 2 also echo the participatory learning theories described by Brown and Duguid (1989), Lave and Wenger (1991), Lave (1996) and Wenger (1998). I plan to use my own participation to enhance my ability to learn about the beliefs and practices of the teachers within this research.

This first section of Chapters 4, 5 and 6 provides the contexts for the case studies; their backgrounds and current teaching contexts and then analyses themes in the data. The themes considered in this section are: the nature of the science capital that the teachers in the case studies bring to their role as a primary science teacher; their beliefs about effective practice in science and how they have developed as teachers of science in their school community.

What are the beliefs about effective teaching practices in three primary science teachers and how are these developed?

Within this main question lie the sub-questions:

1. What impacts on the three teachers' beliefs and practices?
2. What are the primary teachers in the case studies' views and beliefs about effective science teaching?
3. What are the three teachers' views of barriers to using effective practice in primary science?
4. How do the three teachers develop their pedagogy in the current educational climate?

I will give a contextual background to the three teachers, who are the case studies, describe their personal backgrounds, education and teaching context, as well as describing the sequence and process of planning and teaching with.

Chapter 4 Case Study 1- Nathan

4.1 Nathan's background in science

In this section, I intend to provide a context to Nathan, one of the case studies. I will give some details of his background, teaching experience and teaching context throughout the research period. The data for this section comes from the interviews (B1 and B2) and my field research diaries (FN/ Nathan/ 29.2.15/23.2.15/2.3.15/9.3.15).

Nathan did not come from a formal science background, one with parents in scientific careers or with science qualifications. He stated that he lived near the countryside and spent much of his childhood exploring his rural environment (B1/1/4). He reported that his father had a broad knowledge of science and actively engaged Nathan in experiments, such as building rockets (B1/1/3). Nathan described how he enjoyed science at school, as he had an enthusiastic teacher, but that he '*mucked about'* during lessons (B1/1/5). He reported that he had a minimal academic science background but a personal enthusiasm for science.

Nathan did not take a science degree but identified himself as a science specialist on his Primary PGCE course due to his interest in science (B1/1/18). He had worked in EY settings as a teaching assistant prior to his PGCE training. Since qualifying on his PGCE, Nathan had carried out some supply work and then secured a termly-supply role in a junior school, the partner school to the one he had been employed as a TA. In the 14/15 academic year, he was teaching a year 3 class. Nathan completed his NQT year during the research (FN/ Nathan/23.5.15). The school had allocated him a mentor to support his development during this time:

> *When we were sharing a class I really looked up to him about just how good at teaching he was.* (B2/6/31).

The above quote indicates that Nathan admired his mentor's teaching skills.

Nathan's school had a mixed socio-economic intake of children and was situated in an urban area of Bristol. The school was a large, single storey building, next door to its feeder infant school. Half the children in the school came from minority ethnic backgrounds and one-third of the school spoke English as an additional language; a few at the early stages of fluency. The number of children eligible for the pupil premium in 2013 was twice the national average at 49.8% in 2014 (Ofsted, 2016). The school was judged ‘‘good’ by Ofsted in 2013 (school website accessed 11.6.2015).

During the research, the infant and junior school amalgamated under the leadership of the infant head teacher. This amalgamated school was significantly larger than the average primary school in the UK. Nathan’s class consisted of approximately 28-30 children in a Victorian classroom with a sink. His class was one of 3 yr. 3 classes. The other two yr. 3 classes were run by female teachers of three and more years of experience. Nathan had chosen responsibility for the science planning for the year group (FN/ Nathan/ 29.1.2015).

4.2 Research with Nathan

I met Nathan while he was a student on the PGCE science specialism course. He had kept in contact with me and the science technicians in the Education Department. I initially contacted Nathan by email and attached a letter outlining the research, an ethical consent form asking him if he would like to take part. He replied positively. We agreed on a date and I met him after school in his school. We found an empty room for the first interview. He was apprehensive as to what was expected of him during the interview process but was friendly and seemed genuinely pleased to see me. After the interview, we consulted the school commercial scheme of work, ‘Switched on Science’ (Rising Stars, 2014) and identified ‘the skeleton’ as the theme for the teaching. We discussed the type of activities Nathan wanted to teach including the setting up of a science area in his room where the children could explore objects on his topic as part of the participant observation explained in Chapter 3. Having planned activities to teach the topic ‘bones’, Nathan then wrote to me stating that the school topic was now ‘plants’, the conditions of plant growth and germination with an emphasis on data handling (FN/ Nathan/ 5.2.15). We then divided up the planning and sourcing of resources by e-mail sending each other suggestions for activities. We had another misunderstanding when, the subsequent week, Nathan arrived in reception saying he had got the dates wrong and we were teaching the following week. It would be easy to make a judgement from this sequence of events but research by academics must be low down in the priorities of a teacher with 30 children all with differing needs, and another 10 subjects of the curriculum to cover (FN/ Nathan/ 9.2.2015). Figure 5 shows the range of activities we used when teaching the children over three sessions. There was a gap between the last two lessons as Nathan was on a course.

In teaching with Nathan, he appeared to expect me to lead the planning of the science, especially on my first visit (Email/Nathan 16/1/15):

I would love you to plan the first session...

He might have been repeating the pattern of our previous relationship of teacher and student, or he could have just been relieved that there was someone else to do some of the planning for his class (FN/ Nathan/23.1.15). I did not want to overtly influence what he had planned to do, so I tried to build on ideas and approaches he had suggested in the interview and the planning session; pedagogies that he believed were effective (FN/ Nathan/23.2.15). However, the choice of pedagogies may have been Nathan's ideas in the interview, but my emphasis on the strategies in my planning and teaching will have given him ideas about my priorities and beliefs in pedagogies that he may have internalised. This could have distorted the data, especially as Nathan did not yet appear to be confident in his own practice. However, I had the data from the first interview to cross-check the second interview with to identify the influence of myself, as a researcher, on Nathan's beliefs and was aware of the possibility of my influence.

In interviewing Nathan, I was conscious of his apparent lack of confidence and reticence to express his own views, he said:

.... I 'm the worst interviewee ever (B1/2/6) and *God I'm not very good at this* (B1/2/12).

I found that I empathised when he recounted his idea of a disastrous activity, by mentioning one of my own less successful lessons with a bubble investigation, to make him feel better and also to reinforce that I was not there to judge his practice (B1/5/19-23). Although there is an ethical case for making the interviewee feel less stressed by the interview process, there is also an issue of communicating ideas about effective practice in science and the possible influence on Nathan's own responses or creating a 'false trust' (Duncombe and Jessop, 2002).

Working in a well-resourced university department, I resourced the planned activities in a way that he may not have been able to do. I was aware in providing the resources I was trying to support him to achieve his aims in science but also that I was trying to enhance his teaching experience, so he would be positive about continuing the research. By the third visit, he seemed to be confident enough to plan the lesson without any input (FN/ Nathan/ 9.3.15). I had some concerns that Nathan's responses to interviews may have been made to please me; to say what he thought I want to hear (Fontana and Frey, 2008). For example, he stated:

> *That is our goal, yours and mine to make it fun* (FN/Nathan/23.1.15).

However, the interview is a socially constructed narrative, the participant saying what they think is required of them would seem me to be an inevitable part of any interview (Chase, 2008).

I was also conscious of not reverting into the role of a science advisory teacher or teacher educator. At times, I had to stop myself suggesting ways forward for the children in science as I wanted to reduce my influence on Nathan's views. I was probably deceiving myself as all teaching experiences change us, as Nias (1989) noted, and both of our experiences will have changed our views slightly. However, my focus for the research was the views of the teachers on effective practice.

My second interview with Nathan was in the following term (B2), 23.5.2015. He had completed his NQT year before our last session of teaching together. Nathan appeared to be excited when I arrived for our interview after school. He had recently been chosen to be part of the science group whose remit was to develop science in the new school. He described:

> *Learning hubs ... so there are two, four, six, probably eight of us. Um ... in the science team so we are all going to be working together like how we can improve the teaching of science* (B2/ 1/14).

I felt that Nathan was still trying to please me as his former tutor at this point (FN/Nathan/23.5.15). Nathan indicated that he had formed a close professional relationship with his parallel year group class teacher who we had not met the previous term. This was evidenced by this teacher coming in after her class was covered by a supply teacher. Nathan and the class teacher appeared to be unimpressed by the supply teacher's competence and it transpired that Nathan had gone into the parallel teacher's class to take the register as he showed concern at the lack of classroom control (B2/2/14). This appeared to be an act demonstrating collegiality that I had not seen indications of in the previous academic year. It also was, perhaps, a sign of Nathan's increasing confidence in his own abilities and in his position in the school. Nathan was still at an early stage of his development as a class teacher and a teacher of science when I gathered data from him. He was aware of this and at one point in the interview stated:

I am still trying to be the best teacher I can be (B2/8/4).

I found that the teachers in my case studies seemed reticent to discuss their choice of science pedagogy. This lack of verbal reflection on teaching may be habit, or the culture in the staff room, or a lack of time (Dewey, 1938; Schön, 1983; Pollard, 2014).To stimulate discussion on pedagogy, I collected together a list of the teaching and learning strategies we had use over the three sessions and asked the teachers to: firstly rank the strategies first according to their view on the effectiveness of the activities for teaching the children scientific concepts; secondly rank the strategies in terms of effectiveness for teaching skills and processes of science; and thirdly to rank the strategies on how effective they were in teaching the children to understand about the work of scientists (R/ Nathan).

Teaching and learning outcomes March 2015	Planned by	Key conceptual topics and children's activity
Lesson 1 Part of a plant Brambles video/ Explore the snowdrop/ Observe and raise questions about the two broad beans/ draw. Sponge model of broad bean germinating	Nathan/ Mostly the Researcher	Parts of plant and their functions, through exploration and observation of flower parts, Similarities and differences in broad beans due to germination and non-germination
Lesson 2 Investigation of the best conditions for growth	Nathan Researcher	Recap on the last week's learning with reveal slides

Planning and setting up investigation		Planning investigation for growth using planning sheet- ability to control simple variables and control others. Be aware of the variables for best conditions of growth
Measuring the investigation/ modelling measuring and putting results in a chart using pre-prepared set of plants grown in different conditions Writing to Mr Westley	Nathan	What are the best conditions for plants to grow? Measuring and interpreting data- height of broad bean plants in different conditions Use of scientific vocabulary

Figure 5. Activities planned for topic on Plants (FN/ Nathan)

4.3 Case Study 1 -Nathan-Analysis

In analysing the interview data, a number themes emerged which will be discussed in this section. Some of the themes had been explicitly gathered through a direct question e.g. the beliefs about barriers to effective science teachings. Other themes such as the different types of science capital and views on the nature of science emerged from the interview data, ranking task and field diaries. These themes were: the impact and type of science capital the teachers possessed, beliefs about effective pedagogy in science as well as the barriers and the ways in which the teachers developed their professional practice. The themes and corresponding data source codes can be seen in more detail in Appendix 9,10 and 11.

4.3.1 Science Capital and Beliefs about Science

The data grouped under themes of science capital and beliefs about the nature of science and teacher identity and the purpose of science education in the primary school all contribute to this section. In the first interview, through Nathan's description of his background, there were indications of the types of science capital he brought to his teaching job. In the case of science symbolic capital, usually expressed in science qualifications, Nathan did not appear to have a great deal; although in the context of the school environment or field, being a science specialist on his PGCE course may have had some kudos (B1/1/9). At no point did Nathan express any concern for his subject knowledge in science. He appeared to be secure in this aspect of his knowledge in science teaching.

In the initial interview, Nathan reported how no-one in his family had science-based careers but that his father had a great interest in science and used to build rockets with him as a child. He also reported on his childhood in a rural location which he felt had given him a love of nature (B1/1/2). He expressed an enthusiasm for science; he said he found himself wanting to share his knowledge of science with the children, to an extent that he was concerned he did it too much, for example when discussing the Earth and solar rays in a magnets lesson:

> *..then I thought of something amazing Oh God this is sooo cool and like talking about the earth and how it repels solar rays and like my own subject knowledge got carried away and I said that's how magnets work*.(B1/7/11-12).

His exclamations may indicate his wonder at the science and perhaps his desire to share it with the class. This interest appears to have been initiated by his father's interest in science when Nathan was young. This informal family interest could have had a lifelong impact on Nathan's interest and beliefs about science. These family influences could be social or cultural capital as the relationship between Nathan and his father has affected his interest and value of science and perhaps his pedagogy. He indicated his belief in the importance of science above the other core subjects stating:

> *… but learning about science is going to take you further as a race than being good, I don't know, at literacy and numeracy on their own as independent things* (B1/2/9-11).

Nathan also stated that he thought the purpose of primary science teaching was to raise children's interest in the subject and to '*make the children want to find out more'* (B1/2/6). He repeated this on a number of occasions when we were planning, or after teaching, indicating that the spreading of his enthusiasm for science was an important purpose for primary science teaching and learning for him. Although, as he stated previously, the children may have misconceptions when carrying out primary science and perhaps are not ready for full conceptual understanding until secondary school (B1/5/20-24).

Nathan's science social or cultural capital may also have influenced his view of the nature of science. In the first interview, Nathan appeared to describe his view of science being a body of knowledge; *'it is learning about your world'* (B1/1/21). Nathan expressed a belief that science had a role in societal change especially from an environmental perspective, but he also expressed a socio-economic belief that there was a need for more scientists (B1/1/23). He stated an interest in space and the environment that he recognised as being possibly contradictory, but he justified this by saying in response to a question on the purpose of science at primary level:

> *We should be thinking about the environment. It is really easy to lose hope and think there is not much we can get done now, but I still believe in humanity and one way is through science and new technology and things like that that I think we are really going to need in the future* (B1/1/25).

Nathan's view of science can be seen in his concern about pedagogy. In the teaching activities he planned, he used a PowerPoint with a reveal function to reinforce the learning about plants. He stated his concern at the teaching strategy stating when discussing his beliefs on effective practice:

> *The other thing that I do that is maybe not seen as best practice. We have got flip charts on Power-point things and I make slides that I have made for that lesson and there are bits when we can talk and bits where we write down* (B1/4/22).

The children had to guess what was behind the reveal, at times with talk partners. This also formed part of the recap of the scientific vocabulary used the previous week (FN/Nathan/ 2.3.2015). Even if this does not accurately reflect Nathan's own view of science, it could give the impression to the children that Nathan believed that science was facts to be learnt.

Further support for the suggestion that Nathan views science as a body of knowledge was supplied in our discussion on the effectiveness of teaching strategies for teaching conceptual understanding in the ranking exercise drawn from pedagogy we used in our teaching. The ranking exercise was primarily a tool to encourage discussion about effective pedagogy, but the ranking positions pedagogies were placed was also illuminating in indicating the priority ascribed by each teacher to a pedagogy. Nathan ranked '*teacher explanation'* first, followed by modelling the measuring task and observation and drawing of a broad bean (R/Nathan) (see Figure 6). The ranking of '*explanation*' as an effective teaching strategy in science could imply that Nathan thought that the knowledge he imparted to the children was the most useful strategy for teaching children the subject knowledge of science. However, his second and third rankings of the teacher modelling and observation tasks were more process-led teaching strategies.

Nathan's portrayal of science, in his teaching, as a body of knowledge could indicate a positivist view of the nature of science (Kang and Wallace, 2005). In the views of Kang and Wallace (2005), this would be more likely to lead to an emphasis on the didactic teaching of facts than exploring children's ideas or discussion. Guerraramos et.al.'s (2010) theory that teachers' views of the nature of science were more clearly represented by examining their view on pedagogic science activity has a resonance here. With such differing expression and attitudes to the 'science that scientists do' and that which happens in the classroom, I suspect Nathan may have separated science and school science into two distinct ideas in his mind and had separate views on their nature. This may have resulted in in Nathan having beliefs about science but acting in a way counter to these beliefs. Nathan also, alternately, expressed that he believed that children may have pervasive misconceptions that would be resistant to change (FN/Nathan/ 2.3.2015). This is more symptomatic of a 'misconceptions' view of science (Kang and Wallace, 2005), see discussion in Chapter 2, different from a positivist view of science. It may also be at his stage in his career, Nathan was unclear about the relationship between scientific knowledge and methods and his approaches in the classroom.

Nathan has some social science capital. He is still in contact with his training institution technicians and lecturers. He describes how he has visited the technicians to gain an understanding of rockets you can use in school and appears to use his contacts with his tutor, myself, and the fact he was involved in this research could be seen as capital in his science hub. He states:

> *And I told my team I am meeting with J and that I am doing a bit of research with her. They were getting excited about that as well. Yeah.* (B2/1/8).

All the above aspects may have an impact on Nathan's beliefs about science and science teaching but will also impact on Nathan's view of his teacher of science identity and status in the primary school. Nathan did not see himself a 'master' of teaching or teaching science, in fact, he was often self- deprecatory, saying:

> *.. if someone came into my science lesson they would probably say 'what is going on here*? (B1/2/34).

> *God, I'm not very good at this. I should make my… a really clear goal at the beginning of the lesson*. (B1/2/3).

It may be that Nathan was aware of his lack of symbolic science capital and that this aspect of his identity impacted on his confidence. However, it may also be part of Nathan's nature. When I returned for our second interview after our teaching together, Nathan appeared to be more confident in his teaching identity. He had passed his NQT year and had been chosen for the school science -working group (B2/1/2). This public recognition of his science capital seemed to have contributed to his improved his self-image. When I asked him why he thought he was chosen for the science team he stated:

> *Cos I'm a little bit, because I am really passionate about science, obviously* (B1/2/12).

This could indicate that Nathan was aware that his interest in science has some capital worth in the primary school field where few teachers have a science background.
The next section analyses Nathan's beliefs about effective pedagogy in science, his views on barriers to science and how he links scientific ideas to observable features of a lesson.

4.3.2 Beliefs about Effective Science Pedagogy

In the interviews, when asked about effective strategies in teaching science, Nathan described how he believed that practical activities were how children learn best:

> *By doing it, by hands on, that's kind of what you expect* (B1/6/5).

He attributed this belief to his experience in the EYFS, which he encountered when he worked as a teaching assistant. He talked of his intention to have an exploratory table where children would come and interact with materials on an informal basis. He described this with reference to his early years' experiences, perhaps recognising the importance of informal play in children's learning and the importance of the context, in this instance the children's age, on pedagogy (B1/3/10-14). However, he appeared to talk of doing demonstrations in front of the children, rather than involving children in practical enquiry work (B1/3/11). In the context of a discussion on how he would manage the class he said:

> *Where I would kind of, say want to do a practical activity for the whole lesson, I would do a demonstration or give them visual things, get them interested in the first place* (B1/3/11).

In our planning and teaching together Nathan seemed to avoid planning practical investigative/enquiry activities (FN/ Nathan/9.3.15). The third lesson he planned was mainly a literacy task with no practical science element (FN/ Nathan/9.3.15). In our discussion on the effectiveness of teaching strategies for conceptual understanding used in our teaching, Nathan ranked 'teacher explanation' first, followed by modelling the measuring task and observation and drawing of a broad bean as effective teaching and learning strategies (R/ Nathan). This was in contrast to the pedagogies he expressed in the interview where he said practical activity was the best way for children to learn.

Teaching science concept Ranking	Teaching process skills	Teaching about the nature of scientific activity
Explanation Modelling Measuring Looking, drawing and comparing broad beans Snowdrop dissection-hands-on exploration Talk Partners	Planning sheet for growing activity Recording measurement for broad bean growth Looking, drawing and comparing broad beans	Snowdrop dissection -hands on exploration Video of brambles (?) Examples of subject knowledge Recording measurements for beans Making mistakes

Questioning children going around the room	Snowdrop dissection hands on exploration Modelling measurement	Planning sheet for growing activity.

Figure 6: Ranked Learning Strategies from Science carried out in Class for Nathan

In the lesson where Nathan was planning the session on his own, he chose a writing and reporting activity with the children; writing a letter to a Mr. Westley, to tell him how to grow plants best (FN/ Nathan/9.3.15). He supplied success criteria (described as a toolkit, see Appendix 5) of features to include in the letter such as scientific language, features of letter, explanation and evaluation.

There was no evidence of assessment in the teaching we carried out together, however, this may have occurred at the end of the unit of work as described by Nathan when talking about the scheme of work. He stated, '*the Switched-On Science; there is an end of unit test'* (B2/2/6). In an email, he refers to end of year tests:

> *Sorry, we've been super busy last few weeks... we are assessing the children this week and next week (end of year stuff) so how about the following week?* (E-mail/ Nathan/23/6/15).

Whether this included science or not, I am not aware. However, when discussing the whole school science group activities, Nathan stated how he wanted to devise an assessment system that tracks the children's abilities in science at various stages and that would lead to the differentiation of provision to address areas where the children are working below expectations for science knowledge and skills (B2/ 1/22). He also described a range of methods of how he would assess when describing his perfect lesson:

> *They could just have a science book and here you go here is a camera, take a picture of what you have done, tell me what you have done. Stick it in your science book, in fact, that would be an even better way of assessing it. I could have my names on top of it or have ... (taps table with excitement) one on each table, you want to have the learning*

outcomes and what you want them to achieve for that topic....must, should ..could (B1/9/6).

