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The use of questions in primary science: a collaborative action research study

by

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Abstract

Science education research and policy highlight the importance of children being able to ask questions and engage in discussions in order to develop their conceptual understanding (Ofsted, 2013; Kim and Tan, 2011; Scott and Mortimer, 2003). However, 'teacher talk' and tightly controlled questioning sequences often dominates classroom exchanges and does little to develop children's understanding of concepts (Yip, 2004). To challenge this practice, there is a need to understand the variables that support or prevent teachers from reflecting upon and changing their practices. This research, therefore, focuses on qualitative case studies to explore how two primary school teachers engaged in a collaborative action research project designed to advance questioning skills. Using periodic video recordings of lessons and interviews I examine the variables that contributed to a modification in questioning skills over the duration of two academic terms. The teachers chose different teaching approaches to achieve this: puppets or Thinking Cubes.

Analysis of the data revealed that changing practice is complex. The choices teachers make when delivering science lessons are dependent upon an amalgam of variables such as level of subject knowledge, subject specific pedagogy, and the curriculum aims, as well as personal attributes and contextual issues relating to the school. However, the choice of teaching approach is important and may enable a teacher to modify their practice within a shorter time frame than expected. Previous research identified that change often takes more than a year (Postholme, 2012; Loughran, 2002). However, the teacher who used a puppet was able to plan his questioning sequences and the structure of his lessons strategically so that children actively problem-solved and raised questions. The implications of the study suggest that to support teacher development, there is a need to understand the individual biography of each teacher so that support can be personalised as well as supporting them to use a teaching approach that develops problem-solving and discussion.

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DECLARATION OF AUTHORSHIP

I, Deborah Wilkinson declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission.

Signed:

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Chapter 1

Introduction

1.1: Introduction

A collaborative action research study, with two primary school teachers, was undertaken to explore how different teaching approaches influenced questioning skills during primary science lessons. Drawing on periodic lesson observations and interviews with teachers I examine how the use of puppets, concept cartoons or Thinking Dice impacted upon practice as the teachers engaged in collaborative action research. As teachers were keen to develop children's questioning capability, there was also a focus on how well each teacher's chosen approach extended children's abilities to ask and answer their own questions. I also examine the extent to which a collaborative action research approach facilitated a change in practice.

1.2: Rationale

In order to contextualise this research, it is important to be cognisant of the reasons for educational reforms as well as how teachers can best be supported in implementing the changes. Therefore, I will begin by considering the impact of an international study before highlighting the challenges of supporting teacher learning and growth.

One of the key drivers behind recent educational reforms have been the findings from international comparison studies such as the Programme for International Student Assessment (PISA) which aims to assess the knowledge base of children for reading, mathematics and science (PISA, 2016). The results from PISA provide countries with comparative data of their educational processes and systems and many countries have subsequently undergone reforms in order to improve their position in international league tables. It is thus unsurprising to note that the new National Curriculum for England could be perceived as an attempt to take stock on subject knowledge and skills in order to ensure that pupils are equipped with the knowledge, skills and experiences that will help them to achieve in a rapidly changing world (Department for Education, 2016). The new science curriculum echoes this belief that science in school should be aiming to ensure that children have adequate practical, investigative and analytical skills if they are to flourish in a technological world (Ofsted, 2013). Ofsted (2013) continue to assert that for pupils to achieve they should be raising their own questions, taking the initiative in planning science investigations and solve challenging problems by working alongside others.

To meet the needs of the new curriculum teachers are expected to have advanced subject knowledge and an understanding of evidence-based practice in order to raise standards (DFE, 2016). However, Ofsted conveyed that in some science lessons the teaching techniques failed to meet pupils' learning needs because teachers were aiming to cover content rather than developing pupils as 'independent, inquisitive young scientists' (Ofsted, 2013b, p.13). Therefore, supporting teachers in ongoing continuing professional development opportunities may help them to reflect upon teaching approaches. However, too often continuing professional development (CPD) is aimed at attending a course so is not necessarily aligned with the specific requirements of teachers and their pupils (Van Driel and Berry, 2012). According to Clarke and Hollingsworth (2002) there is a need to understand that changes to practice involves teachers being active learners through reflective participation in professional development programmes rather than 'one–shot' development approaches (p. 948). Indeed, Fielding, Bragg, Craig, Cunningham, Eraut, Gillinson, Horne, Robinson, and Thorp (2005) propose that learning is best supported through shared practices so it is timely to consider how universities are best placed to respond to CPD opportunities and collaborative working practices. Therefore, the aim of this research was focused on how a collaborative action research approach supported teacher learning when delivering science lessons.

1.3: Aims

The origins for this research were significantly influenced by my experience as a primary school teacher and teacher educator for primary science. In my role I have been in the privileged position of having the opportunity to observe teaching and to reflect upon how questioning strategies impact upon children's learning. My reflections, relating to the importance of questioning skills, have been shaped and developed from an established body of research related to children's learning in primary science lessons which recognises the value of talk, enquiry and effective questioning to maximise scientific understanding (Scott and Mortimer, 2003; Mercer, 2003 and Vygotsky, 1978). Despite the literature identifying the value of enquiry and effective questioning to facilitate learning, research indicates that teachers often adopt teacher-centred, didactic approaches to test and evaluate if children have understood concepts through a series of tightly-structured enquiries and questioning sequences (Alexander, 2008; Lemke, 1990; Tabak and Baumgartner, 2004). Due to the pressures of delivering the curriculum within a limited time frame, teachers often resort to approaches whereby they 'impart or transfer knowledge' which does little to promote reasoning skills (Alexander, 2008). Indeed, almost all student teachers and qualified teachers that I have had the opportunity to talk with accepted that the Initiation-Response-Evaluation (IRE) questioning pattern was typical in their classrooms and as such teachers become the 'authority of knowledge' and use questioning to negotiate towards the correct answer (with limited opportunities for talk and reasoning). The challenge, therefore, is to move from the transmission-reception model and towards a more learner-focused approach in order to make learning more meaningful to children.

Consequently, this research aimed to establish if teachers could be supported to change their questioning practices and the types of questions posed in science lessons. To achieve this aim, a collaborative action research approach was employed. Action research was deemed as being an effective approach because it recognises the importance of teachers being reflective practitioners (Schon, 1987) and being in the role of 'teacher-as-researcher' (Stenhouse, 1975) in order to improve their practice. When the process is collaborative, as in this research, the role of the researcher is instrumental in guiding and facilitating the research process as well as helping with the co-production of knowledge (Punch and Oancea, 2014). Indeed, the literature identifies that collaborative action research has been used effectively to support teacher learning by increasing their awareness of their practice (Munn-Giddings, 2012; Ernest, 1994) as well as empowering teachers to evaluate their work through reflective actions and professional dialogue (Cohen, Manion and Morrison, 2003; Somekh, 1994).

It was not my intention to intervene in lessons but to support teachers in their reflections relating to the function and use of questions. My expectation was that through dialogue and reflection teachers would ask a wider range of questions and begin to change their teaching. To achieve this, it was important for teachers to study their own practices because this often acts as a catalyst to stimulate change and transform practice (Lebak and Tinsley, 2010).

1.4: Research Questions

1. How do primary science teachers' questioning practices change as a result of collaborative action research?
2. Is there a change in the type of questions posed as a result of collaborative action research?

The two participating teachers wished to improve children's questioning skills as part of the action research process but elected to use different approaches to achieve this. Each of the participating teacher's chosen teaching approach has been formulated into a question:

3. How does the use of a puppet support children in asking and answering their own questions in science? (Year 3 teacher)
4. How do Thinking Dice support children in asking and answering their own questions in science? (Year 6 teacher)

1.5: Summary of Chapter contents

In the literature review I provide a discussion of the place and value of questions within primary science lessons. I begin by considering what effective learning in science is and how this supports children in making sense of the world around them. I discuss the types of questions that teachers ask during science lessons and the impact of these on children's engagement. Research indicates that being able to formulate questions and having the opportunity to answer them is fundamental to active and meaningful science enquiry work (Chin, 2007; Harlen, 2006). Therefore, I also consider the value of children's questions and the functions of these. The chapter concludes by exploring the challenges faced by teachers when planning for effective questioning opportunities and how collaborative action research can influence reflective practices and subsequent changes in teaching approaches.

In the methodology chapter I present and justify my research approach and personal epistemology. My personal epistemology is couched in constructionism as I was developing an understanding of the effectiveness of a teaching strategy on questioning skills alongside teachers. Indeed, Clough and Nutbrown (2012) argue that in order to study the social world a researcher needs to interact and make reference to the thoughts and feelings of those involved. Following a discussion of my positioning, the chapter then focuses on the methodology, methods, ethical considerations and data analysis. The research methodology was a case study design and multiple data collection methods including focus groups, lesson observations and interviews were used in order to collect the required data to answer the research questions.

The aim of the research was to document each teacher's journey, using their chosen teaching approach, rather than to compare practices. Therefore, the learning journey for each teacher is presented as a separate case study. Chapter 4 provides a description and analysis of the teaching approaches and questioning skills adopted during Jack's science lessons when using a puppet. Chapter 5 documents the learning journey for Rob, a Year 6 teacher, when using Thinking Dice to support questioning skills in lessons.

The discussion and conclusions chapter evaluates the effectiveness of the collaborative action research approach. Here I consider the barriers and the enablers for teacher change. I also consider the limitations of the study and implications of the research on my practice before concluding with reference to further research opportunities.

Chapter 2

Literature Review

2.1: Introduction

This literature review provides a discussion of the place and value of questions within the primary science classroom. I begin by exploring the conceptual framework of socio-constructivism to provide an explanation of how children and teachers can be supported to learn through the process of collaborative action research. I then consider what the research literature considers as being good practice to support children when learning about the world around them. The chapter then focuses on the types of questions posed by teachers and the impact of these in relation to children's engagement and learning in science lessons. Here, I also consider the importance of children being provided with the opportunity of asking (and answering) their own questions. I briefly introduce the process of conceptual change, however, as this research is focused on teachers and how collaborative research impacts upon their practices, I do not explore in detail how the process occurs. This follows a discussion of the challenge of employing effective questioning techniques and how collaborative research can support the process of reflection and action in order to change teaching practices.