Nathan may be struggling with practices that allow for on-going assessment at present in science lessons due to his lack of experience.

These contradictory statements and actions on the nature of science and effective pedagogies may be a reflection of Nathan's lack of confidence in organising practical activity, or that as yet he had not developed a repertoire of teaching and learning strategies that felt congruent with his beliefs about science teaching, but it may also be a belief that science knowledge should be transmitted to children through didactic means. It may also be that teaching is changing his beliefs and at the time of the research his beliefs were not fully formed.

4.3.3 Linking Practical Activity to Conceptual Ideas in Science

Data for this section was elicited through questioning in the first interview and through observations made in the field notes. In analysing the links made between scientific ideas and practical activity, the first lesson appeared to have been functioning at the level where the children could demonstrate their understanding of the ideas behind the practical activity. The children demonstrated their recall of the ideas through the initial recap in the following week's lesson (FN/ Nathan/2.3.15). They identified the various parts of the flower and differences in the pre-germinated and dried broad bean and had some ideas that the water had been a part of this and that germination had occurred. As we planned this lesson together, it is difficult to ascertain whether Nathan believed and prioritised the linking of ideas and observables within this lesson's teaching or whether it was through my encouragement.

The next session modelled the measurement and recording of the broad beans' growth and most of the children could interpret the data and stated the best conditions for plant growth. They measured the broad beans and put the measurements in a chart (Figure 5). The second part of the lesson had a literacy emphasis. Although this was identified as a science activity, in observing the class, the main input by Nathan appeared to be on the language features rather than the science. In the session, we appeared to have achieved children linking ideas and observable features of the practical work. The children could recall what occurred and some features of the data, see Figure 1, Chapter 2 (FN/Nathan/ 9.03.15).

When I asked Nathan about how he believed he linked the conceptual ideas of science to the practical processes, the objects, of science, as modelled by Abrahams and Reiss (2012; 2013), he responded '*lots of talk'* (B1/7/7). When questioned further about whether the talk was between him and the children or between the children themselves doing the talking he answered '*both, I try and do both*' but then confusingly followed it up with an example when he was telling the children about how the earth repels solar rays (B1/ 5/19). In using the word 'try' it may mean that Nathan was aware that he prioritised teacher talk when he shared his subject knowledge over engaging with children with their ideas. I conclude that Nathan believed that linking ideas and observables was desirable but that he was struggling to allow the children space to discuss while he developed his classroom management.

4.3.4 Beliefs about Barriers to Effective Science Teaching

Nathan cited classroom management as a factor which presented challenges to his science teaching. He confessed at one point:

> *...probably to my detriment if someone came into my science lesson they would say 'what is going on here' (laughs)B1/2/34).*

He also described his feeling of being limited by the expectations of the school to teach in a prescribed way and the curriculum in the second interview (B2/4/6). Nathan suggested that his views of school expectation of classroom conduct of the children were a limiting factor to his practice (FN/Nathan/2.3.15).

Nathan also discussed the way that his own excitement sometimes stopped him carrying out effective pedagogies; he said of a lesson on the topic of the moon:

> *I have got something in my mind I want to share with them and that ends up coming out anyway…err… but then I am still kind of thinking now we have not finished our planning for that lesson .....(B2/ 5/10-11).*

Nathan's concerns at behaviour in science were similar to those reported in the Score report which identified that 'teacher inexperience' was the second most commonly cited barrier to practical science activity as well as behaviour ranked sixth (Score, 2008). Nathan seemed concerned at the less ordered nature of doing a practical enquiry activity and what others thought of his teaching if they saw the disorder.

Nathan appeared to have a dilemma of wanting to share science knowledge with children, his science knowledge capital, as opposed to allowing the children to enquire themselves (B1/5/31); he stated he believed in exploratory, investigative activity and found himself using didactic teaching methods, perhaps returning to pre-PGCE beliefs about science learning (Gustafson and Rowell, 1995). Nathan's science knowledge capital appeared to be of prime importance to him while he perhaps felt his teaching expertise was not yet fully developed to legitimise his position in the class as a teacher or leader of the learning. Nathan had pedagogies in science, which appeared to be reflect positivist views of science knowledge, as demonstrated by his emphasis on explanation in the ranking task (Figure 6) this seemed to have caused him a conflict as it is not congruent with his espoused beliefs about effective pedagogy. When he tried to pre-empt the research outcomes Nathan stated:

> *… it is obvious I'm going to say. By doing it, by hands-on, that's kind of what you expect. Its probably what people say they want...but in reality, this is probably what your research is going to find out, that it is not…so … (B1/2/20-22).*

He implied that there was a pattern of teachers believing in investigative science but not doing it in the classroom (Score, 2008). This may be his experience in this school, but it also may be his justification for his apparent positivist teaching strategies that he is concerned about.

Alternately, Nathan's experience as a teaching assistant can also be seen as having a significant impact on his beliefs about effective teaching and enquiry (B1/9/17). Being part of an early years' team as his first professional teaching experiences seemed to have contributed to the socio-construction of his beliefs about children's learning; he would have been part of the planning and teaching of exploratory play experiences for children in line with early years' pedagogical practices. This could have been reinforced by his play-like informal first science experiences with his father; that first excited his interest in science. These experiences could be mixed up with his feelings about science teaching, he even admitted to feeling childlike when he planned his perfect science lesson (B1/8/16). These early experiences with science appear to have had a lasting impact on Nathan's beliefs about science.

When Nathan talked about the ideas of incorporating early years' learning strategies into his current practice he unconsciously sighed each time he talked about the topic (B1/3/19). I am unsure as to whether I am in a position to correctly interpret his sighs, but it might have indicated some nostalgia for those types of teaching strategies. On the other hand, at one point he described the science in the early years as being '*a bit dry'* (B1/1/12). Perhaps this suggests he was more influenced by the general teaching and learning approaches in the early years rather than specifically science. He states:

> *Another thing I would really like to try or we could do together is like have an exploration table in my class* (B1/4/10).

This indicates another early years' pedagogy for informal learning. This could be symptomatic of the difficulties in separating the analysis of beliefs about science teaching from ideas about primary and early years teaching pedagogies in general. In primary schools, where teachers teach a whole range of subjects; rather than having set pedagogical beliefs for each subject, they are likely to have transferable general beliefs about children's learning at primary level (Clark, 2012).

Nathan's beliefs about science practice and his early years experiences, mixed with his enthusiasm to share his knowledge, like his father did with him, appeared to possibly cause conflict between his beliefs and his choice of teaching and learning strategies. This may also have been as a result of accommodating the science planning for the other less science confident parallel teachers (FN/ Nathan/29.01.15), or Nathan's lack of confidence in class management and resourcing of practical activities (FN/ Nathan/ 2.03.15). Apprehension about investigative activities may also be enhanced by the child-led nature of enquiry-led pedagogic approaches which may challenge the status and role of the teacher; something that may be uncomfortable for a new teacher (Hayes, 2002).

Nathan may have found the organisational and behaviour management side of practical, hands–on science challenging (B1/3/10), which could have deterred him from planning investigative work for him and his fellow teachers. He says of a practical activity:

> *Yeah, I was doing solids, liquids and gases with like little squeezy pots and by the end of the lesson they were mixing them they were like squirting them out and I had sand mixed up with gel (laughs)* (B1/4/1).

He seems to indicate that the activity was not as ordered as he might have hoped. Nathan's apparent lack of confidence in classroom management skills may improve, allowing him to carry out more practically, investigative/ enquiry-based activities that are congruent with his desire to have a more 'early years' exploratory approach to learning in science. It may also be that he will rely less on his science knowledge capital to give him status in the classroom, resulting in fewer dilemmas about telling the children about science.

4.4 Professional Development

In analysing themes of professional development for the teachers, data was coded according to internal and external CPD opportunities, use of the internet for support in teaching and in school formal and informal support. In interviewing Nathan about his ITE and CPD, he stated that he had developed his teaching knowledge and skills through being a teaching assistant, on a PGCE, where he was a science specialist, and during his newly qualified year where he had been mentored by another, more experienced, teacher (B1/1). He had not attended any course on primary science teaching since the start of his employment or attended any science focused school-based training (B2/8/11).

In his first interview, Nathan mentioned he was still going to get help from the University technicians who he worked with in his science specialism on his PGCE (B2/5/2). He also said of me, as his PGCE science tutor, during a conversation at the end of a lesson:

> *That is our goal, yours and mine, to make it fun and get them interested in science* (FN/ Nathan/2.3.15).

This may indicate an identification of shared values gained on the PGCE science course.

The main influence on Nathan's teaching recently appeared to have been his teacher mentor for whom Nathan seems to have had a great admiration. His mentor was a senior teacher in the school who carried out observations, although not in science, and gave feedback to Nathan as well as forming professional targets and arranging observations of other classes. He said he had been a '*massive'* influence on his practice. He stated:

> *I am still trying to find my own like style of teaching. And I would not say mine is the same as his, but he has got lovely ways of coping with situations and lovely ways of talking. I waffle quite a lot. TEACHER MENTOR is quite concise and sometimes well from some of the work we have been doing If I am talking for 30 min. and they still have not done their writing ... it is like we should have done that 20 min. ago (laughs* (B2/7/1-6).

The teacher mentor still took an interest in Nathan's teaching. Nathan described how he had come into his class to see what he was doing recently (B2/6/21). The teacher mentor was also the leader of the new science hub that Nathan described when I arrived for our second interview (B2/1/18). It may be that the mentor recognised Nathan's science capital, from having closer contact with him, and had chosen Nathan for the science hub.

In the interviews and planning (B1 FN/ Nathan/5.02.15), we discussed Nathan's approach and decisions in choosing effective practices in science. Nathan stated that he took ideas for his practice from a published scheme 'Switched on science' (Rising Stars, 2014). He appeared to use this solely as his guide for activities and for most of teaching strategies he chose (B2/4/4; B1/3/31). He stated that the scheme provided continuity and progression in learning science for the children and was impressed by some of the ideas in the scheme but was unhappy that the scheme was not always a good match for the children's educational needs in science (B1/5/8). Nathan was not impressed by the assessment scheme where the children were tested at the end of the unit (B1/5/7). In our second interview, he talked about how he wanted to change the assessment system to something more formative (B2/10/6-10).

Nathan stated that he did not look online for resources or pedagogies. He stated when asked about the frequency of his use of websites:

> *Not as much as I probably should. I am a member of STEM… err… yeah…and they send me newsletters and I read the news letters, but I haven't really had time to* (B2/7/29-30).

He was not aware of the Association for Science Education (ASE) or the support they offer (B1/10/3). He was aware of the regional science centre at @Bristol (now We the Curious) but was unaware that it had stopped being a regional science centre for CPD (B2/10/22).

In analysing Nathan’s data, looking at his experience in ITE and his lack of training in science teaching since his PGCE, 18 months before the research, (B2/5/2), echoes the findings of the Wellcome Trust (2014). Nathan’s lack of science CPD may have resulted from the attention of the school being firmly based in maths and English where national testing was still in place and whose results can stimulate an Ofsted visit. It may also be the amalgamation of the infant and junior school Nathan worked in, had taken priority over curriculum matters. However, it resulted in little support for science at a time when he was forming and developing practices and beliefs described by Huberman’s model of teacher career development, as reported by Richter et al., (2011 p.118); the time of ‘*survival and discovery*’.

Analysing the CPD science teaching support being given by the school, using the model of Lave and Wenger (1998), Nathan appeared to be on the outer edges of the school community of practice, the periphery, when I first visited him in school. He had only been a staff member for a couple of terms. Nathan did not see himself a ‘master’ of teaching or teaching science, in fact, he was often self- deprecatory about his teaching practice (B1/2/14). This may be a feature of his personality, but it is also maybe that he did not yet feel confident in his own practice. However, he appeared to demonstrate that he had been influenced by the pedagogy of the early years community of practice that he had been part of as a teaching assistant.

In considering the support given by the school’s primary science community of practice, there are, however, significant differences, but also similarities, in the example of the midwives learning their trade in Lave and Wenger’s (1991) legitimate periphery participation and new teachers learning to teach and organise their own classrooms. I have chosen Lave and Wenger's example of midwives as they have a caring role as well as learnt skills; this seems more comparable with teachers than tailors. One key difference is that teachers, such as Nathan, are expected to take on the whole role of a class teacher teaching science, from the first day of term, unlike Lave and Wenger’s apprentice midwives who, at first, took minor peripheral tasks. Class teachers take on the responsibility for the behaviour, welfare and academic development of, often, over thirty children during the school term-times immediately they start their newly qualified year. However, as part of Nathan’s training, he will have had many hours of University-based instruction, making the practice explicit, as well as school experiences which the midwives, such as those in Lave and Wenger’s research, seldom experience. This means

Nathan will have a different learning experience than the midwives in the Lave and Wenger model.

Some of the similar features between the school and midwives' induction is the use of a master to model the role of class teacher. During his first year as a newly qualified teacher, Nathan was paired in classes with his mentor for a term and then in another year group with two parallel classes with teachers with more experience than him (FN/Nathan/29.1.15)The mentor appeared to have been responsible for his general teaching development rather than his development in science, as found by Avalos (2011), and yet had appeared to recognise Nathan's interest in science and had asked him to be part of the science hub (B2/1/6). It could be argued that the mentor was modelling the full participation in the school community of practice (Lave and Wenger, 1991), but not modelling the role of a science teacher, or being part of a primary science community of practice, as Nathan said when reflecting on the research process:

> *It makes me want to keep working with people who want to improve my science teaching* (B2/11/25).

The modelling of practice in science teaching in the classroom might have been a useful process for Nathan to experience and may have helped his development in teaching and managing science teaching.

Nathan seemed to still identify with the external science community of practice at his University, where he did his PGCE, evidenced by him mentioning that he had been to see the university science education technicians a couple of times (B2/5/2). He used the plural pronoun 'we' about the PGCE science specialist group, about me and him but rarely about the school staff in his first interview (B1). These may be indications that Nathan had not yet formed strong relationships in the school community and still felt an allegiance to a previous community of practice he had belonged to. This may have been why, when discussing science teaching, he referred back to the last primary science community he had participated in. Although, having identified this, Lave and Wenger make it explicit that an individual can belong to any number of communities at any one time (1991). At this point in time, it may be that Nathan did not yet feel a full part of this school's community of practice or their science teaching community.

In the second interview, Nathan described his group of teachers in the science hub who shared his interests and who recognised his passion described by him as '*a good little team'* (B2/1/15). He appeared to feel part of the primary science community of practice. He stated he was pleased that the hub was led by his mentor who he admired, who could be one of Lave and Wenger's (1991) masters, supporting and modelling the role of the class teacher and the role of the curriculum leader (B2/1/18). This group may also allow him to explore ideas and strategies he appears to have felt were not appreciated by his previous parallel class teachers. This may have given him the confidence to try teaching and learning strategies he felt were more congruent with his own beliefs about teaching primary science. He had been given the responsibility of reviewing the school science assessment system, described by Nathan as the '*horrible tests'* (B2/2/12). This allowed him to have some impact on the school's teaching and learning in science. However, Nathan explained how the mentor had never observed any of his science lessons or been part of his development in science (FN/Nathan/9.3.15). This may be that the mentor considered that Nathan had more important overarching pedagogies to develop, but perhaps some science education mentoring would have also been beneficial to Nathan in his first year where teaching habits and routines can be formed to give him the confidence to experiment with his teaching. In his own situation, he did not seem to have a 'master' of primary science to model the role, or to open up the practice to him (Hodkinson and Hodkinson, 2003).

It should be remembered that communities of practice are not always beneficial to an organisation or to an individual teacher attempting to develop effective practice in science. This may have been relevant to Nathan's context. The community can equally be responsible for encouraging and perpetuating undesirable forms of practice as desirable forms. Wenger recognises that communities' 'shared repertoires' can be positive or negative, (2000). Nathan did not use any virtual external primary science communities on the internet so had only the influence of his own school science community group on his practice (B2/ 5/10-11). Nathan's lack of a master or any other external communities of practice in science education appeared to mean he had copied school teaching and learning strategies, such as the Power-point reveal (B1/4/21), that he did not feel was effective practice and was counter to his beliefs about science teaching, as a way of fitting in and belonging to a community of practice. If there is not a master, perhaps the community of practice will lie in the peripheries, rather than be led by the school management, subject to the influence of the strongest personality rather than the teacher with the best practice in science.

Nathan did not report any exposure to external science communities of practice for support to develop his practice (B2/9/26), apart from some links with his training institution (B2/5/2). He did not appear to use virtual communities or professional associations (B2/9/26). The fact the mentor attended a science subject leaders' meeting did not mean that Nathan would benefit from the information or contact, as it depended on how much was shared and how much was filtered by the mentor (B2/10/5). The mentor could have been acting as a broker across the boundaries of communities introducing practices from other science communities and making connections, however, Nathan reported that they had not even had staff meetings on science to share knowledge (B2/10/5).

Nathan seemed to be beginning to become part of a school community of practice on my last visit to the school. The science community of practice in this school appeared to be a sub section of the whole community. He appeared to share the teaching and learning aims of fellow teachers (Wenger, 2000) and was pleased to have been asked to join the science working party. Previous communities of practice he had belonged to, such as the community on his PGCE and when he worked as part of an early years' team, seemed to have influenced his beliefs. Wenger (2010) suggests that the journey within any community of practice will shape your identity and beliefs.

In analysing Nathan's use of the internet and published resources to support his teaching, he was solely using the science scheme as a resource as perhaps he was not confident enough to research his own additions or change the activities, he states:

> *I'm definitely guilty of doing that, of trying to plough through (B1/6/27).*

Nathan expressed that the scheme was a good time shortcut when he was learning to manage the planning load of a class teacher. By using the scheme, Nathan did not have to go through the process of matching teaching and learning strategies to learning outcomes in science. He also, perhaps, avoided judgments about his planning from his parallel class teachers as he was using a commercial scheme. He talked about the expectation '*...on you, the teachers to know'* (B1/5/11); he appeared to feel the expectation that he should be able to plan effective lessons in science. In stating this, Nathan seemed to express some concern that the science scheme did not always meet the learning needs of the children but that he was not yet confident to change the planning. Without CPD support, it could be difficult for Nathan to move from this situation to one where he could plan teaching and learning strategies in science better matched the needs of the children and that he felt met the expectations of his colleagues.

In looking at future development of his practice, Nathan suggested that he still needed to develop, and he seemed to recognise the way forward for that development, as he stated:

> *It makes me want to keep working with people who want to improve my science teaching...and doing things like this that make me think and keep on thinking but yes having a bit of time to think is important* (B2/6/ 12-19).

Nathan's data appears to support the benefits of a mentor or 'master' in science to develop his practice in the classroom in science, to introduce him to external science communities of practice and support his planning in science to meet the needs of his class. If recently qualified teachers are not exposed to outside ideas and developments and research in primary science pedagogy, this can lead to perpetuating practice which could be beneficial, or not as beneficial, to children's learning depending on the quality of the practice (Wenger, 2000).

4.5 Chapter Summary

Nathan does not have Bourdieu's symbolic science capital to bring to his school role, yet he seems to have a strong cultural capital from his family where science appears to have been part of recreational activities and was valued as part of the family habitus (2004). This seems, alongside his background in the early years, to have influenced Nathan's beliefs about science as a playful activity with an emphasis of the wonder of science. He has some social science capital through his contacts with his training institution. What he appears to lack is teaching expertise and status in his role as an NQT in his school. This seems to have an impact on his teaching practices where he appears to rely on his knowledge of science rather than his expertise in planning children's activities to reinforce his identity as a teacher in the classroom.

It may be that his more apparent positivist views of the nature of science which conflict with his ideas about effective science teaching pedagogy come from his lack of symbolic science capital. If he had science qualifications he might have experienced the practical side of science to a greater degree and then promote a more process driven pedagogy. However, as stated before, it may be the result of his developing skills in managing children that he sometimes avoids practical tasks.

Nathan's position in the school when I first started the research was very much on the periphery of the school science community of practice and even the school teaching community (Lave and Wenger, 1991). His position appeared to have an impact on his practice in science as he seemed to want to fit in with his peers and he needed to plan for teachers with reported little confidence in science. This seemed to lead to fewer practical tasks and practices such as the Power-point reveal that Nathan felt was undesirable practice gathered from his peers. The parallel year group teachers, also on the periphery of the school science community, appeared to be influencing Nathan's practice; he seemed to want to fit into the expectations of the school. His science capital had meant he had been allowed to plan the science but with perceived restrictions on the type of activity he could plan.

Chapter 5 – Case Study 2- Karen

5.1 Karen's Background in Science

Karen was the second case study in my research. I, again, intend to describe her background, teaching context and the sequence of research in school. I will then analyse the data gathered. The data is collected from two interviews on 8.06.15 and 22.09.15, as well as field notes from the lessons we taught together, the ranking exercise, and emails. The chapter presents Karen's background in science, the context to the research and then analyses the research data.