2.2: How social constructivism provides a conceptual framework for understanding questioning and enquiry in the primary science classroom

Social constructivism views learning as a socially mediated process (Crawford, 2007), whereby learners develop their understanding during social interactions with more competent others (Vygotsky, 1978). The relationship between language and thinking assumes a social constructivist perspective in two key ways; firstly, as a cognitive tool by which children learn and secondly, as a pedagogical tool through which one person (e.g. a more knowledgeable other) can provide intellectual guidance to another (Mercer, Dawes and Wegerif, 1999). Social constructivism underpins the conceptual framework of this research due to the collaborative nature of the interactions that occur in the classroom; either between peers or between the class teacher and children. In addition to relating the theory to children's learning within the classroom, social constructivism can also be applied to the reflective practices of teachers during collaborative action research.

As social constructivism accepts that human thought and understanding of the world evolves from one's negotiated meaning with other learners (Crotty, 2012) it is pertinent to begin by exploring how social constructivism supports children's learning through questioning and enquiry during primary science lessons. I then discuss how the theory can support teachers when reflecting upon their questioning practices and professional learning during the process of collaborative action research.

2.3: How social constructivism underpins and influences children's learning (and questioning skills) in the primary science classroom

With the adoption of the social constructivist theory into science education it is accepted that children have preconceptions before they begin school and that these may be different to the accepted understanding of science. Consequently, teachers need to seek ways to deliver lessons that develop and challenge children's ideas. From a Vygotskian perspective, learning through enquiry can facilitate children's understanding of concepts because children are actively engaged and challenged using problem solving which requires them to talk and question ideas. Therefore, enquiry can be perceived as question-driven learning process whereby children investigate a problem with initial questions, think of ways to answer them, look for evidence, explain and evaluate their work before finally returning to the original question (Kawalkar and Vijapurkar, 2013).

Effective questioning is conducive to enquiry learning because discussions help children to clarify their thinking and develop their reasoning skills. Engle and Conant (2002) maintain that children need to have time to interact and talk with their peers and teachers because as the enquiry unfolds so discourse and questions emerge. Therefore, learning and understanding can be assumed to be inherently social and integral to learning (Palinscar, 1998). Indeed, Vygotsky (1978) postulates that higher-ordered thinking happens firstly in a social plane through social interactions and talk and later in an intrapersonal plane (inside the learner's head). This highlights the importance of co-participation between the child and the teacher (or another child) and the value of dialogue while negotiating the zone of proximal development, that is the zone between what an individual can do or understand without assistance and what they can do with assistance. The 'assistance' could be in the form of feedback, modelling of ideas, explaining, questioning and task structuring and the support may be provided by teachers and/or peers (Newton and Newton, 2001). Therefore, the social and verbal interactions between individuals within a classroom influences whether or not children will ask and answer questions during investigative work.

Consequently, the decisions a teacher makes about how a concept is introduced, the use of questions and the planned activities play a crucial role in determining how children will participate during lessons. Questioning subsequently needs to be flexible in order to accommodate children's contributions and responses during class discussions.

2.4: How social constructivism links to teacher learning

Duschl and Hamilton (1998) credit Vygotsky's work as having stimulated research relating to the social aspect of learning in adults. The process of professional learning may be realised through the engagement in collaborative action research whereby teachers are supported to reflect upon their practice. During collaborative action research, teachers are partners in designing, implementing and interpreting outcomes and reflecting alongside a researcher or mentor in school. During each stage of the action research cycle, language is the primary tool used to support reflective thinking and learning. According to Hackling, Smith and Murica (2011) learning occurs when engaging with others because ideas are created, shaped and refined through conversation. Therefore, talk and reflection may help to provide a clearer, nuanced understanding of the processes involved in changing questioning practices.

Adults, like children, use language and pose questions in ways that elicit and provide explanations to clarify meanings and to help establish an understanding of events. In line with this, the role of a researcher during collaborative action research is not to simply observe a lesson but instead is centred on helping teachers to design interventions to make a difference to teaching and learning. Therefore, a researcher may act as a more knowledgeable other when explaining the theory behind teaching approaches.

2.5: How the conceptual framework of social constructivism was operationalised during the collaborative action research process

Social constructivism can be operationalised during collaborative action research in order to support both children and teacher's learning. Social constructivism underpins learning in two key ways during this collaborative action research. The first relates to the classroom context and the relationships between the teacher and children (and between children) when negotiating towards an understanding of concepts. The second way in which social constructivism is operationalised is in relation to teacher learning and the way in which the teacher engages with the research process to learn about teaching and learning and the use of questions during science lessons. To support the development of children's understanding of science concepts, teachers need to be aware of the effectiveness of their teaching approaches and can be supported to reflect upon their teaching through the process of collaborative action research and reflective thinking.

2.6: How children learn science

The importance of children actively constructing their knowledge through practical experiences and discussion is recognised across the world as being an effective way for children to learn science (Duggan and Gott, 2002; Kim and Tan, 2011; Sharp, Hopkin, and Lewthwaite, 2011). Indeed, Posner, Strike, Hewson and Gertzog (1982) argue that learning is a type of enquiry and the learner often evaluates their understanding based on the evidence presented by investigative work. This way of working is known as scientific enquiry or enquiry-based learning and encompasses the process skills of observing, posing questions, developing hypotheses, making predictions, planning investigations, gathering evidence, interpreting evidence, considering explanations and communicating results and conclusions (Department for Education, 2013).

In enquiry-based lessons children should have the opportunity to organise their evidence and ideas in order to explain *how* and *why* something happens (Duschl, Schweingruber and House, 2006). The aims of the curriculum, therefore, need to emphasise a shift from memorising facts to engaging children in working scientifically in order to develop their conceptual understanding. To achieve this, children need to talk about concepts and ask questions in order to aid their understanding. Indeed, Barnes (2008) argues that talk makes it possible for children to assess what they know and offers the chance for them to modify their thinking.

The value of talk in the process of learning is well-established with researchers such as Mercer (2010) and Scott and Mortimer (2003) drawing on Vygotskian theory and the socio-cultural construction of knowledge. According to socio-cultural theory, ideas and explanations are co-constructed during classroom and group discussions and the way in which the teacher orchestrates opportunities for talk is key if learning is to be successful (Morimer and Scott, 2003; Vygotsky, 1978; Mercer, 2010). Indeed, Hackling, Smith and Murcia (2011) argue that exploratory forms of talk in which tentative ideas are presented and discussed for evaluation and refinement are valuable for developing understanding.

Puppets or concept cartons are designed to stimulate talk using Vygotskian principles and enable children to construct their understanding by presenting them with a problem or challenge (Simon, Stuart, Keogh, Maloney and Downing, 2008). They are particularly effective if the problem is within the child's grasp but in advance of their reasoning because children are more likely to talk about how the problem can be solved. Talk is conducive to learning in this model because talking helps children to clarify their thinking and develops their reasoning skills which, according to Dawes (2004), provides a powerful stimulus for learning. If a puppet is also presented as the weakest scientist in the class, then children are more likely to articulate their reasoning because they are placed in the role of being the expert and will be expected to explain their thinking to the puppet (Hackling *et al.*, 2010).

A classroom environment conducive to ensuring that children feel that their responses will be valued may support them in raising questions (Goldsworthy, 2011). Children need to be able to raise questions, explore initial ideas, reason and evaluate their thinking in a safe environment. They need to have time to interact with their peers and teachers because as an enquiry unfolds, so discourse and questions emerge (Engle and Conant, 2002). However, the social and verbal interactions between individuals within a classroom influences whether or not there are opportunities for talk and question posing.

Children consequently need to learn within a culture that dictates that everyone (teachers and children) listen to each other and are encouraged to ask questions. Within this environment, children know that if mistakes are made, they are regarded as essential to learning rather than being embarrassing or shameful to the learner. However, Lemke (1990) argues that teachers and students often have ‘unequal power’ in the classroom and that the nature of questioning can accentuate the imbalance because the teacher ‘controls’ the conversation by determining the type and sequence of questions.

2.7: Teacher questioning

The previous section identified that enquiry-based learning paired with opportunities for talk and questioning supports children in learning about the world. However, the type of questions that teachers pose during lessons influences the level of thinking operations that children engage in (Chin, 2002). Chin, Brown and Bruce (2002) assert that teachers can support children to think more critically and creatively (rather than simply recalling facts) by being aware of different question types and then using them during teaching episodes.

The use of ‘teacher questions’ has been presented in various taxonomies of question types (Yip, 2004; Koufetta-Menicou and Scaife, 2000; Chin, 2007; Carr, 1998; Elstgeest, 1985). However, taxonomies linked to questioning in science are frequently based upon research undertaken in secondary schools rather than in primary schools.

Table 2.1 identifies some of the taxonomies and the question types identified in previous research linked to questioning in science. The table is by no means exhaustive and there are inevitably examples of questions that do not fall neatly into a category, however, the categorisation offers a starting point for analysing question types employed in lessons.

Yip (2004)	**Koufetta-Menicou and Scaife (2000)**	**Elstgeest (1985)**	**Carr (1998)**	**Chin (2007)**
Lower order Recalling factual information Description – describing a process Higher Order Analysis – may be comparing or identifying relationships Evaluation – judging the value and implications of a material Synthesis – applying knowledge to a new situation e.g. design a balanced meal for … Motivation – focus attention Conceptual change Eliciting – finding out pre-conceptions Challenging- students to review new knowledge Extending – construct new ideas Application – apply to a new situation	Lower order Recall of facts (what, when where) – Do you remember what we did 2 weeks ago? Description of a situation – identifying variables – which is the strongest? Higher order How questions – need a justification of a procedure (How did you measure …? Proof or evidence – what evidence do you have? Patterns seeking trends on graph or data – can you see a pattern – often begin with why Those that begin with why is this fair? What if questions? Prediction questions Conclusion questions – what did we learn about … today?	Productive questions Attention seeking- what do you notice? Measuring/counting – How many? How long? Is it stronger, heavier? By how much? Comparison – Sharper observation – In what ways are they the same? Different? Action questions – What if questions - - to discover relationships, predicting outcomes – children hands on. Problem solving – Can you find a way to...? More of an application activity to apply knowledge	Open-questions – Tell the class about… How do you think that may have happened? What do you think might happen? Probing/Defining questions – requires more detailed information e.g. Can you give an example of… Could you explain how that happens? Reflective questions – Links to vocabulary – to crystallise a point But what if this happened? Are you sure about that? Closed-questions – one word answer required – check understanding e.g. so you mean…? Did you say that…? How many bones in the body? Hypothetical questions – useful for investigative skills – what if…?	Socratic Questioning – a series of questions to *prompt an guide* student thinking Pumping – requires more information from students Reflective toss – questions posed in response to children's answers Constructive – a question to stimulate thinking rather than giving feedback challenge Verbal jigsaw – a focus on scientific terminology Verbal Cloze – a pause in a sentence to allow children to 'fill in the blanks Semantic tapestry– to help students link ideas into a conceptual framework Multi-pronged questioning – questions posed from different angles Focusing and zooming- a focus on big, broad questions and focused questions Framing- use of questions to frame a problem Question-based prelude – questions to identify prior learning Question-based outline – presentation of a big, broad question Question-based summary- to re-cap on learning.