Karen had been teaching for approximately 3 years at the time of the research. Her parents did not have a formal science background, but she described them as being '*very outdoorsy'* (C1/1/10). She described a teacher at 'A' level who drew on a wide range of teaching methods as being a positive influence on her present practice:

> *Secondary style teaching is so different from primary that I don't think it had much on an impact on my teaching, although my biology teacher did do a lot through...we did a lot of presentations, drama and art. Now thinking about it, it had an impact without me really realising* (C1/9/10).

She studied sciences at GCSE, then Biology and Psychology 'A' level and Psychology on a B.Sc. course with a scientific emphasis.

Karen studied her PGCE at the same university as her degree and had teaching placements in schools in areas around the university. Her first post was in a school in East London where she passed her newly qualified teacher year (C1/10/4). At the time of the research, she taught in an urban school in Bristol in a year 4 class.

Karen was the science leader of the school at the time of the research. She appeared to have strong personal and professional friendships with the other teachers; she stated she had been on holiday with some of the teachers (C2/1/5). She also evidenced her professional relationships by mentioning the way her working practice with her partner teacher had got '*better and better*' (C1/9/19).

Teaching and learning outcomes June 2015	Planned by	Key conceptual topics and children's activity
Lesson 1/2 Learning intention: that children will experience and have a model of sound as vibration and of sound travelling through air/ materials.	Researcher and Karen	Identification of sounds around the home Elicitation of children's ideas on sound using a photo Discussion of what makes good science talk/questions framework from previous work in science Carousel of sound activities: Air -Zooka/ string telephones and space phone/ giant tuning fork and little tuning forks/dancing rice/ sound and headphones. One child to record talk. Video of model of sound moving. Catering organisation healthy smoothie talk.
Lesson 3- June 2015. Learning outcome: Planning an investigation into the quietest classroom in the school using remote sensing Children will experience a model of sound moving through air through drama	Researcher and Karen	Planning an investigation into the quietest classroom in school using sound meters. Prediction with talk frame on post-its put on block graph Explanation of decibels with chart of examples Use of planning sheet. Discussion of variables Introduced data-loggers Carrying out investigation around school Recording results Analysing results Drama of sound in playground
Lesson 4	Researcher and Karen	Investigation on pitch in bottles with water

Learning outcome: that children would understand some of variables can cause change in pitch. Design an instrument (D and T) (Taught by Karen)		Investigation on pitch in elastic bands with different widths of bands. Design an instrument using knowledge about sound and pitch.

Figure 7. Activities Planned for the Topic on Sound (FN/Karen)

The school Karen worked in was an urban school of 218 pupils. The school was a single storey, Victorian building, with a large outdoor area, a couple of interior courtyards that had been turned over to play areas, a wildlife garden and an area for growing plants (FN/ Karen/8.6.15). The school had undergone substantial refurbishment over recent years. Karen had 28 children on roll in her class. Karen's classroom had doors to the playground and a sink.

The school was situated in an area of high socio-economic deprivation with 51.1% of children eligible for free school meals; 28.4% of the children spoke English as their second language (Gov.UK, 2015). The number of children eligible for the pupil premium was well above the national average. The school had a higher than average pupil turnover. The school was judged as 'Good' at its last Ofsted inspection in 2014 (Ofsted, 2014). The school had a large change of staff over the last two years; all teaching members of staff had changed.

I first met Karen when I visited her school for a PGCE student-led science day. I mentioned the research to her and she expressed that she would like to be included in the project. I emailed her the letter describing the research and consent form. We had some difficulty in arranging an initial meeting as Karen had school commitments at the end of the school day. When we met it was after school in her class room. Cleaners came in and out during the interview, as did other members of staff. She was quite reserved at the beginning, as probably was I, as we did not know each other well (FN/ Karen/8.6.15).

After the first interview, we discussed topics to teach and dates. She was teaching the topic 'sound' during the research period. We decided to plan and teach the sessions; wo sessions in one week and then a third in another week. We discussed who would plan which activities and the resources I could supply. We finalised plans via emails (FN/ Karen/8.6.15).

5.2 Research with Karen

My working relationship with Karen seemed to be professional and collegiate. I did not know her before bringing a group of students to her school. She stated that she shared planning with the teacher in the next year group and we fell into a pattern of taking responsibilities for different parts of the lesson with ease. She was forthcoming with ideas and led the discussion and planning. Again, I tried to encourage her to allow me to draw on strategies she had mentioned in her interview for my contribution to the planning, to reduce the influence of my practice on her beliefs; although some impact is inevitable. However, Karen seemed confident in our planning sessions and took the lead on activities and pedagogies and was prepared to direct me to certain aspects of the teaching. She particularly wanted me to lead on some data logging and to supply the data-loggers as she felt this was an area of science in which the children had little experience (FN/ Karen/ 8.6.15).

I was careful not to express my own opinions about her responses in the interviews, although I did refer to similar experiences I had, to reduce the power imbalance in an interview situation. An interview is an atypical interchange for individuals, where one person gives information and the interviewer reveals little about themselves; my contribution to the interview was an attempt to mitigate this feature. In teaching, we took distinct leads in the various activities. The first afternoon was cut short by the school's catering company who came in to discuss nutrition with the children and to make fruit smoothies, blended using energy from a static bicycle (FN/ Karen/22.6.15).

Not having any previous professional relationship with Karen made the research role easier to keep separate, as teacher and researcher, than with Nathan. However, I felt it was not until the end of the first session of teaching together that both of us began to feel more trust in one another. This trust appeared to make us both relax in our roles in the classroom.

The next session took the whole of the afternoon and we seemed to alternate our roles as the lead teacher in the classroom (FN/ Karen/23.6.2016). The final lesson had to be run by Karen herself as she had to move the science lesson due to a school commitment and I was not able to go to the rearranged time for science due to my own teaching commitments. Changing curriculum slots in the timetable is common in primary schools and often this flexibility can be useful, however, it is then difficult to arrange co-teaching with higher education staff with fixed timetables.

Our second interview took place in the next academic year. I had sent Karen a transcript of our previous interview asking her to question any parts she did not think I had recorded accurately or add any comments she wanted to. She did not wish to change anything or add anything. We completed the ranking task during the interview (R/Karen).

Since the interview, I have seen Karen when I again took a group of students to teach science in her school. She reported to me that she had joined a middle leaders' course and that she had a number of people to discuss science teaching with. I also met her at an LEA science meeting where she told me of science developments in her school and how she wanted to take her interest in science further. She has now been appointed in an advisory role for science education by her school's teaching alliance.

5.3 Case Study 2-Karen-Analysis

The data for the analysis of the case study, Karen, is drawn from the interviews, field notes and planning. The main themes in the data are organised under: science capital and belief about the nature of science, beliefs about effective science teaching as well as barriers to that practice and professional development opportunities (see Chapter 3).

5.3 Science Capital and Beliefs about Science

The data which was categorised into codes for science cultural capital, as well as data on the nature and purpose of science education, contribute to this analysis (see Appendix 9). In considering how science capital impacts on Karen's beliefs and practices, Karen stated that her parents were based in non-scientific careers but nature loving (C1/1/10). She took science 'A' levels and a science-based psychology degree. She explained, when asked about her background:

> *I did well at science at GCSE and then just took biology onto 'A' level because that was the only one I was really interested in* (C1/1/11).

She, therefore, had symbolic science capital in the form of her degree. A psychology degree may not have much capital in a physics laboratory, yet, as Bourdieu identified, in a field such as a primary school, it holds potential value (2004).

In the discussion on her beliefs about the purposes of science, Karen stated that her belief about the purpose of teaching science at primary level, for children, was to '*make them curious'* about the world around them (C1/2/22), and to encourage the '*love of science, the buzz'* (C1/3/9). She also stated that science provided life skills not catered for in other curriculum subjects:

> *It's life skills that –questioning, predicting, just being interested in the world around you. I don't think other subjects can do that as well as science can as the whole point of science is to question* (C1/3/4-6).

Karen talked about the process of finding out knowledge in science as being important to children. In her description of a perfect lesson, she described a scenario, on her teaching practice, where the children made an imaginary beast adapted to a chosen habitat. She explained how the children used their understanding of the needs of living things and adaptation to the habitat:

> *It was adaptation and it was an art/science lesson where they created their own. They decide on their own habitat and created their own beast. They had to explain what all the features of the beast that allowed it to find the habitat. It just gave them so much freedom and showed how well they had understood adaptation. It just worked so well* (C1/4/25).

The task was a problem-solving task which allowed the children to work independently and to explore their own ideas (C1/4/25-36). This problem-solving approach was also part of the first lesson we taught together, initiated by Karen.

Karen had a view of her own subject knowledge in science as being secure, she stated '*I consider myself good at science'* (C1/1/25). She stated that on her PGCE she saw science as being her strength, indicating she felt more confident with the subject knowledge and pedagogy than perhaps some other subjects. However, she also expressed less confident views about her practice. She made casual comments during our teaching and planning about whether she structured the lessons too much and whether she should allow the children more freedom in investigations/enquiry (FN/ Karen/23.06.2015) She demonstrated a lack of confidence in her teaching as she stated of her investigative work:

> *But I always find science investigations quite chaotic. They never seem as if they are perfect* (C1/5/15).

Karen, however, did not explicitly express her beliefs on the nature of science but when discussing the activities that were the most effective in teaching children about the nature of scientists' activity in the ranking activity, she listed the processes of observation, prediction, testing and reviewing results and concluding in order of priority (R/ Karen) (see Figure 8). This belief of science teaching as a process would indicate that Karen had a hypothetico-deductive view of the nature of the science, where a hypothesis can only be proved by empirical evidence, which some researchers believe would lead to more practical-type activity in the classroom (Koulaidis and Ogborn, 1989; Brickhouse, 1990; Lederman, 1992; Tobin and Mc Robbie, 1997). Karen described how she elicited children's ideas stating:

> *Yeah, we always begin with a lesson to elicit prior knowledge like what we already know* (C1/7/11).

This may represent similar beliefs to the 'misconceptions' of teachers' epistemological beliefs and science teaching and learning styles proposed by Kang and Wallace (2005). These authors suggest that this underlying belief could lead to pedagogies which prioritised the assessment of children's beliefs and alternate frameworks in science, and purposeful planning to address those ideas and offer alternate explanations. Eliciting misconceptions is usually aligned with a socio-constructivist method of science teaching initially advocated in the UK by Driver et al. (1985). However, it must also be pointed out that Karen's ideas in the ranking activity may not relate to her own views about the nature of science as these are difficult to uncover; they may be what she believed she should say. In retrospect, it might have been useful to ask her a more direct question about her ideas on science as a follow up to the ranking activity. The time interval between the second interview and my analysis of this theme meant I was reluctant to chase it up as I had signalled to Karen that the field work stage was complete. I felt there must be limits to the time required from the three teachers for the research.

Public recognition of an individual's science status can, however, make a teacher feel more vulnerable. Karen's concern about the balance of activities in science may be the 'conflict', that Hayes describes (2002), between the role of a teacher in enquiry teaching and the idea of a teacher in control of class behaviour. Karen had obviously lost some confidence in her own science teaching between our teaching together and her second interview. When she got a *'good'* grade from the head-teacher's observation of her science teaching, rather than the '*outstandin*g' grade she expected, she had not yet had time to get more detailed feedback on her performance. She was worried she had done too much exploration or that her pace was not right. At one point she questioned in desperation '*have I got it all wrong?*' (C2/4/25).

Karen appeared to feel she should be a better science teacher than the *'good'* grade she was awarded by her head-teacher in her observation. She seemed to be upset as she stated:

> *I though the pace of learning was really good because look at what they learnt in the end. I don't know how else I could change it I don't know how else I could have done it really* (C2/4/25).

Perhaps, having the role of science leader has made her feel she should be an '*outstanding*' teacher in science. She was feeling tentative about this role as a science leader saying, '*I am just feeling my way around'* (C2/10/10). Karen appeared to be having doubts about her own image of herself and the image which the other teachers in her school had of her after her science lesson observation; perhaps her social identity was no longer congruent with her personal identity. Her public grade of a 'good' science teacher did not appear to align with her idea of how she should be as the science leader in the school. The process of being observed and graded might have impacted on her view of herself. This reliance on external judgments on teaching and leadership appears to have resulted in an undermining of personal identity belief. This apparent lack of confidence may impact on her teaching in science.

Karen had only been teaching 3 years, yet perhaps she wanted to act like Lave and Wenger's (1991) 'masters' in primary science. However, it could be that self-awareness of her own practice and the judgments made against it could be seen as a positive feature; something Wenger describes as necessary features if a community of practice is to be open to learning rather than learning to 'not learn' (2000).

Critical comment on current practice may stimulate a teacher to go out and explore alternatives to practice. Possibly as a result of my presence, Karen had become more self –reflective of her own practice. She may have been imagining her practice through the eyes of a person external to the school. It is an unintentional, but possibly unavoidable, result of being part of a research project.

5.3.1 Beliefs about Effective Science Pedagogy

The data for this section is drawn from the themes of investigative science and other teaching pedagogies, as well as barriers to effective practice and the ways teachers link science concepts and practical work. In discussing effective practice in science, Karen appeared to be certain about the need for practical experiences in primary science as a teaching and learning strategy; this was evident when she talked and in her practice. She stated that effective science teaching involved '*hands on, just practical, generating questions themselves'* (C1/3/22). The practical enquiry science element was demonstrated in her classroom practice where she planned a range of exploratory hands-on activities, organised in a carousel, where the children explored items that made noises, such as a giant tuning fork (FN/Karen/ 22.6.15). There was time in her planning and the lesson for the children to talk to each other about their ideas and to record these ideas. Another session allowed the children to record sounds around the school. Again, in this lesson, there was much group discussion about their predictions and how to make the test fair and about their results. Karen alerted the children to the questions framework for higher order questioning on the wall (FN/Karen/ 22.6.15).

Scaffolding devices were evident in the classroom and in Karen's teaching. On the wall was evidence of brainstorming about the parts of investigations/enquiry and what they might look like (Appendix 3) (FN/Karen/ 22.6.15). Planning sheets were provided for the enquiry and questioning talk frames provided to support children form higher order questions, as well as a questions matrix to exemplify types of questions and their use (Appendix 4) (FN/Karen/ 22.6.15). She stated of the scaffolding:

> '*it is important for our children*' (C2/2/27).

Karen identified observation and initial ideas, prediction using talk frames, testing and reviewing results as her beliefs in effective strategies to teach 'what scientists do' in the ranking exercise (see Figure 8). She also added concluding and the application to everyday life, although she stated she would do more on application if she had a more able class.

Karen described her perfect lesson as being one she had while on her PGCE, in a year 6 class, when the children created their own animal and its habitat to demonstrate adaptation in animals. She talked about the independence the children had in creating their ecosystems and how the children demonstrated their knowledge of differences between a predator and a consumer and the relationship between the two.

In the second interview, in response to a discussion where we talked about Karen's worry about over structuring science, Karen appeared to express concern about how much freedom and how much control should be afforded to enquiry work, especially as she had been criticised in an observation for letting the children explore for too long (C2/4/6).

Karen, like Nathan, seemed to have conflicts about enquiry as a teaching and learning strategy in science. She described science activity as a process of observation, prediction, testing, reviewing and interpreting results, concluding and evaluating. She used language more associated with scientists than primary science when she said, '*having a theory and testing things out'* (C2/7/1). This may reflect on her own background in sciences and the stages she herself used in scientific enquiry work. Perhaps, it also indicated that Karen had a belief of what teaching strategy was useful for a particular science concept.

Counter to the Score research (2008), Karen identified investigative-based activities as effective in teaching all areas of science. She praised the role of investigative work in allowing children to come up with their own knowledge:

> *So actually, thinking of our forces, the children pretty much learnt the subject knowledge through exploring and through carrying out We did things like we give them a question or a statement. All metals are magnetic. And then off they go* (C2/3/17).

However, like Nathan, she seemed concerned at the effects of teaching in an enquiry-based approach; she described the chaos of investigative work and expressed concerns about how much freedom to give children in enquiry. She appeared to like a calm, ordered classroom and this sometimes seemed counter to giving children freedom, even though she stated the benefits (Hayes, 2006) stating:

> *But I always find science investigations quite chaotic. They never seem as if they are perfect. I'm sure they are really good in the sense that the children are making different observations, setting things up on their own, coming to their own conclusions which I love and they come up with 'this is why' using their science knowledge* (C1/5/15).

Her apparent desire for order appeared to have influenced her views of science activity, when she described her perfect lesson, she gave the example of one very much based on subject knowledge rather than a practical enquiry lesson (C1/4/25). This may also indicate a personal conflict between enquiry approaches and the role of applying subject knowledge in science. Alternatively, it may be that she was pleased with the success of a science lesson where the teaching and learning methods were effective at developing the children's thinking on adaptation in animals and required the application of knowledge to a new situation.

Teaching science concepts	Teaching process skills	Teaching about the nature of science
Questioning teacher and child Modelling scientific ideas and vocabulary Through questions to investigate In no order but identified: Talk Partners	Planning in groups, Prediction linked to interpretation of graphs Child-centred exploration. Before planning linked to topic In no order but identified: Planning sheet for sound investigation	Observation and initial ideas Prediction using talk frames Test! Review results: -different investigations (enquiry) -conclusions -application

Prediction using talk frame with justification Drawing how sound travels Modelling in the playground	Prediction using talk frame Interpretation of block graph Discussion on how to improve investigation	In no order but identified: Testing with data-logger Feedback on scientific ideas

Figure 8. Ranked Learning Strategies from Science Activities carried out in Class for Karen

When Karen was asked to rank effective strategies for developing skills and processes in science (see Figure 8 above), the teaching strategies we used in teaching were placed in order of importance for effective learning in science see 3.3.8. Karen identified planning in groups, prediction linked to the interpretation of graphs and child-centred exploration pre-task (R/Karen). This description of active science learning strategies seemed to conflict with her description of a perfect science lesson where there was no practical enquiry work.

Karen's beliefs about the effective use of investigative work in science appeared to demonstrate that she had positive views about the role of enquiry in teaching science knowledge as well as skills. She demonstrated less enthusiasm about the use of investigative science in the classroom, due to its less ordered nature; she appeared to have concerns about controlling the class learning and behaviour. This may mean she was reluctant to use investigative approaches in science, although this was not evident in our teaching together (FN/ Karen). This maybe that she was using enquiry in our teaching as she felt it was expected of her by me.

5.3.2 Linking Practical Activities to Conceptual Ideas in Science

In making an interpretation on Karen's beliefs about teaching, through linking science concepts to the practical activity in science, the lessons appeared to have reached the criteria of Abrahams and Miller's (2008) category where the children show understanding of the ideas linked to practical activities (FN/ Karen/22.6.2015). Karen talked more than the other teachers in the case studies about her belief in the importance of making links between the knowledge and observable features of a science activity (C1/2/25; C1/7/18; C2/3/14 C2/3/18). She describes a staff meeting where she wanted to discuss:

> *looking at investigations but all the investigations were in isolation not linked back to the curriculum content and subject knowledge. ..Which is something I would ideally want to do* (C2/9/21).

Karen also reported that she talked to the children after the lesson and they had remembered the activities they had taken part in and had identified the scientific concepts behind the activities (FN/Karen/23.6.15).

5.3.3 Beliefs about Barriers to Effective Science Teaching

Karen cited the children's lack of ability as a barrier to effective practice. Karen stated that she believed the children were behind in English and maths (C1/3/15); to counter this she stated that she had to scaffold their activity. She said of her class:

> *To start with we have had to do away with independence because they have needed a lot of structure. They just don't know where to start. So hopefully this term we will get to the point when we are teaching more independence, fingers crossed* (C1/4/5-7).

Karen also expressed the view that children in their schools were underachieving for their age and stage of development (C1/3/15; C1/4/5), Karen described them twice as '*children like ours'*

(C2/7/8; C2/7/21). Karen described in more detail the children's education needs, for example; how the children in her school found it difficult to observe. She said:

> *The first term of science here we just taught observation as a scientific skill because they (the children) just couldn't look and see changes or anything* (C1/2/23).

She described how she thought some year groups were behind expected standards:

> *This Key Stage, yr. 3 are not so bad but 4,5, and 6- lots of gaps in every subject* (C1/3/16).

At another point, she stated her belief that the children were not adept at making links between science and everyday life; mentioning, when asked, the ways she makes links between science concepts and practical work:

> *Which is sad thing, they are not very good at linking things. I think we are going to have to do more of that, linking to real life rather than it being science lesson* (C2/8/10).

Clearly, the needs of the children can have an impact on the practice of the teachers in the case studies in science.

5.4 Professional Development

In analysing Karen's development of effective practices, I present data identified under emergent and theory led themes and then provide an analysis. The analysis gave rise to themes which were about science ITT, internal and external CPD, use of the internet for support, informal and formal support networks and its impact on professional development.

Karen talked positively about her ITT training on the PGCE course in science teaching (C1/2/8-16; C1/4/22; C1/9/8; C1/9/8). She stated:

> *We had a lot of science seminars. I think UNIVERSITY NAME pushed science teaching a lot but it was a core subject in the old curriculum and we had a lot of seminars and a couple of lectures, but the seminars were pretty hands-on and good. They showed us a lot of different ways of teaching* (C1/2/11).

In considering school support for her development of effective practice in science, she stated she planned her own science provision with her partner teacher; '*We bounce ideas off each other a lot'* (C1/6/20). She described in detail the way she and her partner teacher worked together, identifying themes, pedagogies and inspiration (C1/6). She reported that the school had a collegiate atmosphere. She told me how she had been on holiday with some of the teachers (C2/1/2). This indicated a close community and perhaps a school community of practice.

Karen demonstrated insecurity about her current science teaching practice and whether she was doing things right or not and how she should develop in the future (C2/5/11). In the second interview, Karen reported that she had undertaken an observation by the head-teacher and that she did not get the 'outstanding' grade for the observation she wanted. She was upset and baffled as to how she could have further improved her lesson (C2/ 3/27) stating:

> *So yeah, it would be really interesting to see kind of 'outstanding' science lessons where children are planning and carrying out science investigations. Because I don't think I know what they look like. If that was not it, I am not sure what they look like* (C2/4/8).

In discussing her role as a science leader in the school, Karen talked about developing science teaching in the school (C2/9/6). She had been made the science leader that year and appeared keen to develop her role further. She stated she wanted to extend the shared understanding of the planning in science through '*peer planning cross phase'* (C2/8/3). At the time, she stated, the teachers were planning independently. She also wanted teachers to team-teach and do observations on one another as they never '*get to talk about it'*, referring to their teaching. She was perhaps indicating that she wanted to develop a primary science community of practice within the school community.

She had been asked to join the head-teacher to do observations of the staff's science teaching. She exclaimed:

> *I actually got to go and observe the other teachers* (C2/4/15).

When I asked her about the kind of provision which helped her develop her pedagogy, she stated she did not keep that up to date. She said she read bits on the Times Education Supplement website but:

> *Like I said before, you do read about things but don't know how they actually translate into the classroom* (C2/8/27).

She did mention that she made use of teaching resources on-line such as the Times Education Supplement (TES), the Primary Science Teaching Trust and the Hamilton Trust (C2/6/3 FN/Karen/ 8.06.15). When I asked her about her involvement in online communities of primary science teachers through these sites she remembered that she had signed up to some of the forums for science leaders in primary schools. She expressed a negative view of the forums saying she had got too many e-mails from signing up, and that the forums were mostly full of people *'bragging'* about their fantastic scheme of work (C2/9/9).

In the interviews I did with Karen, and while we were working together, it was evident that Karen did not take a part in external primary science communities of practice (C2/9/10). Outside school, she mentioned that she talks about her teaching with her teacher colleagues and:

> *..my Mum who is a teacher. .... For reception to year 2. But, um, she always has good ideas for my less able children and how to scaffold it. I share things with her. Other than that, no- one really* (C2/9/10).

Karen had not been on any science training since she was an NQT when she did a couple of sessions on investigative work in science (C2/8/14). She was not very impressed with the sessions on enquiry as she said they were not directly linked to the curriculum. This is similar to the findings of the Wellcome report (2014).

In our second interview, Karen told me that the head-teacher had signed her up for a middle leaders' course where she hoped it *'should explain what a leader does'*. She also discussed how she hoped to meet science leaders with similar tasks to herself (C2/10/10). This appeared to be a generic training course for curriculum leaders. Karen recognised her need for an external science teaching community of practice in her expressed hope that she would meet other science leaders on the course.

In using the model of Lave and Wenger's community of practice (1991) and in-school communities of practice to analyse Karen's development as a teacher of science, one could argue she was not working at the legitimate peripheries of the school community; she was an established member of staff and has an open collegiate manner with her fellow teachers (FN/Karen/ 8.06.15). This may indicate that being part of a strong general community of practice within a school may not be that helpful to developing particular subject areas of expertise if there are few others in the school that share that expertise or interest. She might have had less elevated status in a different school situation with a longer established staff. Working as part of the school community of practice in general did not seem to address Karen's own CPD needs in science. Karen did not, however, appear to see herself as a 'master' of science education; in fact, she seemed to want to have a 'master' of science to learn from (C2/11/7). Karen demonstrated self-doubt and a lack of confidence in her teaching when she expressed the concern that she did not know what an outstanding lesson looks like. Karen had been made to feel that she should be a 'master' of science education by being given her role as science leader in the school and yet had the public humiliation of only being awarded a 'good 'judgement in her observation; a blow to her identify. This may indicate that being part of a strong general community of practice within a school may not be that helpful to developing particular subject areas of expertise if there are few others in the school that share that expertise or interest

The teaching observation by the head-teacher did not just have a monitoring function; it should have a developmental element. Karen wanted to know how she could improve her teaching having been judged by the head-teacher (C2/4/15). Yet, she had not received any feedback or support from the experience, leaving her with no guidance on how to move to mastery in science (B2/4/27). The head-teacher came from a literacy background and may not be the right 'master' to support Karen's development in science (C2/5/8

Karen may also have been questioning if the head-teacher and herself had the same beliefs about effective teaching in science. Indeed, it would be unrealistic to expect a head-teacher to have mastered every one of the National Curriculum subjects and pedagogy. However, I feel this went beyond just a difference in perspective on practice. Karen felt the head-teacher had questioned her use of time to explore and discuss in science teaching and learning (C2/ 4/14). This socio-constructivist view of talk as vital to children's learning appears to be an essentially important belief to Karen, as exemplified by her practice. If she felt the leader of her school did not share this belief it would be unsettling. A feature of communities of practice is that they share aims and beliefs about a practice, if this is not shared by your leader, is there really a community of practice?

Karen had also been assigned the role of a ‘master’ in primary science by the head-teacher as she had been involved in the observation of half of the other members of staff teaching science alongside the head-teacher (C2/5/1). She stated this with a tone of incredulity, perhaps arising from her lack of confidence in her own abilities. This appeared to indicate that the school and teachers were in the process of building a community of practice around primary science teaching. It may be that there was already a shared community of practice in the core subjects of English and maths or even just a shared appropriation of the challenge of taking on a’ broken’ school and making it good, but not necessarily an agreement, or indeed shared practice in teaching primary science. However, in a school trying to teach core and foundation subjects, as well as trying to raise the progress and achievement of the children in what is effectively a new school, there will inevitably be competing agendas from the head-teacher and other staff. The head-teacher may be more interested in presenting an ordered classroom with sound behaviour management, which was incompatible with a less ordered, talking, exploratory classroom and Karen may be more interested in the children’s conceptual development.

In analysing the use of the internet and published resources, Karen expressed the view that reading about innovations in science pedagogy on the TES website was not very useful for her own development as a teacher of science (C2/10/9). Her comments about competitive, bragging comments on teaching blogs (C2/10/18) may be because the resources sites now pay teachers for their resources and planning and they may want to promote those resources through the interest groups, or it could be a reflection of Karen’s feeling of not being the perfect science leader, as well as a lack of time for reading the emails. This could identify the problems with commercial websites for teachers where competitive, commercial elements are at play. She was not a part of any external community of practice for science teaching. She seems to recognise that an external community of practice in science might be helpful when describing her expectation of the ‘middle leaders’ course she was due to join.

For her future development, Karen stated she needed to, ideally, to try or experience the techniques in the actual classroom to be able to put the ideas into practice. She declared that she would like to see ‘good’ science teachers teaching (C2/9/22). She obviously wanted her learning to be ‘situated’.

The dominance of English and maths in the primary school has resulted in fewer resources for professional development in other subjects such as science (Ofsted, 2016). The fact that Karen has not had any CPD in science since her NQT year is not unusual as CPD moved towards generic skills and knowledge in times of budget restraint (Avalos, 2011). She had the prospect of a generic leadership course in middle management skills, but this may not support her own developing pedagogy in science. However, if this is so and there are no ‘masters’ of science teaching in school, common in primary schools due to their size, it challenging to a teacher trying to develop their own practice and then influence the practice of those in their community of practice.

5.5 Chapter Summary

Karen seems to have entered primary teaching with a positive family habitus towards science, forming some of her cultural science capital. She has symbolic science capital from her psychology degree and a few years teaching experience. In a school with little expertise in science, she has the role of science leader. She seems to have no master to learn from and develop her practice in her community (Lave and Wenger, 1991; Wenger, 1998). She appears to have a collegiate approach to her role in school, planning with a colleague. Karen declared she was confident in her subject knowledge in science but appeared to have had her confidence in her pedagogical skills in primary science reduced by the head-teacher’s observation of her. She does have confidence in her ability to manage and organise the class. She appeared to be unsure of how she could develop in her role as science lead as there were no ‘masters’ of science within the school to help her develop. She seemed to believe that her teaching should be ‘outstanding’ so she could be a ‘master’ of science herself.

Karen seemed to have a hypothetico-deductive view of the nature of science and appeared to be influenced by socio-constructivist methods of teaching science. This may have been instilled in her in her experimentally based degree subject. She made use of dialogic learning strategies in her teaching and expressed a belief in their use in learning in science. She seemed to have a deficit view of the children in her school as she believed they were working below age-related expectations. She stated that this influenced her planning and expectations of the children. She cited her perception of the children's low achievement levels as a barrier to her teaching science in the way she wanted.

Karen suggests that she believes in the use of enquiry in science to teach about the skills of science as well as the subject knowledge. She suggests that she finds enquiry work less controllable that other parts of the curriculum and feels uncertain of how long to let children explore and when to guide them. She seemed concerned about having a calm class for external scrutiny. This may be attributed to her only having three years teaching experience or just the more dynamic nature of practical enquiry. She appeared to see the linking of the observable features of science and the scientific concepts as important aspects of her practice.

Karen appears not to use external science communities of practice to support her development in science teaching, apart from sharing her practice with her mother. This may not be enabling her to develop her practice further as she conveys the impression that there are not internal masters to support her. However, in the absence of science CPD, perhaps through budgeting constraints, her prospective middle leaders' course may give her a different community of influence and support.

Chapter 6. Case Study 3- Shamah

6.1 Shamah's Background in Science

Shamah was the third case study in my research. The data is collected from two interviews on 5.02.2015 and 15.07.2015, field notes from the lessons we taught together, the ranking exercise and emails (see Chapter 3). The chapter is structured to present Shamah's background in science, the context to the research and then analysis of the research data.

Shamah's father was a surgeon, then a GP, her mother was a nurse. She said she was brought up surrounded by models of the body and stethoscopes (A1/1/6). Her parents appeared to value education highly, especially in science. Shamah told me she was taken on educational trips and to museums. She stated that it was:

> *natural for me to want to go into the medical field and into science* (A1/1/11).

She appeared to imply it was a predetermined path. She studied biological sciences and then went to work as a biomedical engineer, a microbiologist, and then trained as a histologist. When faced with a lack of job opportunities, she trained as a primary/secondary school teacher completing a PGCE. She recalled memories of her own primary education with enthusiasm:

> *the things I do remember from primary school are, interestingly, the outdoor activities, so when we had this environmental area using the pond having to bring the different insects and having a display in the classroom* (A1/2/8-10).

She stated that she particularly liked chemistry at secondary school, which she described as practical and related to everyday life (A1/2/14). She also described the practical nature of her biology 'A' level where she researched a project on animal behaviour at a local zoo observing monkeys' responses (A1/3/8).

Shamah appeared to enjoy studying sciences at school. In my planning and teaching with her, Shamah stated she was confident in her subject knowledge and pedagogical subject knowledge (A1/2/12). She had a knowledge of being a research scientist, as well as knowledge of a range of bio-medical fields. She also had experience of continuing education through her retraining as first a microbiologist, a histologist and finally a teacher. In our conversations, she explained she had just completed the Primary Science Quality Mark and was now considering a master's degree (A2/ 9/28).

6.2 Research with Shamah

I first met Shamah as part of another university research project. I contacted her by email about my research and she responded positively. When I met her for the first interview it was during school hours, as part of her preparation time. We used a room normally used by teachers and staff for one-to-one interventions with children within the school. At the end of the interview, she showed me her classroom and introduced me to some of her student STEM ambassadors (FN/Shamah/29/1/2015). We met subsequently to plan a sequence of lessons and to agree our roles in the lessons. She then sent me what we had discussed in the school's planning format (FN/ Shamah/ 9.02.2015, Appendix 11).

Shamah had been teaching for over six years. At the time of the research she worked in a school, above the national average in size, in outer Bristol. The school had fewer pupils claiming pupil premium and with SEND than the national average. The children in the school achieved the same as the national average in reading but lower than average attainment in SPAG (Spelling, punctuation and grammar) and maths at KS2 but average at KS1 and in the EYFS. On their last Ofsted inspection, the school was categorised as '*requiring improvement on aspects of teaching and learning'* (Ofsted, 2014, p1).

Shamah's school had a curriculum design focus on science and engineering to reflect the surrounding industries in north Bristol, where many parents worked. Shamah was working in yr. 4 in an external semi-temporary classroom. Her parallel yr. 4 class were in the next-door classroom. Shamah planned the science for yr. 4 using the school's format (FN/Shamah/ 9.02.2015, Appendix 11). The science topic for the term during the research was 'electricity' with learning intentions taken from the National Curriculum (DfE, 2014).

Shamah was the subject leader for STEM in the school. She worked with another male teacher who shadowed her and who was the deputy lead for STEM in Key Stage 1(A2/4/5). Shamah had been instrumental in gaining the school the Primary Science Quality mark. She stated of the application:

> *They said it was a very strong application. It is gold we applied for, so they said it was very strong one so hopefully...*(A2/2/12).

This is an award set up by the ASE to develop the quality of science work within school and by school leaders. The science leaders working for the award met at a nearby university to be guided in the process by a science education lecturer and to share experiences with one another (A2/2/25).

Shamah had written an article in Primary Science Review, the ASE magazine, given talks at conferences and to prospective science leaders undergoing Initial Teacher Education. During the research period, Shamah successfully applied for the role of STEM leader for the group of primary and secondary schools which make up the Schools' trust of which she is part (FN/ Shamah/ 9.3.2015).

Teaching and learning outcomes	Planned by	Key conceptual topics and children's activity
Lesson 1 To construct a simple series electrical circuit, identifying and naming its basic parts, including cells, wires, bulbs, switches and buzzers	Researcher and Shamah	Constructing simple series circuits, identifying and naming parts Modelling electricity with balls in circle Adding another bulb. Draw circuit Assess work using levels mountain
Lesson 2 To recognise that a switch opens and closes a circuit and associate this with whether or not a lamp lights in a simple series circuit	Researcher and Shamah	The importance of a complete loop and battery to circuit with a bulb Lighthouse keeper's problem Use of light tube which works in a circuit of children but not when hands are dropped Thinking frames Write a letter to Mr. Grinling the lighthouse keeper.

Lesson 3 To recognise some common conductors and insulators, and associate metals with being good conductors.	Researcher and Shamah	Problem solving with battery foil and bulb. Gaps and connections film clip Exploration of how ready-made switches work Made switch with a paper clip. Testing energy balls Design and make a burglar alarm to stop sibling coming into your bedroom

Figure 9. Activities Planned for the Topic on Electricity

When we taught the class together we seemed to team-teach in a professional manner. I supplied resources, not available in school, for activities and we both prepared different parts of the lesson. During the planning, Shamah had clearly identified pedagogical tools she wanted to use in teaching. She took a lead in planning and directing the teaching and learning in the class. The relationship between Shamah and me seemed to be the most relaxed and collegiate of all the teachers in the case studies. It may be the status and power differentials were less than the other case studies or that we were similar ages. She had been given a role in her academy trust as a science leader of several schools, very similar to roles I had held in the past. I quickly became aware that she had a wide current working knowledge of recent innovations in science education that I have talked about to students but have never used myself in the classroom. Unlike my usual role in teacher education of helping student develop their practice, I was developing my own.

We met for the second interview later in the same term and same academic year. I sent her the transcript of the first interview for comment and the ranking exercise using the teaching and learning strategies we had used. She prepared her response to the task in advance and discussed her choice of response with me in the interview.

6.3 Case Study Analysis- Shamah

The data for the analysis of the case study, Shamah, is drawn from the interviews, field notes, including photographs and planning. The main themes in the data are organised under: science capital and belief about the nature of science, beliefs about effective science teaching as well as barriers to that practice and professional development opportunities (see Chapter 3).

6.3.1 Science Capital and Beliefs about Science

Shamah, unlike the other two case studies, came from a family where it appeared that science and study was greatly valued. She had several science qualifications and experience of working in the sciences. Shamah stated of her career:

> *I'm glad I went into teaching now as I can offer more with my background, I can show the children and the children get really excited when they hear what I have done they say wow .. is that what you did?* (A1/1/37-39).

In discussing how she taught, Shamah appeared to reveal some of her own beliefs about science. In the pedagogy ranking task, Shamah identified the problem-solving activity as well as the drama, as effective strategies for teaching children about the nature of science (R/Shamah).

She mentioned science subject knowledge as an important part of learning science when she described how learning of scientific concepts, like processes of life (A1/3/30), were important for building on at secondary school level. She also described, perhaps indicating a belief in, the importance of subject knowledge:

> *..my dad, who has incredible knowledge like sometimes you think I'm a biologist I don't know very much about physics But he has knowledge of everything physics, biology and chemistry and he has so much background knowledge on it and you can ask him a question and he can problem solve and you think well it would be because of this, this*

> *and this. He's an inspiration in that as teachers we need to have knowledge of all three and apply what we know to certain problems* (A1/10/20).

Shamah appeared to believe in the social construction of children's knowledge of science; she gave the class learning activities where they were asked to think about what they knew or tested their ideas about electricity with silver foil and a battery alongside discussion and the use of talk partners (A1/9/11). She helped them explore their ideas through one to one prompts and questioning around the class (PS/ Shamah; FN/Shamah /27.04.15). She identified the children talking to one another as an important feature of her teaching when she discussed co-operative working as well as talk partners (A1/5/20: A1/4/5; A2/1/6).

Shamah commented on her belief in the importance of practical activity and first-hand research when she described her beliefs about teaching (A1/1). These expressions about her teaching and own education may indicate a hypothetico-deductive belief in science, that knowledge can be tested by producing a hypothesis that can be tested. This was apparent in her teaching strategies where the children were asked to problem solve and investigate from predictions (PS/ Shamah). This supports the theories of Lotter (2007) and Leonard (2009) who suggested that teachers with a hypothetico-deductive view of science processes would be more likely to value practical work in school science.

In relation to Shamah's views of her class, she introduced her class to me stating apparent pride in their interest in science and engineering (FN/ Shamah/ 27.4.15). In our discussions and planning, she appeared to talk positively about the class achievements in science and engineering. She described the more and less able and how she tried to cater for them in her plans (A2/1/10; PS/ Shamah) and described how a couple of children needed support with literacy in science.

Shamah gave the impression that she had numerous strategies to recognise the achievement of the children in a variety of science skills and processes. For example, using class members as listeners to detect the effective use of vocabulary or effective questioning by the children and using the '*investigation levels mountain'*, a self-assessment tool (A2/1/27).

Shamah's beliefs on the purpose of primary science seems to have drawn from her experience of having careers in science and also her experience of being trained and teaching in secondary schools. She talked about the need to get the investigative element into primary science to engender curiosity about science but also discussed how the children would benefit from knowledge of skills such as graphing and filling in a table accurately. She also indicated that she believed in a grounding of basic knowledge, stating:

> *You want to prepare children in a way so that you give them some background and so yr. 7 teachers can build on it and come out as high-level scientists*. (A1/4/27).

However, she also expressed a wider societal aim of producing students who have some scientific literacy saying:

> *Whatever career you take, it has some science element in it and I think if you want them to make informed decisions about the country about their future, about science we need to teach them science well and it starts in here really* (A1/5/7).

There are some indications that Shamah expressed views which indicate a wide understanding of the nature of science, for example, the problem solving, socio-constructivist strategies and her value of science subject knowledge (R/Shamah). This may have arisen from a greater experience in scientific careers, than the teachers in the other case studies, using a range of scientific methods, as well as the formation and use of theoretical models and problem-solving and design. Her experience and study would have certainly given her a broader understanding of the way scientists work.

Shamah seems to have a positive, confident view of herself as a teacher of science; she appeared to have had nothing to prove about her credibility in teaching science, probably arising from her strong economic, symbolic and social science capital saying:

> *I can offer more with my background* (A1/2/11).

This credibility appeared to be important to Shamah. When describing her first teaching practice with a year 10 class, she described how the children know all the answers to their science quiz, but she mentioned:

> *So, I threw in a couple of chemical compounds and they did say.. I don't know what that one is* (A1/4/19).

In this way she demonstrated her superior knowledge to the class.

6.3.2 Beliefs about Effective Science Pedagogy

In the interviews, Shamah stated a belief about effective teaching in science that:

> *Enquiry should be at the heart of everything in every science lesson... so you have the knowledge and enquiry together* (A1/4/17).

She said of children's learning that she was involved in:

> *Making sure that they are doing some sort of investigation so there is always going to be an investigative element to it.* (A2/ 4/3).