Table 2.1: Research linked to teacher questioning taxonomies

The question categories linked to Koufetta-Menicou and Scaife's (2000) and Yip's (2004) research have an order similar to those in Bloom's taxonomy and can be classified according to the level of thought required for answering them. Bloom's taxonomy was devised in an attempt to help teachers know the range of educational goals (remembering, recalling knowledge, problem solving and creating) and so help them to plan teaching episodes designed to meet these requirements (Bloom, 1956). The taxonomy is a hierarchy of question types including the low-order cognitive skills of recalling knowledge and comprehending facts and the high-order questions relating to application of knowledge, analysis, synthesis and evaluation questions. However, as the taxonomy does not link directly to supporting children in working scientifically additional question types have been suggested.

Yip (2004) built on Bloom's taxonomy by not only identifying the importance of lower-order and higher-order questions but also considered the place of motivational and conceptual change questions. Yip's (2004) research was designed to help trainee secondary biology teachers in Hong Kong to increase the range of questions posed. The questions were designed to provide students with the classroom conditions to resolve cognitive conflict, connect preconceptions to new ideas and to apply learning to novel situations. Like Yip's work, Koufetta-Menicou and Scaife's (2000) taxonomy values high and low cognitive demand questions and the importance of questions to stimulate conceptual change. Koufetta-Menicou and Scaife's (2000) research was developed from previous work relating to the Cognitive Acceleration through Science Education (CASE) Project. The materials were developed so that subject specialist science teachers were well positioned to understand the nature of scientific reasoning and metacognition that needed to be developed and maintained during lessons (Adey, 1999). The CASE Project provided teachers with materials and lesson plans which highlighted questions to help direct learning. Koufetta-Menicou and Scaife (2000) argue that the questioning sequence should recognise that a problem can be addressed in a number of diverse ways and can be thought about using different viewpoints to ensure that children are involved in enquiry based work.

The importance of enquiry is also central to Elstgeest's (1985) taxonomy of question types. Elstgeest's work was formulated from observations in school and like Koufetta-

Menicou and Scaife (2000) the questions are designed to follow a certain pattern during the lesson because the answerability of one type of question depends upon the experiences earlier in the lesson. This is accomplished by asking children productive questions that require thinking and engaging in a type of investigation to find the answers to questions (Elstgeest, 1985). Chin (2007) argues that asking questions that guide students towards productive thinking is not easy because the teacher requires a good understanding of the subject matter so that they can ask interconnecting questions to help students link ideas together rather than learning isolated facts. She continues that in order to achieve this teachers need to have a good understanding of teaching approaches. Chin's work on the use of questions (summarised in Table 2.1) was developed from previous studies to find out how secondary school science teachers in a school in Singapore used questions to scaffold students' scientific thinking. The notion of the framework was to use different questioning approaches across different conditions to promote conceptual understanding.

Carr (1998) orchestrated paired observation work within a science department in a secondary school in England and analysed the questions posed by using the taxonomy presented in Table 2.1. Teachers paired up and observed each other's questioning during science lessons. Carr (1988) established that open-ended questions were not asked often whereas closed-questions were used to consolidate information and to keep children on track. Conversely, Elstgeest (1985) suggests that closed-questioning is the 'wrong approach' as it offers children no opportunity to problem solve and is merely dependent on students recalling knowledge based on rote learning. Harlen and Qualter (2014) add to the argument by suggesting that closed-questions may intimidate children as they provide the underlying assumption that every question has a single correct answer. However, according to Carr (1998), the closed-questions that were posed during lessons enabled teachers to assess recently learned concepts and to modify the lesson (or subsequent questioning) in order to teach pupils through the answers that other pupils in the class have provided. Therefore, this exchange has a 'built in repair structure' whereby incorrect concepts can be challenged.

Although not found in the taxonomies presented in Table 2.1, questions can also be considered from an emotional viewpoint. Indeed, Harlen and Qualter (2014) categorised teacher questioning into two distinct categories: ‘person-centred’ and ‘subject-centred’ questioning. Person-centred questions are regarded as supportive and use the pronoun ‘you’. Asking a child ‘What do *you* think?’ or ‘Why do *you* think that?’ to probe thinking provides limited jeopardy on the part of the child in that they might provide an incorrect answer. Person-centred questions encourage children to focus on their thinking rather than trying to provide the ‘right answer’ (Carin, Bass and Conant, 2005). According to Harlen (2000) person-centred questions are a useful tool to find out what children know, whereas subject-centred questions are often closed and reintroduce an element of ‘right and wrong’.

2.8: Teacher questioning patterns

The previous section highlighted that teachers can ask a range of questions that serve different purposes. The previous section also identified that much of the research undertaken in relation to questioning was focused on secondary school science. There appears to be limited research with regards to questioning in primary science lessons and the work that has been undertaken does not explore further than the use of open and closed questions. Indeed, much of the current research focuses on classroom discourse and argumentation, however, I argue that the use of questioning skills is a specific aspect of classroom discourse. Therefore, this section explores the questioning patterns that teachers adopt during primary science lessons and the implication of these on children’s, learning and engagement.

Most primary school teachers would list questioning as one of the key ways in which they influence children’s learning. Questioning is, according to Harlen (2006), a key feature of scientific activity and of teaching science. Asking questions serves as one of the fundamental modes of communication between teacher and child and is commonly employed for a wide variety of purposes such as assessing understanding or identifying naïve ideas, facilitating thought, evaluating and monitoring progress as well as serving as a behaviour management tool (Park Rogers and Bell, 2008).

However, Alexander (2008) asserts that teachers often ‘impart knowledge’ which does little to promote the skills of reasoning in children. In a teacher-centred approach where the aim is to ‘transfer knowledge’ in a transmission-reception model, this ensures that children are passive recipients (Kember and Gow, 1994). Questioning often follows a certain pattern of interaction: the teacher asks a question, the children respond and the teacher evaluates the answer (Alexander, 2008). Lemke (1990) terms this pattern of teacher-student-teacher interaction as triadic dialogue, otherwise known as Initiation-Response-Evaluation (IRE). In this model the teacher is the authority of knowledge and tests and evaluates whether children have been successful in verbalising the taught knowledge. In research by McGregor and Gunter (2006) it was established that children tend to ‘halt’ their thinking once they perceive they have given the ‘right’ answer. This results from children identifying the positive reinforcement cues that the teacher uses to indicate to the learner what the solution or answer is. In this format it can be assumed that it is only the teacher who asks the questions and knows the answers (Yip, 2004). It could also be argued that this format tends to restrict deeper, reflective thinking and can alter the way in which children behave in lessons. When children feel that they have provided the answer they tend not to think of alternative answers or viewpoints.

Arguably, the IRE exchange is not useful if a teacher is always negotiating towards the correct answer because there are limited opportunities for children to discuss ideas. An alternative approach proposed by Scott and Ameteller (2007) is to use the Initiation-Response-Feedback-Response-Feedback chain (IRFRF) which results in more interactive and collaborative learning as the teacher poses a question, the child responds and the teacher then directs the turn back to the class without evaluating the answer provided. Responding in a neutral way allows for student-to-student interactions to occur and prompts the learner for further thinking and explanations (Rojas-Drummond, Mercer and Dabrowski, 2001). A problem with this approach, however, is that children often wait for the teacher to evaluate the previous ideas instead of responding directly to their peer. This may occur because children are unclear of what is the appropriate way to respond to another child; particularly if they disagree with the answer provided (McNeill and Pimental, 2009).

The challenge, therefore, is for teachers to move from the teacher-centred didactic approach and towards a more learner-focused approach in order to make the learning experience more engaging. The role of the teacher during enquiry learning is crucial if children are to learn the scientifically accepted ideas of science and for Posner *et al*. (1982) the teacher as a clarifier of ideas or presenter of information is not adequate for helping children accommodate new concepts. Teaching science through interactional activities such as guiding and facilitating suggests a more symmetric form of social relationship within the classroom because the child becomes the active enquirer and the role of the teacher is that of a 'fellow investigator' or experienced co-learner, guide or co-inquirer (Martin, 2006).

Table 2.2: Teacher roles during investigative science work as discussed in Tabak and Baumgartner (2004)

Role of Teacher	**Interaction with pupils**
Monitor	• Sets tasks, checks the execution of tasks and provides feedback • Role of authority • Divergent ideas are not considered
Mentor or guide	• Helps students align thinking without dictating actions (supports the enquiry process) • Role of authority
Participant/co-learner or fellow investigator	• The teacher presents as a peer and takes part in the investigation • Both students and the teacher respond to the data they observe • The teacher may pose genuine questions that they do not know the answers to

As alluded to in Table 2.2 when a teacher adopts the monitoring and mentoring roles they are perceived by learners as someone who sets the tone, controls the actions and 'knows it all'. Conversely, the participant teacher is one who contemplates, hesitates, does not necessarily know the answer so will be inclined to think out loud when contemplating and justifying their answers. Collins, Reiss and Stobart (2008) argue that children need to have the reasoning skills modelled to them as this is central to learning and demystifies the practice of 'doing science'. If a teacher suggests the next steps in a process fluently, without hesitation of thought then children may find it difficult to perceive authentic science as being within their reach.