When she described her perfect lesson, she stated:

> *I think it would look like me coming up with that surprise element, the story beginning and have all the children engaged, and interested and, um, asking them right how can we investigate this and they would know how to investigate it and they would go away and plan it and they would be organised into their groups they would have their roles and they would plan their investigation, they would feed back to me ideas, would share ideas, then we would organise resources and they would go away and do it.(*A1/6/15).

In her practice, enquiry learning was a feature of her teaching. The class investigated how to make a bulb light with only a battery, silver foil and a bulb, as well as how to create a circuit tester for a lighthouse keeper when the bulb has blown in his lighthouse (FN/ Shamah/). They designed a switch for a burglar alarm, having investigated what a switch was and what conducted and insulated electrical charge.

To manage the lack of time for science, Shamah discussed how she used data from enquiries in other parts of the curriculum, such as maths, stating:

> *Rather than teaching it separately or link it with another lesson so the line graph I actually added onto my maths lesson* (A1/9/7).

She also covered the design and making of the burglar alarm in design technology (A1/5/25; P/Shamah).

During the research, Shamah made use of a wide range of teaching strategies such as drama, writing, problem-solving, developing vocabulary and 'Thinking Frames', as well as whole class questioning and modelling of scientific concepts (FN/ Shamah/ 18.5.15). She expressed

There was no evidence of avoidance of practical enquiry work in planning or expression of discomfort during the practical activities.

Shamah appeared to use strategies to enhance the learning and made judgments on how much scaffolding to use to support the children's learning. She allowed a group of children who she had identified as the '*making less than expected progress'* in science group explore for a long time as they put more and more wires and bulbs into their increasingly complex circuit (FN/Shamah/18.5.15). She intervened at a couple of points to challenge their thinking through teacher questioning. In her planning, there is evidence of differentiation (PS/ Shamah) particularly for differences in language ability.

Shamah was critical of the ranking activity as she stated:

> *but there were lots that overlap it was quite tough, really, I just did it* (C2/1/11).

The ranking task was reductionist by necessity and really a stimulus for discussion, but Shamah's comment may indicate that she had a more nuanced view of the pedagogies used. Shamah placed writing activities in the ranking activity, such as reporting to Mr Grinling about the circuits in the lighthouse and the poster for the burglar alarm, second in her list of effective strategies for conceptual learning in science, see Figure 11 (R/ Shamah); in this case the writing seemed to be reinforced by an individual review using the 'Levels mountain' (Newbury, 2004) which encouraged children to push their writing and explanation to a higher level of proficiency, (see Figure 10).

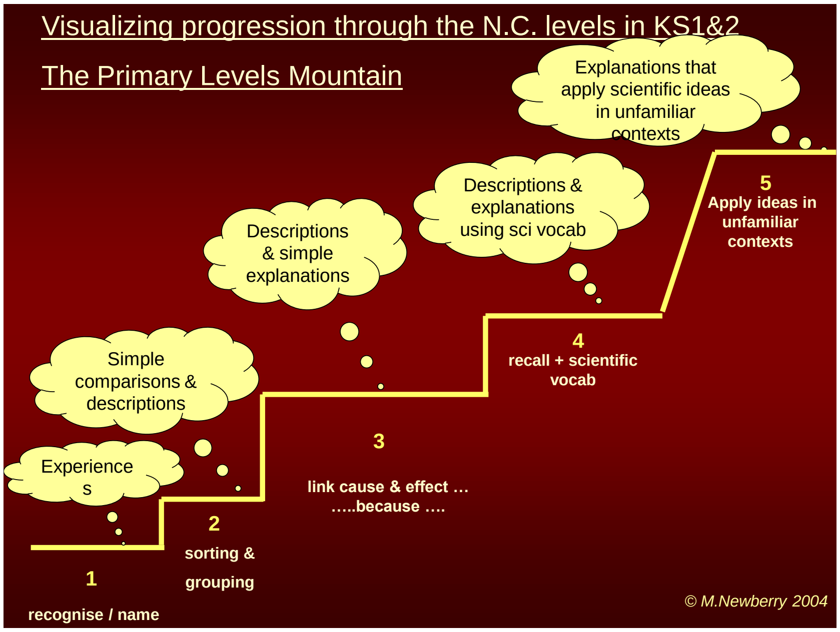

Figure 10. Levels Mountain (Newberry, 2004). Reproduced with permission from CAMS.

Shamah gave the children feedback on what level they had achieved according to the diagram and feedback on how they could achieve a higher level (FN/Shamah/18.5.15).

In the discussion on effective strategies for developing process skills in science using the ranking exercise as a stimulus, Shamah identified the 'gaps and connections' video, talk partners, the classification of electrical appliances, learning detectives, level mountains and teacher questioning (R/Shamah; Figure 11). Shamah talked about getting children to raise the level of their questions. She states:

> *I think it is a big thing getting children to understand questions and getting children to start to pose their own. I've started doing now. It is a big part of the new curriculum isn't it questioning* (A1/5/21).

In the ranking of activities that communicate the nature of scientific activity, Shamah identified problem-solving, modelling with drama, the demonstration with the electric tube, design and make task and exploration activities with the circuits.

Teaching Science Concepts	**Teaching Process Skills**	**Teaching about the Nature of Science**
Thinking frames Problem-solving with tin foil and battery Electricity drama Demonstration of electric tube Building a circuit Writing a letter to Mr. Grinling Exploring switches Design and make a burglar alarm	Gaps and connections video Talk partners, The classification of electrical appliances, Learning detectives, Levels mountain Teacher questioning	The electricity drama Demonstration with electric tube Building a circuit without any instructions Exploring switches Making Switches Design and make a burglar alarm

Figure 11. Ranked Learning Strategies from Science Activities carried out in Class for Shamah

In analysing Shamah's data, it appeared that investigative or enquiry work in science seems to be a significant feature of the beliefs about teaching science expressed in discussions and in her practice. There was evidence to support this through her teaching and in her interviews (A1/7/1; FN/ Shamah). Although many teachers believe that enquiry is an important part of science teaching, it is often used for teaching process skills and about the nature of scientific activity (Score, 2008). Shamah uses enquiry to teach scientific concepts, for example, when the children explored circuits with silver foil and a battery, (see Figure 11). This approach is supported by the meta-study of research into using investigations to teach subject knowledge by Minner (2010). It may be that she also believes that the enquiry makes the science more situated, more similar to the work of scientists, drawing on her own knowledge of the working world of the scientist.

Although Shamah expressed a belief in the importance of enquiry in science, she was also clear about her belief in the role of a wide range of teaching strategies on children's conceptual and practical enquiry learning in science (A2/1; R/Shamah; See Figure11). This may indicate an apparent inconsistency in beliefs and practice or may just be that Shamah believed that enquiry teaches subject knowledge but that there are also other strategies to aid conceptual understanding. There was no apparent avoidance of enquiry-based learning, in fact, there was as much, if not more, than in the other teachers' classrooms but it was interspersed with a wide variety of other practical activities which appeared to be effective in developing learning in science. Science enquiry seemed to be used as a means to an end, not just an end in itself. Shamah appeared to use a much wider range of science teaching strategies during the research than the other two teachers and provided evidence for having a defined focus on linking observable features back to ideas in science. She seemed to skilfully pick an appropriate pedagogy for this purpose. Her knowledge of what was effective for children's learning in science may have supported her chosen mix of pedagogies (Traianou, 2003).

6.3.3 Linking Practical Activities to Conceptual Ideas in Science

In Shamah's teaching, the children appeared to have understood the scientific ideas linked to practical activities (FN/ Shamah/2.3. 15). Shamah reported that at a later stage the children were able to demonstrate that they could recall the ideas she was teaching (FN/ Shamah/9.3.15) (Abrahams and Miller, 2008). Shamah also appeared to take care to refer the practical tasks; the circuit building, back to the drama model, images in the video and previous explanations to reinforce the link between the two (FN/ Shamah/2.3. 15). The range of teaching and learning strategies used in the session, not just an investigation, but through the Thinking Frames, discussion, and modelling through drama were used to apparently ensure the link was made (FN/ Shamah). Through her practice, Shamah seemed to demonstrate her belief in the importance of making the links between ideas and practical work.

6.3.4 Beliefs about Barriers to Effective Science Teaching

Shamah identified a lack of time as a major constraint in teaching science, confirming the views of Eraut (2002). Shamah said of science:

> *One thing is the time. The huge focus on English, as literacy is now English and maths.. um.. and the fact that you get one afternoon to do science and it all has to fit in that one afternoon and if you want your science to be hands-on and an inquiry you don't just want to say now pack up and do something else.* (A2/3/21).

However, Shamah seemed to have found a partial solution to her time barrier, by splitting the lesson and learning into what she described as 'chunks' (A1/7/10). These, she described, are parts of science that have a cross-curricular element, for example, using English for the recording part of science or maths for the graphing and data interpretation element. She also makes use of short periods of un-timetabled time saying:

> *..then I may use up a registration slot, which can be a good 20 min., for example on Friday we have a long slot because we have no assembly , we get 30 min.* (A2/4/22).

Her planning skills and teaching experience across the curriculum probably allowed her to see the opportunities for this cross over and consequently, it seemed to allow more time for the science activity. Perhaps this understanding of the whole curriculum and the distinct nature and contribution of subject like science to the whole is more likely to come from longer experience of teaching and through working with other subject leads.

6.4 Professional Development

Shamah talked of her own KS2 / KS3 training at University on her PGCE. She said of her training:

> *The science sessions were very good. They were hands-on sessions in the afternoon which were fantastic and there were theory sessions as well and they made sure they came and observed us teach science as well* (A1/2/25).

Shamah described how she did not get the opportunity to work with a more experienced teacher when she was an NQT. She described how the science leader in her school at this time was the deputy head who appeared not to be very interested in science. She seemed regretful that there was not someone she could have learned from at that time. When discussing shadowing of subject leaders, she stated:

> *I did not get the opportunity to do that. As part of my NQT, I was part of a science team in my school in London with the deputy who did not get the opportunity to do much. We had a few conversations about ideas for next year but that was it and another teacher and, in all honesty, the other teacher was not very interested* (A2/10/14).

In her school at the time of the research, Shamah was the science subject leader. She had another member of staff from KS1 shadowing her, but she was clearly the main primary science staff member. She seemed to re-assert this saying of the other staff member '*I'm science leader across the whole school but he does more with Key Stage 1'* (A24/14). She appeared to see herself nurturing him; she suggested that he was getting a lot out of the experience, learning from her (A2/7/28). Shamah also described how she had been given the role of mentoring the newly qualified teachers for the following academic year (A2/9/6). She indicated that she had ideas about how the portfolio process for the NQT should work. She expressed surprise that at the NQT meeting the portfolio requirements were not as rigorous as she had undertaken, stating that:

> *I told her I would quite like her to have a folder because I am a bit pernickety about things like that (laugh) get it all in there, photos parent's meetings just slot it in if you get 10 minutes just organise it* (A2/ 9/17).

She talked of staff meetings at her school where she fed back on innovation in science pedagogy she had seen. She mentioned the playground science that she had seen at a talk and how all the staff used the teaching strategy in science week (A2/7/4). Shamah stated that she arranged the whole school science week on an annual basis. The staff chose a topic and the whole school became part of the project for a week in the summer; for example, on a theme of the environment or Tim Peake's space travel (FN/ Shamah/27.04.15)

Shamah's head-teacher appeared to want the school to have a science and technology specialism to reflect the careers of the parents and the local industry in the area (FN/Shamah/9.02.15). Shamah described how she talked to the head-teacher, stating:

> *Yes, the head all the time. If I want to do new things new initiatives, I will go and discuss it with him. Email him, have a chat, update him on the PSQM what I'm doing. Whether I am going to speak at a conference to let him know how it went. So yes, all the time, involving him and asking him what he thinks. His views as well, the deputy alongside him as well. All the time* (A2/6/8).

This implies she is informing and influencing the head-teacher as well as consulting with him. Shamah had been put in the role of leader of primary and secondary science by the head of the schools' trust and been asked to observe other teachers teaching science within this wider organisation. This had the potential to give her the role of an assessor as well as a leader; this may have had implications for her future relationships with those staff in the other schools when she was making judgements about their practice. This monitoring of the curriculum was a different role from the modelling practice described in the example of the master tailors in Lave and Wenger's research (1991).

In her own professional development and for the development of the school, Shamah seemed to actively seek out and learn about pedagogy innovations through science communities of practice external to the school. She stated that she regularly attended the Association for Science Education Annual (ASE) conference in January (A1/6/18). She described several new pedagogical strategies she had seen:

> *ASE conference is like gold, so I learn a lot from there and this time I went for 2 days and tried to go to as many workshops as you can and they are just fantastic* (A2/6/8).

She appeared to have attended sessions in areas not directly appropriate to herself but that she felt would benefit the school, for example, she stated she attended a session on early years' science even though she taught in Key stage 2 (A1/6/23). She also stated how she attended the Big Bang fair in Birmingham, an interactive exhibition on Stem subjects for 7-19-year-olds, in her own time with her own children and researched opportunities and ideas for practice, '*I always go to take my children but also to network myself'*(A2/8/13).

Shamah seemed to have started to extend her influence in primary science to other schools and organisations. She had written an article in Primary Science, the ASE magazine, done talks at conferences and to Initial Teacher Education teachers (A1/8/6; A1/6/25).

When I asked Shamah what she would need for her further development as a teacher of primary science, she expressed the view that she wanted more CPD (A2/9/7). There was also an indication that she wanted first-hand experiences of the pedagogical methods. She stated:

> *Because even though I have heard of playground science to see the pedagogy, as a group he gave us black card and said he would not be unkind enough to make us go outside. He asked us to come up with something that children could show their conceptual understanding of on the playground and we went around and discussed it. It's just different pedagogies and ways to make your teaching a bit more interesting rather than doing the same mundane something you can share with staff, so I shared that with staff we did a whole playground science day as part of science week* (A2/6/32).

In analysing Shamah's data she, like the other teachers, seemed to have experienced a sound training in science teaching and learning on her PGCE (A1/3/17). However, she said that she would have liked a role model in science education to learn from in her first role as a class teacher (A2/10/14). She may have felt that this would have supported her learning as a science teacher.

Shamah was the person in her school who provided the CPD support and her school appeared to have an active community of practice for science education. The definition by Wenger et al., (2002) states that a community of practice is a group of people who share the same passion or concern, who extend their skill and expertise in this area through interacting and learning from one-another. This would describe the way the school staff worked with Shamah from her account, but this research is unable to judge the effectiveness of this community. Having not spoken to the other members of staff, I do not know if there was a shared passion for science but the teaching activities and focus on science indicated action towards a school goal, willing or not. It may be that the other staff did not value science education and although they attended the sessions and discussed the pedagogies it may have had little impact on their practice in science.

Shamah was working as, in what Lave and Wenger (1996) would describe, the role of the master in primary science. Wenger (2000) argues that communities need leaders to ensure the day to day running of science in the school but that it is *enabling* leaders that helps to *develop* communities. Shamah seemed to take responsibility for the day to day organisation, as well as the development of, and influence on, practice, however effective.

As evidence of this enabling trait, Shamah requested her NQT to carry out the portfolio process, to chart and reflect on progress her way, perhaps in her own image, as she was asked to do it this way herself when she was an NQT (A2/13/3). Lave (1996) might propose that Shamah was enabling the staff to become and recognise themselves as teachers who enjoyed and felt confident in teaching science, and NQTs to become fully qualified competent teachers who are part of a school community doing what everyone else does; teach children. The social practice of science weeks, discussion of and science initiatives in school could all be seen as social practices to bring about this change.

However, since the formation of the academy trust and the joining of a number of schools together, Shamah had a new, wider range of people with whom to form a wider community of practice in science education. She said of a new school:

> *but then there is the Junior school that is opening up, but that is in the early stages. They only have early years but the teacher who is joining there is forest school's trained. I am interested in having a good collaboration with her as well* (A2/7/24).

As a newly formed academy trust, a community of practice may not have existed in any subject, at that time. Individual members may not have agreed with the overall vision of the Trust, or its goals and approaches to teaching and learning. They may not have agreed with Shamah's vision for science education. Initially, her role was to be a monitoring one, not a supporting or modelling practice role. This may or may not be a community of practice for science education that would develop Shamah's practice in the future. The boundaries of Shamah's community of practice may extend, as Wenger describes (2010) drawing in the other schools in the academy trust. However, there is a risk that the boundaries retreat as her attention is required by other schools and less science Community action happens in her own school. Wenger (2010) states that boundaries in communities of practice are not fixed and are dynamic at all times.

Shamah's data indicated strong links with other external science education communities of practice. Shamah gathered information and new pedagogies at CPD events, even in her own time, demonstrating her personal desire to develop her own practice (A1/3/17-25; A2/3/12-14). When asked what she needed to develop her own practice she replied:

> *Oh gosh, all the time to do CPD* (A2/9/7).

This process also informed and developed the practice of others, through staff meetings indicating that she felt responsibility for science across the whole school, not just within her own development and articles for external audiences.

Shamah's participation in the PSQM had also exposed her to a primary science community of possibly like-minded primary teachers with the goal of improving science provision in their schools (B2/2/25). She kept up to date with a wide range of virtual networks and resources online. This had helped her to find out about different methods and pedagogies in science education like the Thinking Frames used in the classroom (A1/5/23).

One of the features that was significant about Shamah's approach was her apparent confidence to ask for help from others in other science communities of practice. She reported how she took down the details of speakers at conferences, or people she met at conferences, authors of articles in journals and then contacted them when she needed help or wanted more information (A2/8/1). She also wrote to an author about the transition between primary and secondary schools:

> *there was a really interesting article written by a teacher who was a primary science teacher who has moved into secondary and now is a transition coordinator at secondary school but still does a day at primary to keep in and I thought she would be a great person to contact so I did and we had a telephone chat* (A2/7/1).

This possibly proactive strategy seemed to be useful in extending Shamah's skills and understanding of practice in primary science.

Wenger (2000) talks about individuals, like Shamah, as 'brokers of boundaries'. She seems to travel across the boundary of her own school's community of practice to other communities and gains knowledge, objects and practices that she brought back to her own community and vice versa. Wenger argues that brokering knowledge is 'delicate' as it requires the broker to have the credibility to be listened to but a distance to be able to offer something different and novel (2000). Shamah appears to have a background in a science career to bring her credibility and as part of other external communities of practice, enabled by the head-teacher and her own enthusiasm which gave her the distance to be able to offer new pedagogies to her own staff. Wenger (2000) also describes brokers of boundaries as those who enjoy making connections and the transfer of knowledge. Shamah appeared to be adept at making connections and the transfer of knowledge and practices; 'the import and export' (Wenger, 2000, p.235).

However, in considering the future, she seemed to have a desire to improve further. She stated that she would like more courses on science pedagogies (A2/9/7). This supported her discussion of the playground science activity she did at a conference where the facilitator got the participants to do the 'playground science' themselves (A2/9/14). The hands-on experience of the playground science had obviously had a much greater impact on Shamah than just hearing about it. Perhaps the experience of doing the playground science gave her an opportunity to judge whether it would be useful to the staff and children and also the confidence through a model of CPD, to train the staff back in school.

6.5 Chapter Summary

Shamah came to primary teaching with a strong symbolic and cultural capital in science, a profile unusual in a primary school. Her background and family habitus evidently gave her the aspiration to follow a scientific career. She held an apparent strong belief in her science subject knowledge and a knowledge of the nature of scientific activity of which she had vocational experience. Her belief in the nature of science seems to be a hypothetico- deductive view but her teaching indicates a more complex view where there are indications of a socio-constructive view of children's learning in science.

Shamah intimated that she had views that a wide range of different teaching and learning strategies were important to children's development in primary science. She expressed a view of the importance of enquiry for teaching subject knowledge, as well as process skills but also strategies such as talk, drama, explicit learning of vocabulary and thinking frames. This may have originated from her own experience of a range of activity in science or through her experience teaching or a combination of the two.

She identified the lack of time in the curriculum as a barrier to the children's learning in science but had developed a range of strategies to gain more time for science activity.

Shamah appeared to have a significant position as a role model and leader of science within her school science community of practice. She appeared to work closely and possibly influenced the head-teacher and conducted training for the teachers in the school. She gains her support and development through external primary science communities of practice such as the Association for Science Education, ASE. She also shares her own knowledge through writing and talking at external events acting as Wenger stated, as a broker of boundaries (2000). Her status and science capital contribute to her identity and status to carry out these activities.

Chapter 7 – Discussion

7.1 Influences on Beliefs about Science and Science Teaching.

This research set out to explore the influences on three primary teachers' beliefs about science and effective science teaching and how this is developed in schools. Accordingly, this research portrays an understandably complex picture of how beliefs about science and science teaching are formed, develop and change. What is apparent is the socially constructed nature of the belief formation through family habitus (Bourdieu, 2004), school experiences, own experiences of science education and teaching in schools, as well as received messages from the science and science education communities. The case studies teachers' knowledge and beliefs about teaching appear to come from the social construction of belief and meaning (Vygotsky, 1978), as well as through participatory, situated activity (Lave and Wenger, 1991; Brown and Duguid, 1989) when teaching or being part of a school community of practice. This chapter will consider how beliefs are apparently formed about science and science education, the beliefs of the teachers in the case studies about effective practice and how they develop their pedagogy across the three case studies. The combined use of model of Lave and Wenger's community of practice used alongside Bourdieu's social theory model of the impact of science capital will be reviewed. The implications of the research will be discussed, as will the potential for further research. I will, firstly, consider the formation of beliefs about science and science education and review the use of the two theoretical models, communities of practice and science capital, in tandem.