Therefore, it could be asserted that by modelling thinking processes to children during science lessons, the verbal interactions (or talk) impact upon children's knowledge-building experiences of science (Oliveira, 2010). This approach may also enable the teacher to better assess the understanding of children. This process may begin with the way in which teachers ask and respond to questions provided by children. Instead of a teacher asking questions and rephrasing children's answers to align them with the accepted scientific knowledge they instead 'restate' the answer, pause and add the discourse marker 'so' in order for the child to add their interpretation of the answer. Wells (1993) asserts that when the third turn in the IRE dialogue takes the form of feedback rather than evaluation then new opportunities arise for dialogue and knowledge refinement, thereby, suggesting to the learners that there is more to learning than rote memorisation of scientific facts.

However, Edwards and Mercer (1987) argue that many teachers adopt an authoritarian stance when teaching science. Questioning within this approach often requires children to respond to factual questions which, according to Carlson (1997) tend to be at the lower cognitive demand level and may 'close-down' classroom participation because some children may fear getting the answer incorrect. Conversely, Goodrum (2007) argues that closed-questions can challenge pupils to recall facts and this approach may focus the students' thinking. Martin (2003) extends upon this idea and maintains that teachers should sometimes pose low-cognitive demand questions during lessons because if a child is to be supported in thinking at a higher level, they must know the facts and understand them if they are able to apply the learning to a new situation. Newton and Newton (2001) add that if a teacher wishes to develop conceptual understanding over time, then they can tailor a series of questions that move the student from recalling ideas to predicting, applying and explaining.

Scott and Ametller (2007) concur with Newton and Newton (2001) in that teaching should include both authoritative and dialogic teaching approaches. When using a dialogic teaching approach the teacher considers a range of ideas, asks pupils for their points of view and there is an attempt to develop discussion about a science concept. Conversely, discussion is closed-down by an authoritative approach so that children are informed of the science concepts. Scott and Ametller (2007) continue that if children have been told about a science concept via an authoritative approach, then time should be available during the lesson for children to enquire and talk through ideas (a dialogic approach). By using both authoritative and dialogic approaches, the teacher is able to intervene, classify and ‘bridge the gap’ between student knowledge and the accepted scientific view of phenomena.

Regardless of the teaching approach adopted, van Zee and Minstrell (1997) maintain that the teacher should encourage children to be responsible for doing the thinking and this is achieved through an extended series of questioning exchanges in which the teacher furthers and guides the child’s thinking. Here the child is expected to justify, reason and articulate their thoughts and ideas at each stage of the enquiry process. In these discussions the use of wait-time is important if children are to provide considered responses to their observations. However, children need to have time to formulate a reasoned answer. In her research, Budd-Rowe (1986) identified that when teachers ask a question they typically wait less than one second for a response. She argued that if teachers were to increase the wait-time by three seconds or more then there would be pronounced changes in the responses from the learner in terms of the language and logic employed.

2.9: The value of children’s questions

So far it has been identified that teachers can adopt authoritative and dialogic teaching styles during science lessons. However, research seems to indicate that questioning sequences are often controlled by the teacher; with the IRE format being a frequent component of science lessons. Indeed, Dillon (1988) identifies that student generated questions linked to enquiry work are a rare feature of science lessons, therefore, this section will focus on the value of children’s questions.

Being able to ask questions and have the opportunity to answer them is fundamental to active and meaningful science enquiry work (Chin, 2006). The formulation of a question that deepens understanding is considered to be a creative act at the heart of what science is all about (Chin, 2007). Student generated questions can serve different functions for learners such as confirmation of expectations as well as helping them to problem solve and develop their knowledge base (Biddulph, Symington and Osborne, 1986). Chin (2002) asserts that question generation is an important cognitive strategy as it focuses the learner's attention on the main ideas and content of the lesson and plays a significant role in learning. Therefore, being able to pose questions enables the learner to make sense of the world, to construct meaning, help to scaffold ideas, explore concepts and advance understanding (Chin, 2007).

The value of student-generated questions in science has been emphasised in research as they serve to fill a recognised knowledge gap and thus extend knowledge (Osborne, Erduran and Simon, 2004). In order to close the knowledge gap, teachers need to listen carefully to the questions that children ask as these will serve to guide the teacher in understanding what children have been thinking about, their current conceptual understanding, their alternative frameworks, their reasoning as well as what they want to know (White and Gunstone, 1992; Pedrossa de Jesus, 2012). Where classroom conditions are 'safe' children will ask a range of questions from the curious to those which reveal 'troubled thinking' (Watts, Gould and Alsop, 1997, p. 58).

Pedrosa-de-Jesus and Watts (2014) argue that learners often have questions to ask but in general avoid asking them. The reasons for this are complex but are linked to students feeling confident that their questions will be well received and taken seriously by the teacher. Indeed, Rop (2002) maintains that some teachers are ambivalent when children pose questions and may have contradictory feelings about how best to address them. Some teachers listen to a student's questions but often feel that they do not have the time to honour the question due to limited teaching time and the need to cover the content of the curriculum. In addition to this, if teachers have themselves been subjected to didactic teaching methods they may feel that control is a necessary feature of teaching. In lessons where the learning is tightly controlled by the teacher it is well documented that student questions are normally;

> …shallow, short–answer questions that address the content and interpretation of explicit material; they are rarely high–level questions that involve inferences, multistep reasoning, the application of an idea to a new domain of knowledge,

> the synthesis of a new idea or the evaluation of a new claim (Graesser and Person, 1994, p106).

Chin (2004) asserts that the level of thinking required of students influences the kind of questions that they ask and thus how active they will be in their learning. When assigned tasks that require instructions and step-by-step procedures, children are not engaged at high-cognitive levels and as a result children will be more inclined to ask procedural or factual questions to make sure they do things correctly and in accordance with teacher expectations (Chin, 2004). Wood and Wood (1988) argue that where there are high levels of ‘teacher control’ this encourages student passivity and should be avoided. Conversely, problem-solving activities engage children in conversations at a higher level and deep-thinking questions may be asked. Questions asked in response to curious items often support children to predict what might happen and results in a cascade of enquiry and procedural work. It could be surmised that unless children are stimulated to be curious, they will not ask questions at the higher cognitive demand level.

The starting point in developing children’s questioning skills is to encourage them to raise any kind of question because to indicate too soon that science is concerned with certain types of questions might deter children from raising their own (Harlen and Elstgest, 1990). However, Chin (2002) found that when teachers begin to apply question-production strategies with students the result is the generation of a large proportion of factual questions. This may be because closed-questions with a single unambiguous answer are easier to generate than open, imaginative questions that require reflection and understanding (Chin *et al*, 2002). Becoming aware that some kinds of questions can be answered by enquiry based learning, is a point of progress. Once this is understood then children can be supported in rephrasing vague questions into a form that can be investigated (Harlen and Elstgest, 1990). To achieve this aim it could be reasoned that teachers need to be modelling the use of different question types to children so that they become accustomed to hearing the range of question types.

A main reason for children’s questions being posed in lessons, according to Watts *et al.* (1997), is when learners find the content and context of the lesson confusing because they do not understand what is being said by the teacher or their peers. The confusion on the part of the learner ensures that they will need to ask for clarification in order to make sense of what is being said (Lemke, 1990). However, when there is a need for clarification of an idea or scientific concept, the questioning may take place silently, in the learner's mind, rather than out loud. Here, the child is reflecting upon their learning by asking themselves questions to help them to monitor their own understanding. During this phase they engage in an internal dialogue as they look for patterns and connections as well as establishing relationships with their prior learning (Chin, 2004). If children are not verbalising their thinking then teachers may have a compromised understanding of the cognitive conflicts that lie behind the learner's confusion (Lemke, 1990). Conversely, if children were to verbalise their questions, this would enable the teacher to diagnose the child's thinking (Watts and Alsop, 1995). Therefore, the questions that children pose are indicative of a child's understanding:

> By posing questions, pupils are shaping and exposing their thoughts and hence opportunities will be provided for teachers to have some insight into children's thinking and conceptual understanding. Questions asked by children can lead teachers towards making appropriate assessments of children's understanding or alternatively their misconceptions (Woodward, 1992, p.16).

Woodward (1992) asserts that the type of questions asked by children provides teachers with an understanding of conceptual understanding or confusion that learners may be experiencing. This enables the teacher to plan for learning opportunities in order to address the naïve idea or confusion. However, Chin (2002) maintains that children rarely ask questions to which a teacher (or indeed another child) responds to, therefore, it can be challenging for a teacher to comprehend the confusion relating to concepts that children have during a lesson.

Just as teacher questions have been presented in various taxonomies of question types, so have children's questions. Table 2.3 identifies some of the taxonomies from previous research.

Table 2.3: Research linked to children questioning taxonomies

Scardamalia and Bereiter (1982)	Watts, Gould and Alsop (1997))	Chin, Brown and Bruce (2002)
Basic information – to generate questions in response to cues e.g. what does the dictionary say about salt? What colour is that? Wonderment questions – result from deep interest and include 'what if…? Questions.	Consolidation questions – pupils are attempting to clarify ideas and confirm their understanding. Exploration – here pupils have a sense of understanding and are exploring concepts to test their understanding Elaboration – Children will consider counter claims and will ask higher order questions such as what if…? And why…?	Factual – only require recall of information e.g. what is…? Procedure – requiring clarification of a procedure of task e.g. where is…? Wonderment – shows deeper thinking. Children apply their learning e.g. what would happen if…?

From Table 2.3 it is evident that there is an overlap between the various taxonomies. However, Watts *et al* (1997) assert that it is possible to use children's questions to identify their current thinking and that there are different categories of questions (consolidation, exploration and elaboration) that link to the process of conceptual change over the duration of the learning experience. The questions can be indicative of the frame of mind of the learner and the quality of the understanding that they have about scientific concepts (Watts *et al*, 1997). If children are posing consolidation type questions this indicates that a child has an idea about a concept but are seeking to confirm their understanding. The child is attempting to say what they think, confirm explanations and consolidate their understanding of key ideas. Here children are seeking reassurance that their ideas are correct. The second category of questions is exploration. During this phase students have an understanding of a concept and are attempting to apply their learning to a new situation. The third category is elaboration and learners examine claims and counterclaims. During this stage of conceptual development, children are self-checking and monitoring their learning (the metacognitive dimension of learning). It could be asserted that when children are working at this level they are following the process of 'real science' and are working as scientists work because it is in this stage that questions tend to arise almost automatically. It could be argued that at each stage it is important that children are able to have practical experiences and the opportunity to work scientifically through their enquiries.

Watts and Alsop (1995) found that consolidation, exploration and elaboration questions linked to the process of conceptual change are important if a teacher is to engage in dialogue with children. However, the number and type of questions posed by children during lessons may be linked to a number of variables including the age of the child and their prior learning experience, skills and attitudes as well as the influence of the teacher and their teaching style.

White and Gunstone (1992) argue that children should be supported in asking 'what if…' 'why does…' and 'how would…' type questions to ensure deeper thinking ensues rather than simple recall type questions (what is…?). The 'what if?' question help students to explore possibilities and to consider alternatives and test relationships whereas the 'why?' type questions stimulate children to think about cause and effect relationships. This links to the taxonomies proposed by Chin *et al.* (2002) and Scardamalia and Bereiter (1992) in Table 2.3. Teaching categories of questions may support children in understanding that different types of questions elicit different thinking processes and that answers can be derived in different ways. If children ask comprehension questions this generates explanations; hypothetical questions let students test ideas; inferential questions help them to identify patterns and relationships in the data collected; planning questions help them to structure their search and plan of action.

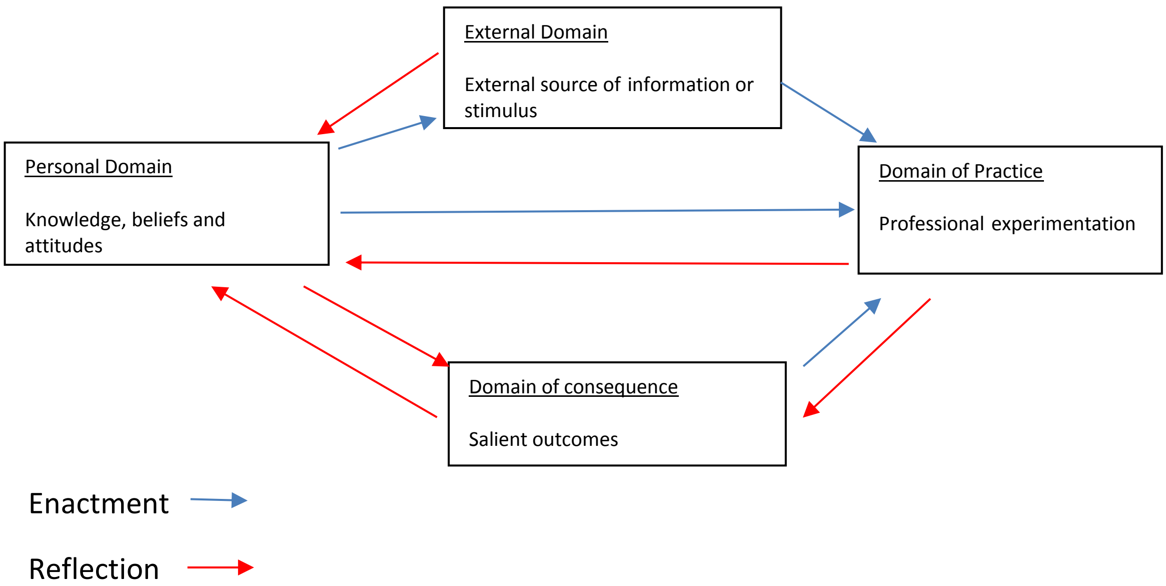
Therefore, children need to be taught questioning typologies if they are to ask more challenging questions. When students generate questions in each category of a typology this will provoke thought and the generation of questions that may otherwise not have been asked (Chin, 2004). However, it could be asserted that sometimes the questions asked by children during the lesson can be termed as 'thought experiments' and are not intended to be formal or even necessarily answered. These include questions such as 'what would happen if…?' 'is the sky cold?' These question types are more to do with exploring a situation rather than necessarily requiring an answer.

2.10: The challenge of teacher education

This literature review has identified that teachers often control the questioning sequences during science lessons whereas children's questions are a rare feature of science lessons. This section aims to explore why that is the case and how this teaching approach can be challenged so that learning can be more child-focused.

The link between good subject knowledge, confidence and knowing *how* to teach science is well documented with research indicating that teachers who possess a good understanding of science concepts are more confident when teaching (Holroyd and Harlen, 1996; Newton and Newton, 2001; Parker, 2004; Sharp *et al,* 2011). However, Appleton (2008) questions the correlation between subject knowledge and good teaching and argues that there are other factors that impact upon teaching. Indeed, Clarke and Hollingsworth (2002) recognise the complexities relating to teacher learning in their Interconnected Model of Professional Growth. In the model there are four domains; the external domain, personal domain, professional experiment and the domain of consequences.

Figure 2.1: Clarke and Hollingsworth (2002) Interconnected Model of Teacher Growth



Clarke and Hollingsworth (2002) maintain that change can happen in any of the four domains (see the rectangular boxes). When teachers experiment with a new teaching strategy, change resides in the domain of practice; new knowledge links to the personal domain and a change in perceptions occurs in the domain of consequences. The Interconnected Model, according to Clarke and Hollingsworth (2002), is non-linear and identifies the mediating process of reflection and enactment as being a key mechanism for change; as indicated by the interconnecting red and blue arrows in Figure 2.1.

Although Clarke and Hollingsworth (2002) identified four domains linked to teacher growth, Appleton (2008) argues that teacher confidence is improved when CPD focuses upon subject knowledge and pedagogy. Shulman (1987) refers to this amalgam of subject knowledge and pedagogy as pedagogical content knowledge. In later work, Shulman and Shulman (2007) probed the complexities of teaching and identified six domains of knowledge required for effective teaching as shown in Table 2.4.

Table 2.4: Domains of knowledge linked to effective teaching according to Shulman and Shulman (2007)

Knowledge domain
1. Knowledge of learners - links to child development theories
2. Knowledge of school contexts and the classroom dynamics and wider school community
3. Knowledge of educational ends; values, philosophy of teaching
4. Content knowledge - including the teacher's awareness of the value of group work, use of analogies and identification of misconceptions
5. Curriculum knowledge – understanding of subject matter
6. Classroom assessment

In terms of subject specific knowledge, teachers need to understand the content of what needs to be taught because having a good comprehension of the subject matter, is according to Shulman (1986), important as it will influence pedagogical content knowledge. The pedagogical content aspect of teaching requires teachers to know how to present the knowledge so that is can be comprehended by learners. There is no one right way of presenting information to children so the teacher needs to make judgements and consider which approach (e.g. demonstration, analogy, illustration, explanation, example etc.) is best matched to the child's needs. To achieve this, the teacher needs to consider the starting point of the child along with any preconceptions and misconceptions that they may have. The curricular knowledge refers to knowing how ideas fit together in a curriculum (e.g. understanding the requirements of the National Curriculum and planning for progression).

2.11: Teacher learning

Based upon the research presented by Shulman (1986), Shulman and Shulman (2004) and Clarke and Hollingsworth (2002) it is clear that teaching science in primary school is reliant on a range of inter-related variables as well as socio-cultural factors such as educational biographies of teachers, the extent of identification with science as a subject as well as cultural perspectives within school settings (Danielson and Warwick, 2014). Figure 2.2 shows the complexities of variables that impact upon teacher learning.

Figure 2.2: The interplay between variables that impact upon teaching approaches in science