The type and amount of science capital, symbolic, cultural or social, that the teachers bring to their role appeared to influence their beliefs about science and science teaching (Bourdieu, 2004). The three case study teachers' science capital varied in its type from qualifications, their personal contacts in science, an understanding of the substantive and syntactical elements of science, to having a family interest in science. All three teachers possessed a level of science capital that was likely to allow them to identify themselves as primary science teachers, or specialists in the field of primary schools where science capital is low. In this research, there were indications that the type of science capital had an impact on belief and practices. In this study, the teacher with only 'family interest' science capital had different ideas, more positivist, about the nature of science than those who have higher education science qualifications. It is proposed that these ideas might originate from the informal science interest in his family.

In examining life experiences which may impact on the development of beliefs about effective science education, the teachers in the case studies' families, type of science capital, interest and confidence in science appear to have contributed to the formation of beliefs. Neither science capital nor qualification appear, in this sample, to be a prerequisite for the teachers in the case studies being enthusiastic about science or their level of confidence in science in this sample. However, family interest or cultural science capital appears to be a common starting point for the three teachers' own interest in the subject and seems to support an early socio-construction of beliefs about science and attitudes to science. Other aspects, such as public recognition in school, seem to have an impact on the self-image and status of the teacher in science (Wood and Jefferies, 2002). Bourdieu's model of science capital and types of science capital are used here, in a novel approach, to analyse the teachers' life experiences in science and the impact this might have on their beliefs about effective teaching and about themselves as teachers of science (2004). I propose that a further exploration of whether different types of science capital leads to different views on the nature of science, and therefore different beliefs in effective science pedagogy, would be informative to science teacher education, as would exploring different routes into primary teaching, such as working as a teaching assistant in the early years, and its effects on beliefs.

The position of the teacher in the case studies in their school communities of practice appears to be affected by their amount and type of science capital. Lave and Wenger's model (1991) has been criticised for not recognising the differences in power and agency in individuals (Eraut, 2002), or the conditions which give equal access to learning in a community of practice (Cobb and Yakel, 1996; Hodkinson and Hodkinson, 2003; Hodkinson and Hodkinson 2004; Cox, 2005). My research indicates that science capital impacts on the teachers in the case studies' beliefs about science and their power and agency within their own community of practice. The teacher, Shamah, with a large amount of science cultural capital, appears to have more power to influence her school community and other national communities of practice in science than the other case studies. This may arise from the confidence in her identity which her science capital has given her.

The theoretical model of the communities of practice and theories of situated learning combined with Bourdieu's theories of social practice has been used in this research to analyse the teacher in the case studies' beliefs and ability to access learning within a community of practice.

The amount and type of science capital and the teacher's relative position in their school and external communities a of practice appears to be bound up with their identity as a science teacher and their certainty in their beliefs identified in this study. As Swartz suggests (2012), identity is not just who you see you are but who others see you as and who you act as. Nathan, with low science symbolic but some cultural capital in science, was at the peripheries of his school community of practice and primary science community of practice, appeared to be unconfident in his own practice and beliefs. He seemed to be susceptible to taking on the practices from his colleagues at the peripheries of the community, which may, in turn, impact on his beliefs (Nias, 1989 and Turner- Bisset, 2001). Nathan appears to have limited access to learning about science teaching from others and is influenced by his fellow year groups' teachers, even if he does not agree with their practices. He does not have the influence to challenge practices and is only required to plan from a published science scheme. He gains more agency when he is asked to join the science working group. He has retained a connection with a previous community of practice; his university where he trained and where he keeps in touch with the technicians. His beliefs about teaching and learning appear to have been influenced by a previous early years' community of practice. Karen, with stronger science symbolic capital in her field, seems to doubt her beliefs in her practice when she only gets a 'good' grade from her observation; she seems to be conscious of how the other staff see her. She appears to desire to have influence in her general school community of practice but does not seem to feel that she is judged an 'excellent' science teacher to act like a master leading a primary science community. She is not part of an external science community of practice but indicates she would like to be and appears to be able to envisage the benefits of such a community. In both the cases of Nathan and Karen, external within school verification affects their identity as a science teacher. Shamah, with strong science capital for her field, has a secure self-identity and expresses few doubts about her beliefs or practice and sees herself as spreading good practice within her school and in the wider science education community. With substantial symbolic, cultural and social capital, Shamah appears to have a position of power and influence over science within her school science community of practice and is beginning to influence other primary science communities of practice with her own beliefs about science education.

In my research, the combined use of the model of communities of practice and science capital theory has provided a useful tool to analyse the power, agency and situation for productive learning about primary science pedagogy in a primary school. As discussed previously, further research of the impact of different types of science capital on beliefs about science would appear to be a useful way to inform science education about the teachers who teach primary science.

The influence of the teachers in the case studies' views on the nature of science and views about the purposes of science, appears in this research, to be difficult to separate from other life experiences but seems to differ from much of the body of research on secondary science teachers (Koulaidis and Ogborn, 1989; Brickhouse, 1990; Lederman, 1992; Tobin and Mc Robbie, 1997). The three teachers' views could be similar to those of primary teachers, but different from the majority of secondary teachers, made up of a complex mixture of socially constructed views on science, life experiences, and influences from a number of sources and with views on children's learning. As primary teachers come to teaching science with a wide range of experiences, not many with higher level science qualifications, it is probable that they have a wider diversity of influences on their ideas on science than secondary science teachers with science degrees and substantial science symbolic and cultural capital. This research identified a mismatch of views on the nature of science in the teachers in the case studies compared to the current, mostly secondary based research, implying that the secondary based research models may not be appropriate for the range of background and routes to teaching in the primary school. Perhaps secondary teachers are more like to have degree level science with greater immersion in the world of science and so more polarised ideas about the nature of the subject. Some primary teachers will only have GCSE science which they may have studies many years before.

7.2 Beliefs about Effective Primary Science Pedagogy

This section compares the research findings on the teachers in the case studies' beliefs about effective pedagogy in science, particularly enquiry, and socio-constructivist pedagogies, and the linking of practical activities to science concepts beginning with an enquiry and practical activity.

Enquiry or investigative approaches were identified by all three teachers as effective strategies in teaching and learning primary science, in line with the Score research (2008) and yet the teachers appeared to advocate the use of enquiry to develop knowledge in science which was not so common in research reported by Mulopo and Fowler (1987), Watson et al. (1995) and Hofstein & Lunetta (2004). Enquiry approaches are one way that teachers can support children socially, constructing their ideas in science (Anderson 2002; Minner, 2010), especially when the children have some autonomy in the planning and when ideas are linked to the scientific ideas (Ofsted, 2013). As Varma (2009) states, enquiry is embedded in constructivism. Socio-constructivist approaches in science teaching were analysed in this research as a theme in response to literature which states that the social construction of ideas and its corresponding pedagogies in science have been dominant in education since the late 70s, (Driver, 1985; Solomon, 1994; Osborne, 1996; Skamp. 2008; Garbitt, 2011) (see Chapter 2).

In analysing the beliefs of the primary teachers in the case studies on effective practices in primary science they all drew on investigative or enquiry science pedagogies in their practice and fully endorsed the role of practical enquiry work in learning science in their discussions. Shamah and Karen both believed that enquiries were useful for developing subject knowledge as well as process skills and teaching about the nature of scientific activity, supported by Minner's research (2010; Score, 2008), (Figure 8 and 11). Nathan's ranking of effective teaching strategies indicated that he thought investigations/enquiries were more suited to teaching process skills and about the nature of science (Figure 6). There seemed to be a significant tension in the teachers over the balance between science knowledge and stated beliefs on how children learn in science, which was likely to have had an impact on practice. Nathan's views were not always exemplified in his practice. Karen also had conflicts over the more chaotic nature of science and science knowledge learning. Their life experiences and consequent science capital, appeared to impact on their pedagogies and beliefs; Nathan's early years background and Shamah's scientific career appeared to have affected what they believed and what they did in practice.

7.3.1 Socio-Constructivist Pedagogies

The three case study teachers demonstrated beliefs in the importance of socio-constructivist science teaching methods, in interviews or in their practice, even if they did not explicitly name them as such (A1/5/15; FN/ Nathan; C1/5/1-5). There was evidence in their practice of grouping children to discuss ideas, as well as the use of talk partners and, in one case, the joint construction of 'Thinking frames' to develop children's scientific models. There was also some elicitation of children's alternative frameworks at the start of a topic (FN/Karen/ 23.2.15; FN/ Nathan/ 27.4.15; FN/ Shamah/23.2.15). There was less evidence of allowing children to test out their misconceptions. However, the children's alternative frameworks, where they were elicited, were not assessed or explored further, or followed up as advocated by Driver (1985) and the Space project (Osborne et al., 1992) or the learning progressions based on misconceptions of Allen (2016). When asked, Karen said there was no time (C2/4/27) as they had to move on to another part of the curriculum. This is symptomatic of the pressures in primary schools where maths and English take a large amount of curriculum time. This has inevitable negative consequences for children's understanding of some of the counter-intuitive ideas of science.

The three teachers appeared to identify beliefs in the importance of talk for learning and mentioned the use of talk partners, open-ended questioning and grouping children in the research interview and in the ranking exercises; all tools for a dialogic learning approach (Figure 6,8 and 11). All three of the teachers mentioned 'talk partners' in their ranking of effective teaching strategies R / Nathan; R/ Karen/ R/ Shamah). Although talk partners as a class routine can be used to increase children's interaction in a lesson, a two-way conversation and a challenge or questioning of ideas in the talk can be useful to develop the ideas of science which are apparent in practice. Perhaps, as Mercer et al. (2004) found, children benefit from the teacher being trained to lead effective talk, interactive talk and to develop clear ground rules about talking in groups for the children.

7.3.2 Linking Practical Activity to Conceptual Ideas in Science

All three teachers appeared to demonstrate beliefs in the importance of linking the observables to the science in the lessons, yet my research suggests that the more experienced teacher used a wider range of strategies to achieve this link. This indicates an implicit belief that this is an important facet of learning science, which may increase with teaching experience. This may be an inherent feature of primary school teaching and learning across the curriculum, where teachers use a range of strategies to support children's learning in their science teaching as found by Abrahams and Reiss (2012; 2013). The fact that primary teachers teach children across a range of subjects during the day means that meaningful links and reinforcements can possibly be made. In terms of linking the ideas to the observables, this research suggests that over the sequence of activities, links could be made in different ways, not just using one pedagogy.

However, this application of the Abrahams and Millar 2 x2 effectiveness matrix model (2008), (see Figure 1) was applied to a series of activities rather than individual lessons as described in their research paper. This research also uses the model to analyse the three teachers' beliefs about effective science teaching, rather than judging the effectiveness of a lesson. This may be a difficulty of using a secondary science model with primary teachers, as science is not always a discrete lesson in a timetabled slot as in many secondary schools. Sometimes the activity can be part of a cross-curricular study, for example, an analysis of the science graph in maths lessons or recording an investigation in an English lesson. This may also be a reason why Abrahams and Reiss (2012) found that primary teachers made more links between the observables and ideas than the secondary science teachers.

7.3.4 Other Pedagogical Strategies

The teachers in the case studies drew on a wide range of teaching and learning strategies in primary science. This appeared to be underpinned by a belief about what pedagogies were effective in teaching primary science. Shamah appeared to have used her implicit knowledge of science and science concepts in planning to choose the appropriate teaching and learning strategy according to the nature of the scientific knowledge; complex, simple, abstract or concrete (PS/ Shamah; FN/ Shamah /9.02.15). This resulted in the use of a wide range of pedagogies in science. Although not apparent in Shamah's beliefs and pedagogy, this could create a tension between the belief between the importance of enquiry work and the use of a wide range of strategies designed to make the links between ideas and observables. Investigative enquiry can be a useful teaching strategy when allowing children to explore their own misconceptions or areas they are interested in but can be less useful than modelling and analogy when a concept is highly abstract. Enquiry is also useful in teaching the parts of 'working scientifically'; in the National Curriculum (2013) but these skills and processes can be taught through shorter investigative, exploratory activity, rather than full recipe-style enquiries. Perhaps in primary science teachers are still trying to emulate secondary science teaching, even when it is possibly less effective in teaching the subject matter of science (Abrahams and Reiss, 2012). In teaching children how scientists work, perhaps regular, full enquiries are not the most effective way to achieve this goal in the primary school.

This apparent careful choice of pedagogy appears to come from, not only knowledge of the children, but an inherent understanding of the nature of the scientific knowledge to be taught. This implicit knowledge of the nature of the science to be taught and the appropriate pedagogies for that science may have arisen from Shamah's science knowledge, or her experience of the science areas to children. The less experienced teacher used a scheme of work that avoided the need to match pedagogies to subject knowledge, or more of an undifferentiated recipe approach; whole investigations/enquiries with planning on a scaffold, carrying out the investigation and evaluating the results.

There were some features of the teachers in the case studies' discussion on effective pedagogy which were notable by their absence. There was little discussion or practice of differentiation by task and assessment to address conceptual understanding or the development of process skills such as measurement. There was evidence of differentiation in Shamah's planning but this was not obvious in practice (FN/ Shamah; Appendix 11). Differentiation through the formative assessment of children's needs and planning is currently seen as one of the most effective teaching strategies (Black and Wiliams, 1990; Hattie, 2012). Yet, this was not a major part of the teachers' planning or activity during the lessons. There was, however, some evidence of the teachers who altered the language burden or appeared to differentiate by language ability with support and time. It seems strange that in an educational climate where you would not consider planning and teaching a maths or English lesson without addressing children's developmental, educational needs, that science learning needs are not addressed. Perhaps this is symptomatic of the demise of the status of science in the National Curriculum, lack of time in a packed curriculum, or maybe it is a lack of knowledge of how to go about differentiating by task in science. However, without addressing the science learning needs of children in a class can there really be effective science teaching? As Lister and Leaney (2003) suggest, it is not the underlying theoretical framework of a teacher that is important but their response to children's needs

7.4 Barriers to Effective Primary Science Teaching

Barriers to effective pedagogy was identified in response to the Score report, where teachers identified barriers to practical science activity (2008). A specific question was asked in the interview to explore this issue. The findings in my research were more complex than the Score report (2008), perhaps due to their use of questionnaires to elicit opinions. In the Score research, curriculum content was identified as the most cited barrier to science, followed by lack of resources. This difference between Score and my own research is, perhaps, an indication of how different schools may present different challenges as different personalities find aspects of the role more challenging. It is also likely that different contextual circumstances in schools are more challenging to teachers at different stages of their careers (Huberman, 1989, cited in Richter, 2011).

The teachers in the case studies identified time as a barrier, which is closely related to curriculum content but also identified some different barriers to science from the Score report. Three teachers talked about what they thought was effective teaching in science, but each teacher cited different aspects of school life that obstructed that teaching (see Appendix 9.)

Nathan cited classroom management as a factor which presented challenges to his science teaching. He also described his feeling of being limited by the expectations of the school to teach in a prescribed way and the curriculum (B2/4/6). Nathan suggested that his views of school's expectation of children's classroom conduct were a limiting factor to his practice (FN/Nathan/2.3.15). Nathan also discussed how his own excitement sometimes stopped him carrying out effective pedagogies. Nathan's concerns at class behaviour in science were similar to those reported in the Score report which identified 'teacher inexperience' as the second most commonly cited barrier to practical science activity as well as behaviour ranked sixth (Score, 2008). Nathan and Karen were apparently concerned at the less ordered nature of doing a practical enquiry activity and what others thought of their teaching if they saw the disorder. This may mean learning in science is compromised by a school's need to look orderly and calm.

Shamah, contrastingly, identified a lack of time as a major constraint in teaching science, confirming the views of Eraut (2002). Shamah had seemed, however, to have found a partial solution to her time barrier, by splitting the lesson and science learning into what she described as 'chunks' (A1/7/10). She then taught the chunks through other subjects in the curriculum. Her planning skills and teaching experience across the curriculum probably allowed her to see the opportunities for this cross over and consequently, it allowed more time for the science activity.

Karen and Nathan both cited the children's lack of ability as a barrier to effective practice, unlike the Score report. Karen and Nathan stated that they believed the children were under-achieving in science (C1/2/29; C1/3/78; B1/5/26); to counter this Karen felt she had to scaffold the children's science activity. Karen described them as '*children like ours'* a couple of times (C2/7/8; C2/7/21), as explored before in section 5.4.2. At another point, she stated that the children had difficulty making links between science and everyday life (C2/7/10). Nathan talked about how the children lack life experiences to draw on in science lessons (B2/7/26).

The view of the needs of the children will inevitably have an impact on the practice of teacher in the case studies in science. All the three teachers were aware of the needs of the children in science in their class, but two teachers described the children as having a deficit of science skills and understanding, 'othering' the children, I assume, from what they consider the norm. These views may be formed from their own experience, but as children's educational needs are comparative, it is likely that these ideas are formed through socio-constructed sharing of views in school, in the community of practice, as well as through engagement with teachers in the local area. It is possible that these teacher beliefs can become self-fulfilling prophecies through low teacher expectation and support (Brophy 1970; Timmermann et al., 2016).

In contrast to much reported research (Sorsby, & Watson, 1993; Sharp & Grace, 2003; Murphy et al., 2005; The Royal Society, 2010; Science and Technology Committee, 2011), at no point in my data did the participants describe that subject knowledge was a barrier, or an issue in their science teaching. In fact, probably the opposite, Karen talked about how she knew science was an area of strength for her (C1/1/10), Shamah stated how she considered it important to share her subject knowledge with the children, gathered from her degree and her careers in a couple of biological science companies (A1/3/28). Nathan found himself wanting to share his knowledge of science with the children, to an extent that he was concerned he did it too much (A1/7/11). It may be that the participants in this research counter the trend in primary teachers, perhaps through their selection. On the other hand, it may just be that although 60% of teachers declare they are not confident in teaching science that leaves 40% who do feel confident and that I have a sample of primary teachers in that 40% (Score, 2008). This is likely as I chose teachers with an interest in teaching science.

The stated beliefs and some practices of the three teachers have been analysed in this section. Their practice and beliefs appear to vary according to their backgrounds, life experiences and dominantly their experience in the science classroom, and their views of their classes. There is diversity in their approaches and their continued professional development needs. The next section analyses and compares the beliefs on the structures and practices of schools and the science education community for developing these teachers in the case studies in science.

7.5 Professional Development of Science Education Pedagogy

In this section, I intend to compare the reported experiences of the three teachers in the case studies in their own professional development in science education. I will, firstly, consider their initial teacher education, provision for training in schools, their use of communities of practice for learning, and external support for their professional development.

The three case studies appeared satisfied with their Initial Teacher Education but two of them had not experienced targeted Science CPD since their PGCE qualification, in line with the findings of Wellcome (2014) and Cordingly and Buckler (2014). The teachers in the case studies seemed to regret the lack of a role model in science when they first qualified and, for the less experienced teacher, a role model to support their development, at the time of the research, to open up the practices and make them explicit (Wenger, 1998). This lack of expertise in science in the three teachers in the case studies' schools and schools they had previously taught in, appears to be a feature of some concern. The two less experienced teachers expressed a desire to know how to improve their practice and to see a 'good' science teacher teaching. This was not apparently available in their schools. Having a strong school community of practice does not appear to address the needs of specific subject teaching development if there is no other science teaching expertise in the school. Karen was also concerned that the head-teacher doing her observation did not have or share her beliefs about effective science teaching; a key feature of a functioning community of practice (Wenger 1998).

The combined model of communities of practice and science capital can also be applied to the potential for professional development within school's learning communities. Communities of practice in the teachers in the case studies' schools appeared helpful to generic development in primary teaching and middle management roles or had the potential to be helpful in the future, in their own development. However, these internal communities of practice did not necessarily have science teaching expertise, or 'masters', to support the teachers in the case studies; two case study teachers *were* the science teaching expertise in their schools, even if they did not feel they were. The model of learning communities of practice, suggested by Lave and Wenger (1991), had a resonance with the teachers in the case studies' progression in developing effective science teaching practices as the three teachers acted in science leader roles in the school, working towards becoming 'masters' of science.

The interplay of identity and status in the school, experienced by the teachers in the case studies, due in part to science capital, as well as the desire to feel part of the community, was complex. In one case, it appeared that one teacher was prepared to use practices he thought were ineffective for learning in science to fit in with the other teachers. In another case, the assigned role of master caused problems if the teacher was concerned that they did not merit the title.