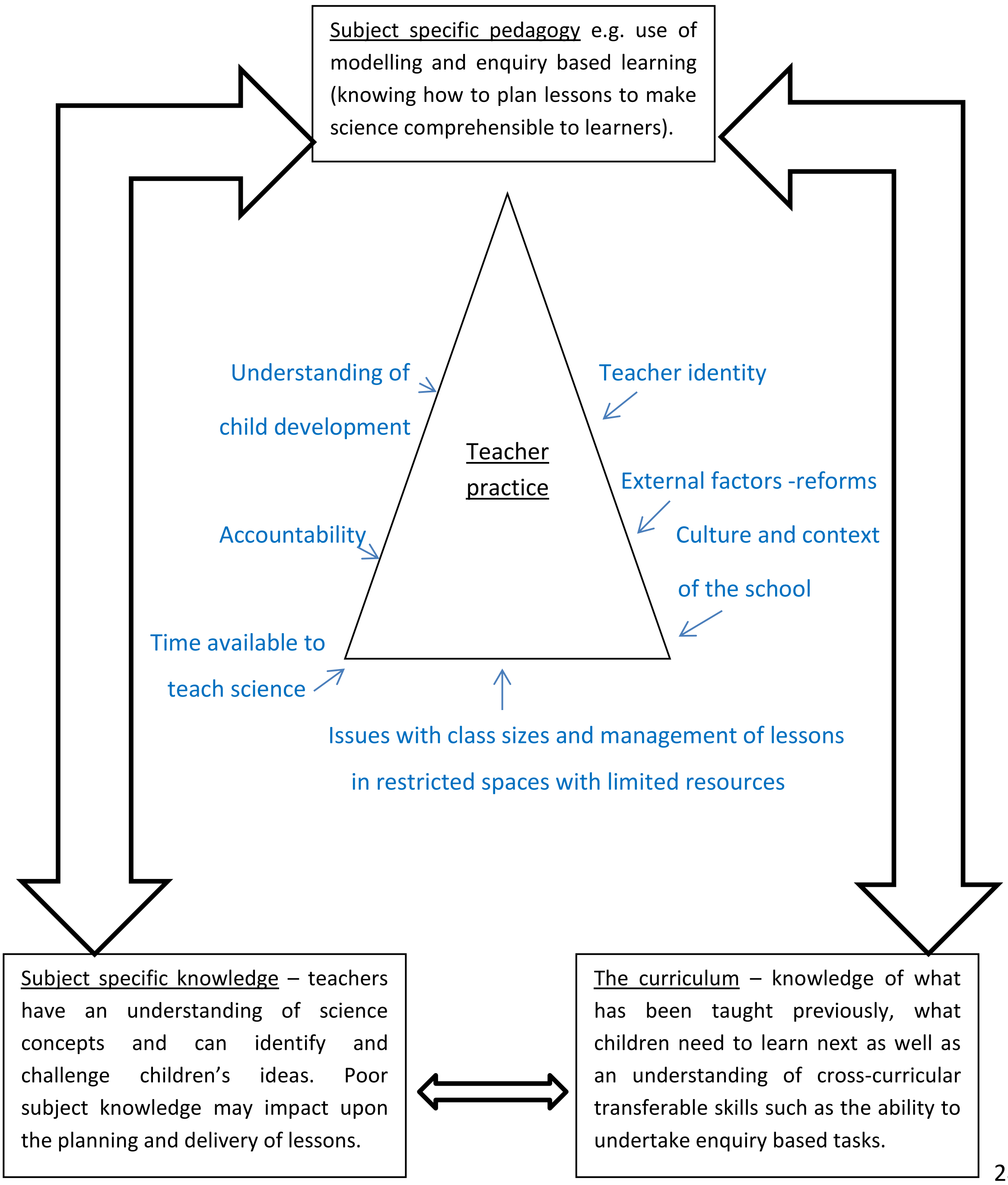


Figure 2.2 incorporates the key tenets of the research presented by Shulman and Shulman (2007) and Clarke and Hollingsworth (2002) to illustrate the dynamics involved in teaching by acknowledging that personal, social and external influences affect teachers' choices when planning and delivering lessons. Teaching is viewed as a human endeavour and is subjected to inter-connected variables, therefore, the triangle, in the centre of Figure 2.2, represents 'teacher practice', and highlights the complex web of variables (as indicated by the blue arrowed comments) that impact upon the choices that teachers make when planning and delivering lessons. I will begin by explaining how the work of Shulman and Shulman (2007) influenced Figure 2.2 before discussing how a teacher's professional identity and understanding of child development impact upon their practice. Here, links are made to the work of Clarke and Hollingsworth (2002) and the personal domain in their Interconnected Model of Teacher Development (see Figure 2.1). Finally, I will unpack how the external variables of the culture of the school, accountability and issues of classroom management affect teaching choices.

The amalgam of subject specific pedagogy, subject specific knowledge and the curriculum (as indicated in the rectangular boxes) was developed from the work of Shulman and Shulman (2007) who probed the complexities of teaching and identified three categories of knowledge required for effective teaching; subject specific knowledge, pedagogical content knowledge and curricular knowledge. Research indicates that if a primary school teacher's conceptual understanding of science is not 'good' then confidence can be eroded and s/he may cover the topic from textbooks or worksheets and encourage the children to 'learn' it (Murphy *et al.,* 2007). Harlen (2000) concurs and asserts that teachers with a 'superficial understanding' of concepts either avoid teaching them or adopt 'safe teaching methods' with an emphasis on the transmission of factual information. Here the teacher tells the children the 'accepted knowledge' and children are expected to memorise the facts. However, when a teacher has a good level of subject knowledge this may impact upon a teacher's attitude and the teacher may have the confidence to encourage active learning or enquiry-based approaches to learning.

The personal domain from Clarke and Hollingsworth's model, which correlates to beliefs and attitudes, are shown in the blue comments in Figure 2.2 and are included because

Driver (1989) maintains that philosophy and views of learning shape the role of the teacher and may influence planning and teaching choices. Teachers who believe that a social constructivist approach to learning equates to successful science learning are more likely to employ approaches that utilise enquiry and problem solving experiences. The role of the teacher and beliefs about science teaching are established and nurtured through their experiences as learners (Crawford, 2007). Indeed, Eick and Reed (2002) maintain that science teacher identity can be described as an extension of past biography and experiences of science instruction and learning. From an early age perceptions of what teaching science should look like are formed and serve a role in helping teachers to justify their professional choices and actions to themselves. The formation of beliefs relating to the role of the teacher, therefore, plays an important role in whether a teacher conducts open-ended or highly-structured work. However, to complicate the situation, Yoon and Onchwari (2006) assert that many teachers feel unprepared to teach science due to the misconception that science, as a subject, is difficult to teach. This misconception may cause teachers to lack confidence resulting in a reluctance to teach the subject. This is a view that is echoed by Tymms, Bolden and Merrell (2008) who reported that some of the science taught in primary schools is perceived to be too difficult for the teachers themselves and the consequence is that they either avoid teaching these topics or simply tell children the facts rather than using child-centred teaching approaches.

Teachers are members of a school community and this also influences beliefs and practices. School communities are subjected to external pressures and reforms and this impacts upon priorities for schools and consequently, teaching. Jones and Leagon (2014) assert that central to the quality of science education is the role of the teacher, however, the changing landscape of educational policy and curriculum design shape the way they respond to challenges. If changes to policy and the curriculum are perceived to be too challenging, then a teacher may employ traditional, teacher-centred approaches and will teach facts rather than teaching for understanding (Sagor, 2005). Therefore, Figure 2.2 includes contextual variables such as accountability, issues with class size, external factors and the culture of the school (blue arrowed statements in Figure 2.2).

The context of the school is pivotal for how teachers deliver lessons. Accountability issues and pressures of schools to demonstrate progress can impact upon teaching approaches employed and teacher-focused approaches may be used to enhance achievement (Lee and Tsai, 2011). Indeed, the chance for children to talk and discuss their thinking through open-ended teaching approaches (enquiries) may be limited because teachers are often required to follow an overloaded curriculum (in terms of the number of objectives to be taught) and this may limit the breadth and depth of discussions that take place. Due to the pressures of coverage, teachers may be 'limiting the learner's experiences to pre-determined, narrow and precise and academic descriptions of school science' (Lehesvuori, Joni, Rashu-Puttonen, Moate and Helaakoski, 2013, p. 22).

Loughran (1996) argues that a lack of time also inhibits teachers from learning how to develop appropriate tasks that help children to develop conceptual understanding. Currently, there are demands made on teachers to employ teaching approaches that help children to perform better on tests rather than using enquiry-based learning approaches. Therefore, the transmission-reception style of teaching in science could arguably be to the detriment of affording opportunities for children to pose their own questions relating to their observations (which they can subsequently answer through investigative science work). However, Hayes (2002) maintains that teachers may adopt the transmission-reception instruction model as a pedagogical approach due to their uneasiness at relinquishing control and allowing children to undertake self–directed investigative activities. This may be as a result of teachers being unprepared to effectively cope with the management demands of inquiry teaching with a class of children. Indeed, Parker (2004) argues that learners with the same staring point in a lesson could easily arrive at different conclusions and that this can, for some teachers be demanding. This complication arises as understanding is constructed by each individual and it can be challenging for the teacher to know how best to facilitate learning within the individual learner's framework (Parker, 2004). Morgan and Saxton (1991) observed that teachers, who lack confidence, tend to avoid investigations because they pose the opportunity for pupils to express many divergent views which may result in the perception of the lesson losing focus from the planned learning objective. To complicate the situation further, pupils may also introduce ideas which are difficult for teachers to answer.

In summary, it is not an effective strategy to focus upon any one variable in isolation but instead to consider ways of improving the three strands of subject knowledge, curricular knowledge and subject specific pedagogy if attitudes towards teaching science are to be improved (as shown in the rectangular boxes in Figure 2.2). However, Fullan (1992) asserts that the delivery of a curriculum is influenced by many 'complexly inter-related' features and these need to be considered when planning for teacher learning. The development of teachers is perhaps best viewed as:

> A complex interplay between knowledge of subject matter, teaching and learning, and context, and the way in which teachers combine and use this knowledge to express expertise (Van Driel and Berry, 2012, p.33).

Therefore, teacher learning needs to consider teacher subject knowledge, educational beliefs, in combination with the opportunity to reflect upon their experiences. The following section considers how the process of reflection can be supported in a school setting.

2.12: Teacher development

Learning to teach is an ongoing process of professional learning. CPD is seen as an essential mechanism for enhancing teachers' knowledge and practices. Opfer and Pedder (2011) assert that if student learning is to be improved, then the provision for professional learning should be promoted. Professional development is most effective when the sessions focus on knowledge but provides teachers with 'hands-on' learning opportunities and is linked to the school curriculum (Gareth, Porter, Desmond, Birdman and Yoon, 2001). However, there is often limited access to CPD for teachers and the training that is provided tends to be generic in focus e.g. improving teaching and learning generally rather than being personalised for individual teachers (Ofsted, 2011).

The Department for Education (2011) echoes this viewpoint and argues that there is a need to continue to provide personalised professional development to teachers throughout their careers. Indeed, professional learning is most likely to be successful if teachers have time to reflect and to receive feedback from a critical friend (Muir, Beswick and Williamson, 2010). However, Postholme (2012) adds that teachers must also have 'a will to learn' from their reflections.

Reflection plays an important role in professional life and according to Pollard (2014) is necessary for acquiring expertise. The concept of reflective-teaching is a term that stems from the work of Dewey and is an orientation towards enquiry and the ability to think about experiences, to examine beliefs and practices about experiences in order to reach decisions. Dewey (1933) argued that professional learning is part of the experiential continuum and is a spiralling or cyclical process in which teachers monitor and evaluate and revise their practice. For the process to be successful, reflective-teaching requires an attitude of open-mindedness and Dewey identified five characteristics or processes that an individual should pass through in order to deliver higher quality standards of teaching (suggestion, problem solving, generating a hypothesis, reasoning and testing).

Schon (1987) extended upon the work of Dewey and depicted reflective practice as a 'dialogue of thinking and doing through which I become more skilful' (p. 31). He introduced the concepts of reflection-in-action and reflection-on-action. Reflection-in-action is the process of shaping what is happening while working e.g. a teacher makes decisions about the suitability of their teaching during a lesson and considers which questions to ask or which task to set as the lesson progresses. If something is not working then reflection occurs and a conscious decision is made regarding what needs to happen next in the lesson. Reflection-on-action, however, happens after the activity or lesson when the teacher has the opportunity to judge how successful the lesson was and whether or not a change to the task would have resulted in different outcomes for learners.

However, the ability to reflect effectively depends upon the time, situation and context as well as the teacher's own proclivity to reflect (Chamoso and Cacers, 2008). The process involves not only cognitive but also emotional and personal dimensions. Kaasila and Lauriala (2012) found that the personal biographies of a teacher and school-time memories of learning may impact upon the style and pedagogy employed. For, example, in their research they established that teachers who were exposed to traditional, didactic teaching would often assume this style of teaching during their lessons. In addition to this, individuals need to be interested or motivated to learn from experiences and some individuals can be resistant to change (Loughran, 1996). Indeed, fear of failure can have a negative impact upon a teacher's development (Ghaye and Ghaye, 1998).

Reflection is most effective when it is a social process in which the sharing of ideas with others is central to the development of a critical, open perspective of events (Solomon, 1997). The support of others is important in helping to build and establish a climate of collaboration and understanding. However, to be successful, there needs to be a climate of trust because without this, the sharing of ideas, concerns and challenges can appear threatening. Schon (1987) highlights the crucial role of a more knowledgeable other to 'emphasise indeterminate zones of practice' rather than to simply observe and point out errors or correct procedures. Here the focus is upon engaging teachers in a professional dialogue that seeks to analyse classroom interactions to promote reflective practice.

However, teachers' work is often aligned with individualism and privacy thus collaboration and collective efforts are not always customary in school settings. Nevertheless, classrooms should not be viewed as individual islands whereby teachers work in isolation but should instead be learning communities whereby teachers share their work and are provided with the time to reflect upon their teaching and to learn from each other (Stenhouse, 1975, cited in Pollard, 2014). It could be surmised that if teachers are able to share practices then there can be a positive change in teaching across the school.

2.13: The collaborative action research process

A way to share 'best practice' and evidence-based learning is to engage in action research. Action research has often been linked with the professional development of teachers because it is situated *in* the workplace and is *about* the workplace (Collins and Duguid, 1989, cited in Cohen *et al.*, 2003). The cyclical process of planning, acting and reflecting to effect changes in practice can have profound effects on teaching and subsequently the enjoyment and engagement of children. In their research, Lebak and Tinsley (2010) argued that the process of action research served as a catalyst for teachers to reflect and had a significant impact on transforming practice. Action research is a tool which empowers teachers and by engaging in this process they become more involved in learning; an essential component of enabling a teacher to investigate and evaluate their work. According to Smith and Dela (2005) when the process is collaborative the action research process should aim to bridge the gap between theoretical knowledge (‘discovered’, written about and published by academics) and practical knowledge (intuitively understood by teachers) by inviting teachers to engage in research that is meaningful to them. For Kemmis and McTaggart (1992) collaborative action research is not only problem solving but also problem posing and is motivated by a desire to improve understanding and should help individuals improve how they work. Collaborative action research can be considered as a form of self-reflective enquiry in order to evaluate and improve practice along with another person such as a colleague or researcher.

Little (2003) argues that studies should go ‘inside the teaching community’ to examine interactions and dynamics to help teachers put innovations into place. To achieve this a collaborative research partner can guide teachers through four processes including the clarification of the research goals; explain how theory guides the plan of action; support with the implementation and collection of data and finally, engaging in critical reflective discussions in relation to the data and subsequent future actions (Segar, 2005). Here the aim is not for the collaborative researcher to intervene but to support the process of reflection in order to create an awareness of the area under investigation.

A collaborative action research approach was adopted for this study because although teachers were motivated to develop questioning skills in their science lessons they were cognisant that they did not know enough about question types or how best to change their practice. In line with the work of Smith and Dela (2005) I was able to ‘bridge the gap’ between theory and practice by providing the theoretical background linked to question types and teaching approaches (e.g. the use of a puppet or concept cartoon to problematise science). In addition to providing theoretical understanding, I was engaged in conversational interviews to help teachers to evaluate their practice. Throughout the research it was important that teachers were co-constructors of knowledge because they were best positioned to understand the data.

Although collaboration and reflection have been identified as a foundation for successful learning, Glazer, Abbott and Harris (2002) found that although teachers develop a deeper understanding of themselves professionally and personally, these experiences did not always result in changes to practice. Conversely, if a teacher had control over the research and had decided on their own research questions and were supported with analysis and critical reflection then changes were more obvious. Therefore, in this research, teachers were supported in formulating their own research questions.

However, availing one-self to engage in the process of research is dependent upon an individual's motivation to change. Motivation to engage and continue with an activity can be fragile if a teacher is exposed to negative influences such as contextual factors of the workplace and a teacher's personal appraisal of themselves as effective teachers (Dornuei, 2001). Therefore, collaborative research partners need to be aware of these variables because they are responsible for dictating why teachers wish to change their practice, how long they are likely to persist with an activity and the effort that might be required to change and embed practices into teaching. Understanding the variables that support or inhibit change was elicited in this research by undertaking different types of interview throughout the research process so that teachers could discuss any challenges that they faced. It was also important to retain the self-esteem of teachers so no critical comments were made by the researcher.

2.14: Summary

This literature review identified that children need to actively construct their knowledge about the world around them through practical experiences and discussion. During knowledge construction, being able to talk and ask questions is fundamental to active and meaningful learning (Chin, 2006). There are a range of different question types that may be posed to children to support their construction of science concepts as well as supporting them to work scientifically (Yip, 2004; Elstgesst, 1985; Carr, 1998 and Koufetta-Menicou and Scaife, 2000). However, research by Alexander (2008) highlights that teachers often control the learning by adopting authoritarian, didactic teaching approaches that requires children to respond to factual, recall questions rather than being provided with the opportunity to reason and justify their thinking. Therefore, the transmission of facts from teacher to child is detrimental in affording children to generate their own questions and children's questions are consequently a rare feature during science lessons.

However, the role that teachers adopt during lessons is reliant upon a range of inter-rated variables that may enable or inhibit teachers from employing enquiry based approaches to learning or asking a range of question types. It is recognised that teachers with low levels of confidence, understanding of subject specific pedagogy or subject knowledge employ 'safe' teaching approaches that rely upon worksheets rather than active learning (Shulman and Harlen, 2000). In addition to this, the cultural factors of the school community influences the teaching style employed. The literature review concludes by arguing that engaging teachers in collaborative action research provides a means of supporting teachers to reflect upon their practice so that learning outcomes can be improved for children.

Chapter 3

Research Methodology

3.1: Research Questions

This research focused on how teachers engaged in a collaborative action research intervention in order to develop their questioning skills and teaching approaches during primary science lessons. The research questions for this research were:

1. How do primary school teachers' questioning practices change as a result of collaborative action research?
2. Is there a change in the type of questions posed as a result of collaborative action research?

Each teacher also chose a different teaching approach to develop children's questioning skills, as indicated by the questions below.

3. How does the use of a puppet support children in asking and answering their own questions in science? (Year 3 teacher)
4. How do Thinking Dice support children in asking and answering their own questions in science? (Year 6 teacher)

In order to provide the data to answer the research questions, a research methodology was needed that was suitable to interpret teaching and learning episodes. The following section makes the case for the use of a qualitative methodology using an interpretative approach.

3.2: The research approach

The aim of this research was to explore how questioning could be improved in primary science classes because the way in which questions are posed has been identified in the literature as being a key way in which teachers influence children's learning. However, too frequently questions posed by teachers (and children) are often of low-cognitive demand so restrict deeper, reflective thinking (Yip, 2004). The need to understand how and why teachers plan for questions during lessons requires a qualitative, interpretative approach because the focus is on the social context of the classroom and on the meanings teachers attach to their interactions with children during lessons.

In relation to this research, I have aligned myself to the interpretive paradigm which is suitable for the study concerned with the complexities of teacher reflection and teaching and learning. It is through interpretivism that researchers are required to seriously consider the standpoint of those being studied (Crotty, 2012). Through dialogue, a researcher can become aware of the perceptions, feelings and attributes of others. Consequently, 'meaning-making' becomes a social process and enables researchers to become aware of the experiences of others and to interpret these meanings in an open way.

Educational research is shaped by numerous variables including culture and the socialisation of participants. Interpretivists attempt to make sense of the human aspect of education and thus the complexities of an individual's perceptions, understanding and feelings (Clough and Nutbrown, 2012). It could be asserted that it is not possible to study the social world without interactions with people and reference to individuals involved in the process. The knowledge gained from the research, therefore, becomes more personal and unique as insight is gained from working alongside participants.

3.3: Epistemological and ontological positioning

Research is concerned with developing an understanding of the world and how an individual understands and comprehends their world is informed by their ontological and epistemological assumptions. According to Cohen, *et al*. (2003) an individual's ontological position gives rise to epistemological assumptions and therefore, impacts upon methodological choices and the way in which the data is framed, collected and interpreted. If a researcher believes that reality is external to the individual and is something that is separated from consciousness, then they will assume a realist ontology (Cohen *et al*, 2003). In adopting this approach it is assumed that 'the truth' is a reality to be found, however, if reality is open to interpretation, can be negotiated through human interaction, is not fixed but is the product of the 'individual's consciousness', as in this research, then a nominalist ontology is assumed to interpret and understand events.

The nominalist ontology influenced my epistemological positioning and to an extent, dictated which methodology and methods were adopted in order to obtain data. This research was aligned with the epistemological positioning of constructivism, which is based upon the view that meaning is not discovered but created 'in interaction between human beings and their world, and developed and transmitted within an essentially social context' (Crotty, 2012, p. 42). Therefore, teachers were able to participate in the construction of knowledge relating to their teaching approaches and questioning skills. Through discussion, it is possible to understand why a certain question is posed at a key point during a lesson or to explain the function of questioning patterns during lessons. Indeed, for Clough and Nutbrown (2012) people do not gain knowledge by simply observing the world but by interacting with people who are part of the research. It was important that the teachers' perceptions of what was happening mattered. I was interested in the nature of questioning sequences and wanted to know more about why these occurred. For example, I was interested to learn whether or not the use of Thinking Cubes, puppets or concept cartoons were effective when supporting the posing of questions and how teachers evaluated these approaches. However, Plummer (2000) asserts that meaning 'shifts' and is ambiguous; therefore, it could be asserted that how teachers perceive and evaluate a lesson may vary on a day to day basis and according to how they felt during discussions. Indeed, children may respond to similar lessons in different ways according to how they are feeling which may include variables such as level of understanding, motivation and interest in the activity and lesson (Smith and Call, 2000). Therefore, it is accepted that the data collected was subjected to these variables.