The less experienced teachers in the case studies, Karen and Nathan, did not use any external communities of practice, either real-life or virtual, to support their own development. Models, such as Lave and Wenger's anthropological model (1991) are, by their nature, a simplification of human behaviour. This research points to the complexity of human behaviour and social interaction that occurs in any school situation. Shamah, however, had become a broker of science education innovation for her school, although we cannot tell how this is received or implemented in her school. This may be her personality, but I also conclude this is to do with the confidence the credibility of her science capital as well as the support of her school senior management provides. In this situation, she has also gained further social capital, but through science education contacts, from the ASE, science education lecturers and authors writing articles about science teaching. This continues to strengthen and specialise her original science social capital into a science education capital of greater impact in school. Shamah was acting like Wenger's 'broker' between communities and searching out other communities to learn from, which benefited her own practice and possibly that of the teachers in her school (Wenger, 2000).

The present and previous government (2010-) have put in finances to develop the STEMNET as a central support, and perhaps, the idea of a virtual community of practice for science teaching. It is important to note that although the teachers in the case studies in this research used STEMNET or commercial resource sites for curriculum ideas, they did not see them as places for developing new pedagogies or refining existing pedagogies. The teachers in the case studies expressed a desire for situated CPD, whether informal or formal, as cited by Ritchter et al. (2011) and Grosemans et al. (2015). Virtual forms of CPD cannot be replacements for face to face training as they do not appear to influence pedagogy in this research. The lack of CPD identified in the local area at the time of the research was a cause for concern. Without science masters or CPD, it is difficult for the less confident, isolated teacher to find science teacher training. Local primary science CPD could be a solution to this issue but the diverse form of school governance and the demise of the LEA and science centre do not make this easy.

7.6 Contribution to Academic and Professional Research

The current study contributes to academic knowledge by proposing a new model which is based on Lave and Wenger's learning model of communities of practice and peripheral learning (1991;1998) but that enhances the model by also using Bourdieu's social practice model to acknowledge what experiences, knowledge and social contacts an individual brings to a field or community (1999). This model can be used to analyse the influences on beliefs and practices in science according to the teachers' science capital. The teachers' science capital also appears in this research, to determine their position, power and access to learning within the school science community of practice. The combination of theoretical models addresses Eraut's (2002) criticism of Lave and Wenger's anthropological model by recognising the possible power dynamics between individuals with differing amount of science capital with a field, the school, with historically and nationally low science expertise. A master, science leader, in a primary school may possibly have less science capital than a newly qualified teacher with a physics degree. It also provides a model to analyse the impact of the views of Cobb and Yakel 1996, Hodkinson and Hodkinson, 2003, Hodkinson and Hodkinson 2004, Cox, 2005, who suggested that teachers will be chosen or bypassed for further training according to their science capital and therefore their status.

This research raises the question that different types of science capital may have different impacts on teacher's beliefs about science and effective practice. The subdivision of cultural science capital appears to be a broad category. In this research, the teachers' cultural capital varied from a father's interest and involvement of his son in his interest, to substantial emersion in scientific processes of biomedical sciences. These different types of cultural capital appeared to have different impacts on beliefs and practices and warrant further exploration.

From a professional perspective, I consider that the communities of practice and science capital models could be a helpful tool for identifying NQT teachers' science CPD needs in different schools. The needs of the NQT could be met through analysis of the science capital they bring to the school and analysis of the corresponding expertise and science education capital of the existing staff in the school. If there are no 'masters' of science within the school, pairings with science expertise in other schools could be a productive alternative. It is a concern that there appears to be limited science expertise within schools; with high rates of teachers leaving the profession this can only get worse.

7.7 Limitations of the Research

In a research project of this size, there will always be limitations of time and resource as there is only one researcher. The use of qualitative case studies should not act as a limitation, although over generalisation from a small sample may be not inappropriate (Flick, 2011) but as Flyvberg states it can provide detailed examples of behaviours (2006).

There are areas that I would have liked to research, such as the role of assessment and differentiation in science learning, which now I believe would have informed the discussion on the teachers' views of addressing individual needs in science. However, this was not in my initial interview design and was not referred to directly by the three teachers in interviews.

In commenting on the practice of the teachers in the case studies it is difficult to unpick whether I or the teacher initiated a particular pedagogy, although I tried to let the teacher lead the practice as Hitchcock and Hughes (1989) warned. However, I do not see this as a problem: in the way an interview is a joint construct our practice in primary science was also a joint construct. I believe that similar decisions would have arisen if I had been silent during the planning process.

7.8 Concluding Comments

Throughout this thesis has been the recurring theme of 'situational learning', starting from my own experiences, learning by teaching alongside others to becoming a teacher educator, to the theories of Brown and Duguid (2001) and Lave and Wenger (1991) and the nature of enquiry learning. I chose my research methods to be as situated in the case study teachers' context as they could.

It is probably a belief that underpins my own practice in ways of which I am unaware. I have learnt much from 'being' a researcher as well as learning alongside these teachers; in the process, I have probably altered myself, my identity and my own beliefs.

Learning...doesn't just involve the acquisition of facts about the world, it also involves acquiring the ability to act in the world in socially recognised ways. Learning, in all, acquires identities that reflect how the learner sees the world and how the world sees the learner (Brown and Duguid, 2001, p.200)

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Appendices

Appendix 1 Interview 1 Questions

1. Tell me about your background and pre-service training and how you became a primary teacher who teaches science.

2. Tell me about your experience of being taught science at school

3. Tell me about your experiences with science courses in ITT and teaching practices.

4. Why do you think we should teach science?

5. What are your broad goals for teaching science?

6. How do you believe children learn science best?

7. What are your most effective teaching strategies in science and why do to you think they are effective?

8. Explain how this relates to what scientists do (inquiry)?

9. If I came into your room and you were running your perfect science lesson, with perfectly behaved children, endless resources and time. What would that look like? What would you be doing? What would the children be doing?

10. How do you think you help children to link their concepts to practical experiences?

11. Describe for me how you would teach a science topic of your choice, from beginning to the end, in terms of the sequence of events that would occur. Practical activities at the end, beginning? Why?

12. Is there anything you would like to add, related to anything that we talked about today?

Appendix 2 Interview 2 Questions

Did you have any more thoughts about our initial interview I sent you?

Let’s look at what we used in teaching. Tell me about the strategies you have put at the top/bottom and explain why you think they help to develop children’s skills/ knowledge or understanding of the world of science

What was it like working to teach science with someone else?

Is there anything you have done this year that you have not done before and where did you find out about it?

Is there any factor that stops you teaching the way you want to?

What science training have you been on since you started teaching?

Who do you talk to in school/out of school about teaching?

Who do you talk to about science teaching in or out of school?

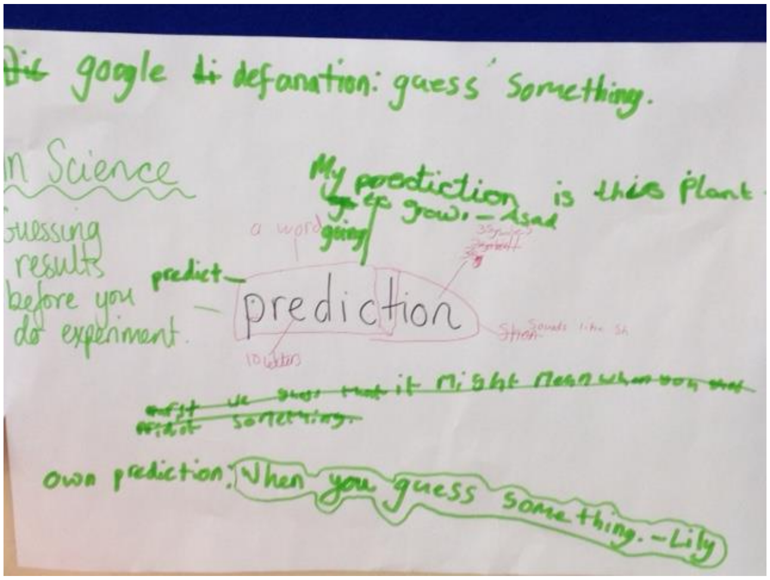
Where do you think you learn most about new methods/ approaches in science education?

When you go online to support your science teaching where do you go and what do you look at- science activity ideas/ ready-made power-points/ approaches for teaching science? Materials from industry/ science institutions?

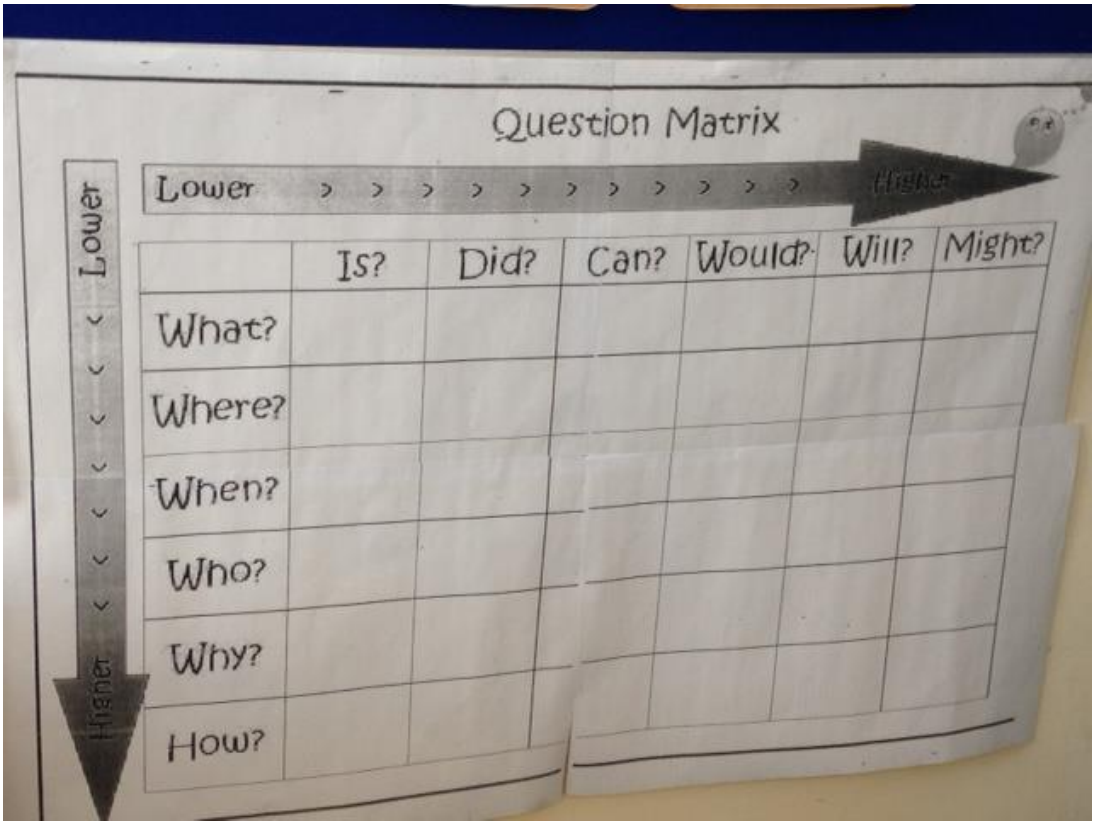
What do you look for in a good online resource?

What support could make you an even better teacher of science?

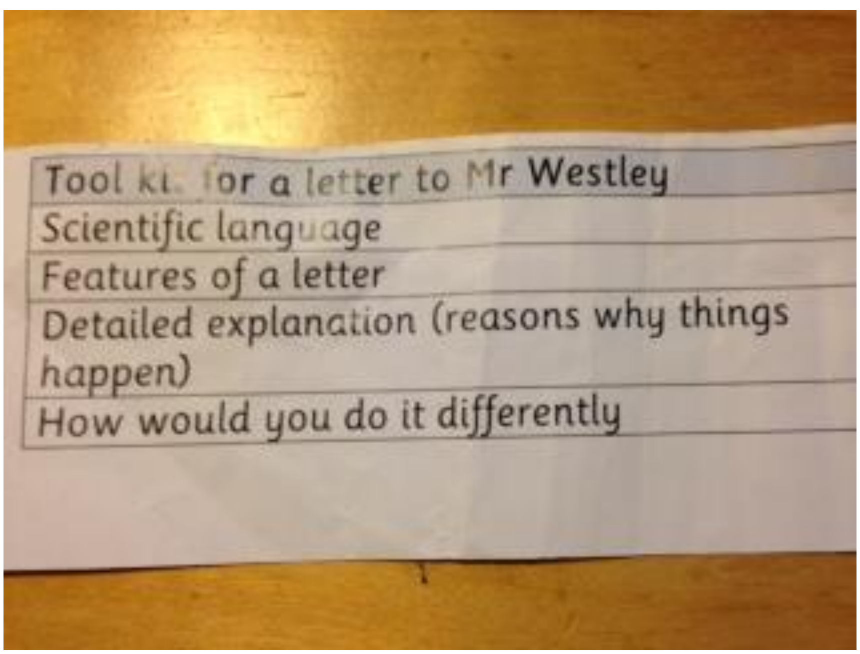
Appendix 3- Poster in Karen's Classroom from Field Notes



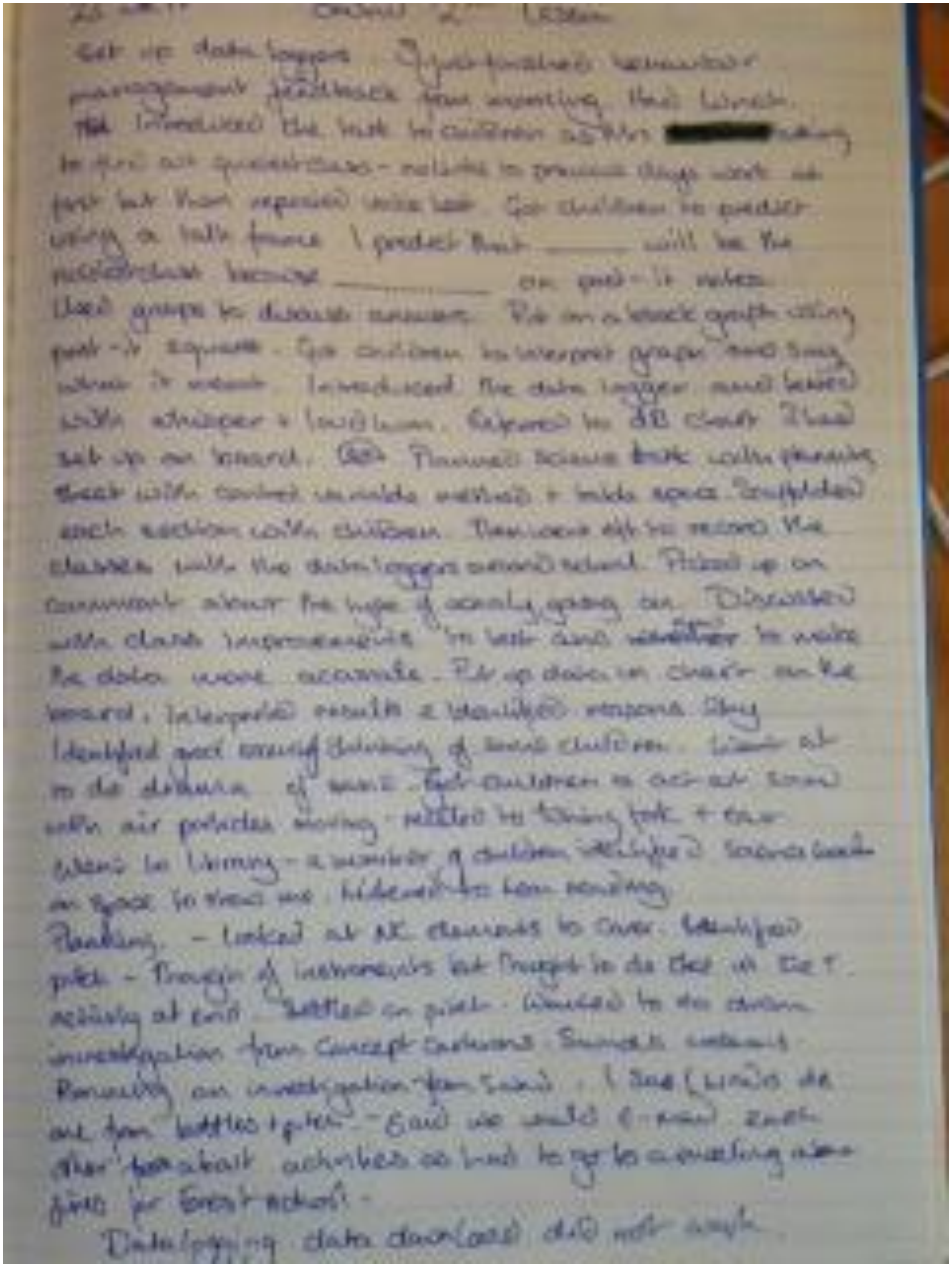
Appendix 4- Karen’s Questions Matrix from Field Notes



Appendix 5 Nathan’s Toolkit for Recording Growth Activity from Field Notes



Appendix 6- Sample of Written Field Notes from Karen's class



Appendix 7. Teaching and Learning Strategies Ranking Activity- Shamah

Thinking frames

Problem solving with tin foil and battery

Electricity drama

Demonstration with electric tube

Building a circuit without instruction

Writing a letter to Mr.Grinling

Exploring switches

Making a switch

Design and make a burglar alarm

Poster for burglar alarm

Gaps and connections video

Questioning going around room

Buzzing balls exploration

Talk partners

Learning detectives.

Classification of electrical appliances

Levels Mountain.

Appendix 8 Themes and Data Sources on Impacts on Beliefs

A1- first interview with Shamah, A2 Second interview with Shamah, B1 First interview with Nathan, B2 Second interview with Nathan, C1 First Interview with Karen, C2 second interview with Karen. Numbers indicate page and line numbers in transcribed text.

Themes	**Shamah**	**Nathan**	**Karen**
Science Capital: Family interest	A1/1/45 A1/1/7-8 A2/11/26 A2/6/19	B1/1/1-5 B1/1/20 B1/1/9	C1/1/10
Science Capital: Qualification – economic capital	A1/1/12 A1/2/2 A1/1/14 A1/1/17 A1/2/12 A2/6/9 A2/13/15	B1/1/17	C1/1/11 C1/1/12 C1/1/4
Science Capital: Cultural capital –science educ contacts	A2/2/21 A2/14/12 A1/4/20 A1/15/27 A2/6/9 A2/6/27 A2/8/5 A2/10/13	B2/1/11 B2/5/2-4 B1/1/17	C1/9/20
Attitude to school science	-ve A1/1/1 +ve A1/1/8 A1/1/25	-ve B1/2/4 +ve B1/1/3	+ve C1/1/25 C1/3/2
Nature of Science: Hypothetico-deductive	A1/3/8 A1/4/28 A1/5/0-21 A1/1/6/17 A1/7/12 A1/8/26 R/Shamah PS/ Shamah FN/ Shamah/ 27.04.15	B1/1/3 B1/3/1-4 B1/1/9 B1/3/10 B1/4/10 B1/5/12 B1/6/5 B2/1/21 B2/4/12 FN/ Nathan/23.02.15	C1/3/22 C1/7/26 C1/4/ C1/4/8 C1/5/15 C1/8/6 R/ Karen FN/ Karen PS/ Karen

Nature of Science: Positivist	A1/4/14 A1/10/11	B1/4/21 B1/8/1 B1/6/13 B1/7/11 B2/9/3 B2/6/15 B2/8/25 R/Nathan	C1/4/25
Nature of Science: Misconceptions	A1/7/12 A1/7/14 FN/Shamah/27.04.15	B1/7/23 FN/ Nathan/23.02.15	FN/ Karen/ 23.06.15
Science Teacher Identity: Positive	A1/9/28	B2/5/20 B2/6/20	C1/2/9 C1/3/19 C1/4/22
Science Teacher Identity: Negative	A1/5/15 A2/4/15 A2/5/13 A2/8/21 FN/ Karen/22.09.15	B2/8/22 B2/9/11 B2/1/2 B2/9/16 FN/ Nathan/23/03/15	C1/5/15
Purposes of science a. Fun b. Prep for secondary c. Curiosity	a. A1/3/9 c. A1/9/20	a. B1/2/21 B1/3/1 b. B1/7/22	a. C1/5/10 b.C1/4/21

Appendix 9- Themes and Data on the Three Teachers' Beliefs on Effective Teaching in Science

A1- first interview with Shamah, A2 Second interview with Shamah, B1 First interview with Nathan, B2 Second interview with Nathan, C1 First Interview with Karen, C2 second interview with Karen. Numbers indicate page and line numbers in transcribed text.

	Shamah	**Nathan**	**Karen**
1.a Belief about Investigation for teaching subject knowledge	A1/7/12 A1/5/11 FN/Shamah/9.02.2015/ 23.2.15/ 2.3.15/9.3.15 PS/ Shamah R/ Shamah	B1/2/1-2 B1/3/21 B1/4/-2 B2/ 5/ 1-16 B1/5/8 FN/ Nathan/27.4.15 11.5.15/18.05.15 Appendix 5 R/ Nathan	C1/1/5 C1/6/26 C1/2/2 C1/4/25 C1/5/18 C2/3/25 C2/4/13 C2/3/28 FN/Karen/8.06.15/22.6 .15/ 23.6.15 Appendix 4 R/ Karen
1.b Belief about Investigation for teaching process skills	A 1/7/23 A2/2/1 A1/8/26 FN/Shamah/9.02.2015/ 23.2.15/ 2.3.15/9.3.15 PS/ Shamah R/ Shamah	B1/2/1-2 B1/4/10-15 B1/5/8 B2/3/19-20 B1/6/14 B1/8/19 FN/ Nathan/27.4.15 11.5.15/18.05.15 R/ Nathan	C1/2/2 C1/3/12 C1/8/9 C2/3/1-2 C2/2/13 C2/3/28 C2/4/12 FN/Karen/8.06.15/22.6 .15/ Appendix 3 and 4 23.6.15 R/ Karen
1.c Belief about Investigation for teaching about the nature of science	A1/7/21 A2/2/9-12 FN/Shamah/9.02.2015/ 23.2.15/ 2.3.15/9.3.15	B2/3/15 FN/ Nathan/27.4.15 11.5.15/18.05.15	FN/Karen/8.06.15/22.6 .15/ 23.6.15

	PS/ Shamah R/ Shamah	R/ Nathan	Appendix 3 and 4 R/ Karen
1.d Belief about didactic teaching methods	A1/8/18 A1/10/10	B1/3/11-12 B1/4/22 B1/7/11 B2/7/16 B2/6/10 FN/ Nathan/27.4.15 11.5.15/18.05.15 R/ Nathan	
2.a Belief about science social constructivist approaches	A1/5/1 FN/Shamah/9.02.2015/ 3.2.15/2.3.15/9.3.15 PS/ Shamah R/ Shamah	B1/7/23 FN/ Nathan/27.4.15 11.5.15/18.05.15	C1/3/22 C2/1/7 FN/Karen/8.06.15/22.6 .15/ 23.6.15 R/ Karen
2.b Belief about socio-constructivist dialogic teaching methods	A1/5/13 A1/1/17 FN/Shamah/9.02.2015/ 23.2.15/ 2.3.15/9.3.15 PS/ Shamah R/ Shamah	B1/3/22 FN/ Nathan/27.4.15 11.5.15/18.05.15	C1/7/12 C1/7/16 C2/2/15 FN/Karen/8.06.15/22.6 .15/ 23.6.15 R/ Karen
2c Belief about other teaching methods	A1/5/18 A1/6/25 A2/1/4 Vocab- A1/8/6 A1/8/12 FN/Shamah/9.02.2015/ 23.2.15/ 2.3.15/9.3.15	B2/5/6 B2/6/10 Vocab B1/3/9 FN/ Nathan/27.4.15 11.5.15/18.05.15	C2/1/7 C2/3/13 C2/2/20 C2/3/19 FN/Karen/8.06.15/22.6 .15/23.6.15 Appendix 4 R/ Karen

	PS/ Shamah R/ Shamah		
3. Belief about barriers to science teach	A 2/4/18-25 A2/5/6-15 FN/Shamah/9.02.2015/ 23.2.15 / 2.3.15	B2/6/7-15 FN/ Nathan/27.4.15	C1/5/15 FN/Karen/8.06.15
4. Belief about making links between observable and ideas in science	A1/6/25 A1/8/6-13 FN/Shamah/9.02.2015/ 23.2.15/ 2.3.15/9.3.15 PS/ Shamah	B1/7/9 B1/7/7 FN/ Nathan/27.4.15 11.5.15/18.05.15	C1/2/2 C1/7/18 C1/2/8 C2/3/14 C2/3/18 FN/Karen/8.06.15/22.6 .15/ 23.6.15
5. a Use of differentiation strategies	A2/1/9 Appendix 10 PS/Shamah		
5.b Use of assessment strategies	A1/8/12 B2/2/26 A1/9/4 FN/Shamah/9.02.2015/ 23.2.15/ 2.3.15/9.3.15 PS/ Shamah	B1/8/26 B1/9/12 B1/9/7 B2/1/25 FN/ Nathan/27.4.15 11.5.15/18.05.15	

Appendix 10- Themes and Data Sources on Professional Development in Science.

A1- first interview with Shamah, A2 Second interview with Shamah, B1 First interview with Nathan, B2 Second interview with Nathan, C1 First Interview with Karen, C2 second interview with Karen. Numbers indicate page and line numbers in transcribed text.

	Shamah	Nathan	Karen
ITT positive	A1/1/29 A1/2/1-2	B1/6/23 B1/1/9 B1/1/20	C1/2/8-16 C1/4/22 C1/9/10 C1/10/9
ITT negative	A1/4/9		C1/8/16 C2/6/23
CPD Experiences	A1/3/17-25 A2/3/12-14		
CPD Lack of	A2/10/14	B2/8/11 B2/10/2	C2/9/19-27
Internet support	A2/8/14 A2/8/20		C1/6/3 C1/6/9-10 C2/10/2 C2/10/9 C2/10/16
In school COP	A1/5/17 A2/14/14 A2/8/5 A2/9/15 A2/11/18	B2/1/2-4 2/1/18-26 B2/2/20 B2/3/27	C1/6/25-7 C1/7/10 C1/9/19-23 C2/1/3 C2/3/23 C2/5/1-2 C2/9/1-2 C2/9/6
External Cop	A2/5/18-25 A2/6/9-10 A2/7/10-13 A1/5/23-28	B2/5/2	C2/9/11
Desire for Future CPD formal	A2/6/18 A2/7/1-2 A2/9/14-15 A2/9/7	B2B2/10/15 B2/11/12/ B2/8/16-22 B2/9/7	C2/6/4-5 C2/6/15 C2/12/22
Future CPD informal	A2/9/7	B2/10/16 B2/12/25	C2/11/22

Appendix 11 Sample of Shamah's Planning

STEM Science, Tech Engineering

Key Questions for session:	What do switches allow people to do? How do electricans show/use circuits?			**Resources** (incl. adults)	Batteries, bulbs, wires, switches
Warm up:	Peer asses understanding from last session and mark each other's work				
Introduction:	Explain to the children that you will mime using a switch and that they have to guess what appliance you are using. The actions are the important thing in this activity because it will demonstrate to the children that there are different ways switches can work. You may like to: push as in turning on a computer, or light switch; slide as in turning on a torch or selecting a function on a CD player; or turn as in a dimmer switch for a light or volume control, pull as in turning on a bathroom light. Write up the words: push, pull, turn and slide on f/c and ask the children to look around the classroom or to think of their home and suggest objects that work when a switch is moved, and to then sort that object into the corresponding place on the f/c. Ask the children to think about why these objects have switches. Through discussions with the children the main idea that should come out is that *a switch allows you to turn an appliance on or off or to select a different function. It can also save electricity (turn lights out, turn appliances off – don't leave them in standby mode, etc.).* Show the children a few pre-made examples of switches: • Paper clip & split pins in card • Foil with crocodile clips to attach wire in folded card that has to be pressed to make the link; • Split pins in small piece of card plus paper clip. Explain to the children how they work and how they were made, but ask them to suggest *why* they work. Chn investigate different types of switches and then have to design their own switch to stop their brother/sister coming into their room!				
Main Activity (incl. support & guided groups)	**BA**	**A**	**AA**	**Specific provision**(as approp) **for:** SEND	G&T
Assessment	To explain how to make a switch using time connectives using a word bank	To explain how to make a switch using time connectives	To explain how to make a switch using time connectives using scientific vocabulary independently	To explain how to make a switch as a storyboard using time connectives and a word bank	
Plenary:	Show chn how to draw circuits and the different symbols.				

Session 5

J: (Explains her own background in science education) Tell me about your own background in science. What were you like when you were a child, where you interested in science, what were you like at school, did you like science, that kind of thing?

K: That is one of my main primary school memories of science being taught I can remember going outside and we had, it was about evaporation and I remember our puddle investigation and condensation, that is my stand out memory I think. And then when it came to secondary school I really did not like it so much, especially physics and chemistry. I was very interested in biology and I carried that through onto ‘A’ level.

J: Are either of your parents in sciences?

K.: No, neither of them. We are quite outdoorsy and very animal loving and into nature – I think that is why I like biology such a lot. I did well at science at GCSE and then just took biology onto ‘A’ level because that was the only one I was really interested in. And then did psychology at university, quite a lot of my modules when we had a choice leant towards Psychology– perception, the psychology of aging, looking at neurological causes of dementia and things like that so... Yeah, I probably lean more towards the science side of psychology rather than.

J: Where did you do that?

K.: At UNIVERSITY NAME.

J: Oh, I went to UNIVERSITY NAME.

J: How funny. You are a lot younger than me. I was there before the trees. They planted loads of fully-grown tress suddenly in my last year. That’s why there are huge trees. They were not there before. It was really bleak, and the wind used to howl across.

K: So, then they planted some trees.

J: So, when you were at school did you consider yourself good at sciences.

K.: I considered myself good at science I think because I did not have to try too hard to get it.

J: Were you at a girl’s school or a mixed school

K.: I was at a mixed comprehensive.

J: So, what happened when you. Did you do a PGCE?

K.: Yes, I stayed there to do it.

J: What was your science courses like then and what were you teaching practices like for science?

K.: Well, science was expected to be taught on our first placement, so we had three placements and our first one was only a month. We were expected to teach English, Maths and Science so straight into that. I really enjoyed teaching science so that was my strength at that point in time I think because I was interested in it. It was yr. 6 and adaptation so .um and then continued science throughout the other two placements, it was a requirement around the foundation subjects. We had a lot of science seminars. I think UNIVERSITY NAME pushed science teaching a lot but it is was a core subject in the old curriculum and we had a lot of seminars and a couple of lectures, but the seminars were pretty hands-on and good. They showed us a lot of different ways of teaching. We would be given a topic say space, for example and we would look at the QCA plans and come up with activities ourselves and be shown different activities.

J: Was it in the little labs at UNIVERSITY NAME?

K: Yes, but it was in the new building there in the nice Institute of Education now. There were still some 60's buildings there but we did not go into them.

J: Why do you think we should teach science to children this age as some people don't agree with that?

K: To make them curious. To make them want to find out about the world around them. Especially a child like ours who don't observe. That's the hardest thing I have found. The first term science here we just taught observation as a scientific skill because they just couldn't look and see changes or anything. I think it is trying to get them to question things around them. Just that desire to find out more like how does this work why does this happen? Make predictions. The follow up observations to see if they were right in the first place and then getting some of them. We have been ...Last term we have been getting them to make science predictions and then use their scientific knowledge to back it up. When they realised it all fitted into place and that they knew, that they could guess based on what they knew.. it is like linking knowledge. It's a life-skills that –questioning, predicting, just being interested in the world around you. I don’t think other subjects can do that as well as science can as the whole point of science is to question so.

J: So, what do you think you we. This might overlap a bit. What are your broad goals for your classes in science. What would you have liked to have achieved by the end of the year?

K.: The love of science, the buzz. So, when they found out they were having science they said ‘YYYESSSS’. That’s a massive start and I what I said before that observation is just getting them to look around and to see what’s happening and to try and figure out why it is happening and try and help them with their fair testing and their actual planning and setting up an experiment. They are not good at that at all.

J: Do you think they had a lot of that before or not?

K.: No. At Key stage 1 we can see that in maths and literacy. These areas are weak for them, so they don’t have a foundation in it. This Ks yr. 3 are not so bad but 4,5, and 6 lots of gaps in every subject

J: But you have got a new team, so it should get better and better every year.

K.: Yes, and we can see that. We can see it in the year 3.s coming up. It’s making such a difference. Before they must have struggled quite a lot.

J: So how do you think children actually learn best in science?

K.: Hands on just practical generating questions themselves trying to give them a bit more independence. I don’t really know. That sounds silly to say I have not really thought about it but yeah.

J: We do a lot of things in primary schools we have not really thought about. Sometimes there is not time to think about it is there?

K.: No, I just try and make it as hands on and as interesting as I can really.

J: So what kinds of things have you found really works when you do it with them. That might be again have things that overlap there. What kind of things have you found really helps their learning?

K.: To start with we have had to do away with independence because they have needed a lot of structure. They just don’t know where to start. So hopefully this term we will get to the point when we are teaching more independence, fingers crossed. It's like all the growing we are doing now we are. They can get so hands on and they can see this all in action and over a long period of time. It is almost like incidental science learning, so it is not just lessons and picking up on it whenever you can.

J: A bit like when we say, don't we, that teacher should try and bring on the literacy and numeracy of children in every opportunity they can. You suddenly think oh let's do some more words and introduce some more words and in a way, it is the same with science as actually it is everywhere. (yeah)

J: So, Ok. If I came into your room and you were running the most perfect science lesson. (Goodness) Nothing is a barrier. The children are immaculately behaved they are clever they are well trained, you have all the resources you want what would it look like. What would you start off with, what would you do, what would you be doing, what would the children be doing?

K: What sort of a science lesson?

J: It could be anything you like. What would be your perfect science lesson?

K: I think I have had it once. (J. Did you?) That was the PGCE experience. I could not have changed it at all and I still can't think of any changes

J: What did you do?

K: It was adaptation and it was an art/science lesson where they created their own. They decide on their own habitat and created their own beast. They had to explain what all the features of the beast allowed it to d, allowed it to find the habitat. It just gave them so much freedom and showed how well they had understood adaptation. It just worked so well. They created it all. So, they drew the beast labelled it and some tables had just worked together and they went off and created their own mini- ecosystem where they had all different creatures that all linked together, and this was quite an able year 6 class. And why this creature could have been a predator for this creature and they had done this independently. It was independent, but they were sitting on a table on this table they decided that this is what they were going to do. Beasts that work together. (10.05)

J: Oh, the beasts were working together, I thought the children were working together.

K: No. Well they were working shows how much knowledge they had

J: Was this the culmination of quite a lot of work?

K: Yes. The final science lesson. It just worked

J: It is really interesting way to draw all that together and making links so that seems to have a purpose and form.

K: But I always find science investigations quite chaotic. They never seem as if they are perfect. I'm sure they are really good in the sense that the children are making different observations, setting things up on their own, coming to their own conclusions which I love, and they come up with 'this is why' using their science knowledge. But that lesson has been the best science lesson I have ever taught just the way the children worked I think it must have been, like you said, it must have been the end point where they had so much knowledge that it worked so well.

J: When you say doing investigations. Obviously, there is quite a lot about teaching investigations alongside other types of enquiry. So why do you think enquiries are specifically good for your children?

K: Umm. (long pause) Can I think about that one, have you got another question? I can come back to that one.

J: Tell me how you would teach a science topic. How would you start off what would you do? What kind of things do you plan? That kind of stuff.

K: I always go through the STEM websites because I think they have so many hints and so many resources- it gives you inspiration and all over the place and I always find it difficult to get to the right place but actually even before that I go to the NC and see what it is they need to learn. We have got a really good tracker which highlights the key objectives, really clearly so some things only have three or four. I think how can I… Then I go to the STEM website and see the kind of activities, I can link to those learning objectives that the kids have got to hit. And then it is quite a lot of I don't every plan anymore, I used to plan medium term plan over the holiday, but I always found that you feel as though you have to stick with what you have done when you have dedicated some much time to it. It is quite difficult to peel away so to peel away so.

now I plan with my partner teacher. So, she will take one week, and I will take the other picking up on that

J: Are you two form entry?

K: No, one form but we have a cycle. We do CLPE together every year and then our foundation subjects are the same. So, over the two years they will cover year 3 and year 4 activities/ it just makes it easier for to plan and resource. I think we probably get better quality lessons doing it that way

J: It is just nice to have someone to talk to about it

K: We bounce ideas off each other a lot. It is almost like we have a look on-line for inspiration/ ideas and then come back to it a little while afterwards and mull it over in our heads a bit,, um Yeah. Was that the whole question?

J: Ok so you have decided what you are going to do plan by week

K: So, we will have 3 lessons a week and we will try and hit one or two objectives over that time. So especially if we have an investigation it gives us lots of time to focus on it not like the hour that you can have for a science lesson that you have to squeeze everything in .

J: So, you do 3 lessons of science a week when you are doing your science topic?

K: Yeah, which is really good. So, if it is a history focus this term we do two history lessons that we squeeze in, so we might try and do the same next term. So, there will be at least two science lessons a week. They are about 1.5 hour each.

J: Then would you do a mixture of practical activities and.

K: Yeah, we do, I'll just get a plan. Our last term we have had quite a few students so this year quite a lot of our science was planned by students but with input from us. Um Term K. science term: rocks

J: Do you share your planning on?

K: Yeah, it's all on the T drive so people can um get it whenever they like to. (Looking)We don't seem to have a lot up there.

K: I wonder where that is (looking on lap top). Yeah, we always begin with a lesson to elicit prior knowledge like what we already know. I remember what we did for this lesson. It was a materials unit so we went for a walk around AREA and we were looking for different materials what do you think and thinking about them. Looking to see here we see glass and thinking about why glass is used there. What is made of metal? We found a lot of plastic which is the most common thing and so we will always begin with a lesson that generally has some excitement and helps them to see they already know something about this, so they use that knowledge and the processes as well. Umm, I think this is the only thing on rocks that we have done so far actually. So, what have I got here? We are looking at the layers of the Earth. We have different things to represent the layers of the Earth like top soil and the bed rock to represent the rock and we used all sorts of things to represent it.

J: Like soil profiles?

K: Yeah, they were labelling the different layers trying to think of other examples that we do. You could so easily show them a video, show them a picture but actually that is not going to help them at all it is the creating it themselves. What other things did we do for rocks? Oh quite a few just investigations for the properties of rocks, identifying different rocks. They were kind of more boring lessons actually we did quite a lot of.

J: Yeah, I find rocks and soils difficult. I quite like doing chocolate rock cycles.

K: We did that as well (laugh), to show how metamorphic rock is formed. *They loved* it

J: When I did it the children were licking the tables and I was thinking this is not entirely hygienic.

K: It is doing things like that presenting in a way that is appealing to them I think. It will be interesting with forces when we can get a lot more fair-testing in. Um and then we have sound as well which will lend itself to a bit of fai- testing.

J: That will be good

J: So, has there been any particular person or ... who or what has been some of your, the greatest influences on the way you teach?

K: I don’t know really. um.

J: Was it people you saw when you were at school or people on your course or people here or..?

K: I did not see a huge amount of teaching on my PGCE. No, I was left to my own devices on my teaching practices pretty much. My first placement was in Stoke in Coventry which I loved. My teacher there was great. He was the year six teacher, I spent a lot of time in the class watching him teaching, he was a very good teacher. And then I was at SCHOOL in Sydenham near Leamington, which was lovely catholic school, very easy. My teacher there was the deputy head and the SENCO, so she was like ‘can I go to the office and do stuff?’ so I had an HLTA with me a lot. But I think actually that school really helped me because the first placement was pretty challenging, inner city Coventry and it was just quite hard work. But this school was easy, easy, easy. I think it allowed me to be a bit more creative and can’t think what we did for science oh it was rocks um they had so many resources and things It just meant I could do what I wanted really, I did not have to worry. I think that school was .. just allowed me to experiment a bit and then my final school. We did sound. That was year 1. But a very heavily pregnant teacher who went off on maternity part way through my placement (j. and left you in charge? .Ok) laugh.

J: Did they plan to do that?

K: They must have. She was meant to leave at the end but she was in and out of hospital, so it was not really her fault but.

J: It probably gave her the option of going off a bit more knowing the class was in safe hands.

K: I think they were a mad bunch, but I did not really think they were just insane. I had a child running off into the far distance in a lesson during an observation on sound but anyway.

J: Maybe he was seeing how far away he could hear the sound from.

K: Maybe, maybe. I think my PGCE allowed me to do what I wanted. I did not have somebody breathing down my neck. The freedom was really good and then I loved my psychology teacher at secondary school and one of my biology teachers at ‘A’ level, but I don’t think. Secondary style teaching is so different from primary that I don’t think it had much on an impact on my teaching although my biology teacher did do a lot through we did a lot of presentations, drama and art. Now thinking about it, it had an impact without me really realising. And then I don’t know.

J: Do you have people here who you particularly admire, teachers or do you not see enough of each other's teaching?

K: We see quite a lot of each other's teaching but science teaching I have not seen anyone. I will have to go and watch but we all watch each other like xx and I work well together, we have been such a good partnership jut always trying to get better and better and it has worked so well this year. And we are surrounded by Cxxx and Lxxx, Cxxx, we have got really good teacher here.

K: I think living in London made huge difference as well my first year of teaching as you had everything on your doorstep. We had the Royal Observatory took my kids there it was just so interesting we were doing earth and space and the children were really interested and the trip happily coincided with our topic.

J: Do they do good events there for children?

K: Yeah, really good, the planetarium and they have lots of different workshops run by the astronomers there, so we made sundials with them. Yeah, really good and the science museum, just incredible.

J: So, you were in XXLEA

K: Yeah.

J: Did they run courses?

K: No not a huge amount. They had quite a good NQT programme and we had a couple of science ones there which was always that putting science into context putting investigations into context.