An objectivist epistemology was not suitable for this research because as Hammersley (1997) notes objectivism is problematic if the researcher is only focused on searching for a direct relationship between an intervention and the subsequent formulation of rules for successful pedagogy. When researching the effectiveness of teaching there is a human involvement and people are not 'objects' where causal relationships between intervention and subsequent behaviours can be inferred. There are many variables that impact upon the learning and teaching process.

3.4: Case Study Design

In line with qualitative research and my positioning, a case study approach was adopted in order to interpret real-life situations in natural settings. Indeed, Yin (2009) argues that case studies have a particular ability to answer ‘how’ and ‘why’ research questions rather than ‘what’ questions so have the potential to evaluate or explain why an approach did or did not work. The purpose of this research was to explore how questions were used in primary science classrooms and case studies were utilised because they can provide a narrative of real people in real situations while recognising the complexities of dynamic interactions (Cohen *et al.*, 2003). Therefore, this approach is suitable to explore the complexities inherent during science lessons and teacher professional learning.

Case studies can be single or multiple in design and the employment of each is based on the aims of the research. Single-case studies are often utilised to explain and understand extreme or critical events or unique cases (Yin, p.47), whereas a multiple-case studies are used when the cases complement and/or contradict each other and can highlight similar findings or differences in outcomes. For the purposes of this research a multiple-case study approach was employed to explore, in depth, how different teachers developed their questioning skills and to illustrate ways that teaching skills can be developed in primary science classrooms.

3.5: The Context of the Study

The research was conducted within a school and it is expedient to be cognisant of the impact that a school learning community has on teachers and their practice. This section will begin by providing the contextual background of the school and will reflect upon how the philosophy and ethos of the school may influence the research outcomes. I will then explore how the biography of the two participating teachers (and their classes) impacted on this research.

The teachers who participated in the study were working in the same junior school in West Sussex. Convenience sampling was used because the school was chosen based upon my knowledge and ease of access to the teachers; I had worked as a University link tutor in the school for a number of years and had developed good working relationships with the staff. In order to recruit teachers for the study, I was presented with the opportunity to explain the research to teachers during a meeting and three teachers were keen to participate. Three teachers were keen to engage in the research. Two of the teachers were male and were in their second year of teaching; the third was in her fourth year of teaching. Jack worked in Year 3 class (7-8 year olds), Jenny in a Year 5 class (9-10 year olds) and Rob in a Year 6 class (10-11 year olds). Two of the three teachers (Jack and Rob) were able to take part in the study throughout the year and thus they have been chosen as a focus for this research.

The school where the research was conducted had been graded as ‘good’ by Ofsted and in the most recent report identified that the monitoring of teaching was ‘robust’ with teachers being ‘offered constructive advice to improve their practice’ (p.4). The school has an ethos of supporting teacher development and the head-teacher is viewed as being instrumental in helping teachers to identify the next steps in their professional practice. To improve teaching and learning, teachers are afforded opportunities to observe others teach, receive coaching by other staff members and can attend bespoke training programmes. It would appear that the school is keen to develop a learning community whereby teachers are able to learn from each other, however, in line with many schools, the school sets challenging targets linked to pupil progress, which are carefully monitored by senior members of the school’s leadership team, to determine if pay increases are awarded. The impact of this may deter teachers from engaging in collaborative action research and changing their practices. Indeed, Martin and Hand (2009) argue that teachers are often reluctant to change their pedagogical strategies if these have been previously successful in fulfilling mandated requirements to assess pupil’s learning.

Schools are mobile and fluid because they are constantly changing when situations and new sets of circumstances arise and it is a challenge for teachers to respond to the inner school life (needs of parents, colleagues and children) as well as external contexts (Ofsted, policy and curriculum changes). For the school in this research, the external pressures of implementing a new curriculum provided additional work for subject leaders in terms of supporting colleagues so engaging in collaborative action research placed extra time demands on teachers. The teachers were not provided with further time to reflect upon their teaching and according to Jaipal and Figg (2011) release time is important to facilitate sustained engagement in the collaborative action research process.

However, both Rob and Jack presented as being committed to professional development and volunteered to engage in the research over the duration of the academic year. Although previous research suggests that it is only when teachers perceive their teaching as being inadequate that they will seek support to change their practice (Day, 1998) both teachers had been graded as 'outstanding' for their science teaching by Ofsted and were keen to reflect upon and change their teaching to improve outcomes for the children in their classes.

Jack, the year 3 teacher, was leaving the school at the end of year so it could be argued that there were fewer risks presented to him if he changed his teaching approach because he would not be subjected to performance management in the same way as Rob, who was teaching Year 6 and was preparing children for end of year testing. The age of the children may also have influenced the outcomes. From age 11 children are more influenced by group norms and are less willing to have attention drawn to themselves by asking and responding to questions (Dillon, 1998). According to Dillon (1988) younger children often ask more questions and engage in classroom discussions, therefore, the age of the children could be a variable that needs to be considered.

3.6: Using case studies to explore questioning skills through collaborative action research

An intervention was designed to look in-depth at a naturally occurring phenomenon in a naturalistic setting (classroom). The intervention was based on a collaborative action research model because the literature indicates that collaboration supports reflection and enactment can enhance teacher growth and learning (Clarke and Hollingsworth, 2002) and is in line with the conceptual framework of social constructivism that underpins this research.

Collaborative action research in this instance was the chosen approach as it has been described in the literature as being a powerful tool for change and improvement (Cohen *et al.,* 2003) and it was felt that by working in partnership with teachers, it was possible to co-construct an understanding of how to improve practice by collecting and analysing data together.

One of the aims of the research was to engage the two participating teachers in a reflection of their planning and delivery of science lessons when focused on the use of questions in science lessons.

3.6.1: The teaching approaches chosen by teachers

To develop questioning skills in the classroom, each of the teachers elected to use a different teaching approach to support the raising of questions during science lessons. During Stage 2 of the research I suggested that Jack could use a concept cartoon and puppet to support his questioning skills. These teaching approaches were suggested because Jack was familiar with them and because I was aware, from the literature, of how they change the dynamics of a classroom from being teacher-focused (with the use of tightly controlled investigations and questioning sequences) to being more child-focused (with more open-ended questions being posed and the teacher acting as a facilitator for learning). Indeed, research by Simon, Naylor, Keogh, Maloney and Downing (2008) assert that puppets and concept cartoons provide a resource to scaffold teachers who wish to change their teaching style to incorporate talk but are unsure of how to achieve this in practice. When concept cartoons and puppets were suggested to Rob he declined to use them because he was keen to use Thinking Dice. Thinking Dice had been recommended to him during a Professional Development Meeting (PDM) and he understood the theory and wished to apply this to his classroom. The next section provides a discussion as to how concept cartoons, puppets and Thinking Dice can develop questioning skills during science lessons.

3.7: Rationale for the use of concept cartoons and/or puppets in science lessons

The conceptual framework underpinning this research links to social constructivism and in any constructivist science class, the teacher needs to be open to students' ideas, allow for interactions and encourage thought, debate and questioning. Concept cartoons were developed by Keogh and Naylor (1999) in an attempt to clarify the relationship between social constructivist theory and teaching. Concept cartoons combine the visual elements of a cartoon picture with specific science concepts and are designed to provide opportunities for teachers to elicit children's understanding. An important characteristic of a concept cartoon is the fact that only one statement is scientifically correct; other statements while scientifically incorrect are not implausible and are often based on children's experiences or intuitions so stimulate discussion (Stephenson and Warwick, 2002). In line with constructivist views of teaching, concept cartoons provide opportunities for children to experience challenge and help with the re-structuring of ideas. Therefore, the use of concept cartoons were encouraged in this research as they allow teachers to present problems to children which stimulate learning conversations and enquiry rather than providing children with instructions and guided investigations.

Research with puppets in science has demonstrated that, like concept cartoons, they can be used to effectively engage children in discourse. The key idea when using a puppet is that it is the weakest scientist in the class so that children are in the role of the expert. Previous research has established that when a teacher uses a puppet to present a problem, rather than using instructions, it is more probable that children will engage in learning conversations (Hackling, Smith and Murica, 2011). The use of a puppet also results in children providing more extensive explanations when answering questions posed by a puppet rather than a 'more knowledgeable teacher'. Puppets, therefore, change the dynamics of classroom interactions so that there is a stimulus for talk that involves children in reasoning and can support teachers in asking the right questions to promote higher-ordered thinking.

3.8: Rationale for the use of Thinking Dice to develop questioning skills

Thinking Dice were designed to support teachers in developing children's thinking and questioning skills. Each set of Thinking Dice (as shown in Figure 3.1) consists of six foam dice, which have a question stem on each face designed to promote thinking at a specific level linked to Bloom's taxonomy.

Figure 3.1: Picture of the Thinking Dice

Thinking Dice can be used by both children and teachers and aims to provide a classroom environment that inspires higher-order thinking by encouraging children to ask questions or by supporting teachers to use a wider range of questions. However, although there are claims relating to the educational benefits of using the Thinking Dice on the web-site that sells the resource, there does not appear to be any small scale action research undertaken within classrooms to support assertions. Therefore, there is to date, no empirical study to evaluate the effectiveness of this teaching tool to change teacher practices and questioning skills.

During the research it was anticipated the teachers would be involved in every stage of the research process – as outlined in Figure 3.2. The red text relates to the researcher input and data collection points. The green text shows the teacher actions. Teachers were supported in developing their own specific research questions, reflecting on lessons and deciding on the next cycle of planning (Munn-Giddings, 2012). In this way the action research process alternates between enquiry and action so that data from discussions informs the development of the next stage. This echoes the ideology of Hannon (1998) who perceives research as taking place in the context of the community environment and likens educational research to a 'living plant' that is 'interacting with its environment, constantly renewing itself, sometimes growing, sometimes declining' (p. 150). This perspective links to the notion that research itself changes as social contexts and the construction of knowledge changes. The research process was designed to incorporate stages that included developing an action plan, implementing it, reflecting on the lesson and then refining ideas (Check and Scutt, 2012).

Figure 3.2: The research process used for each of the participating teachers

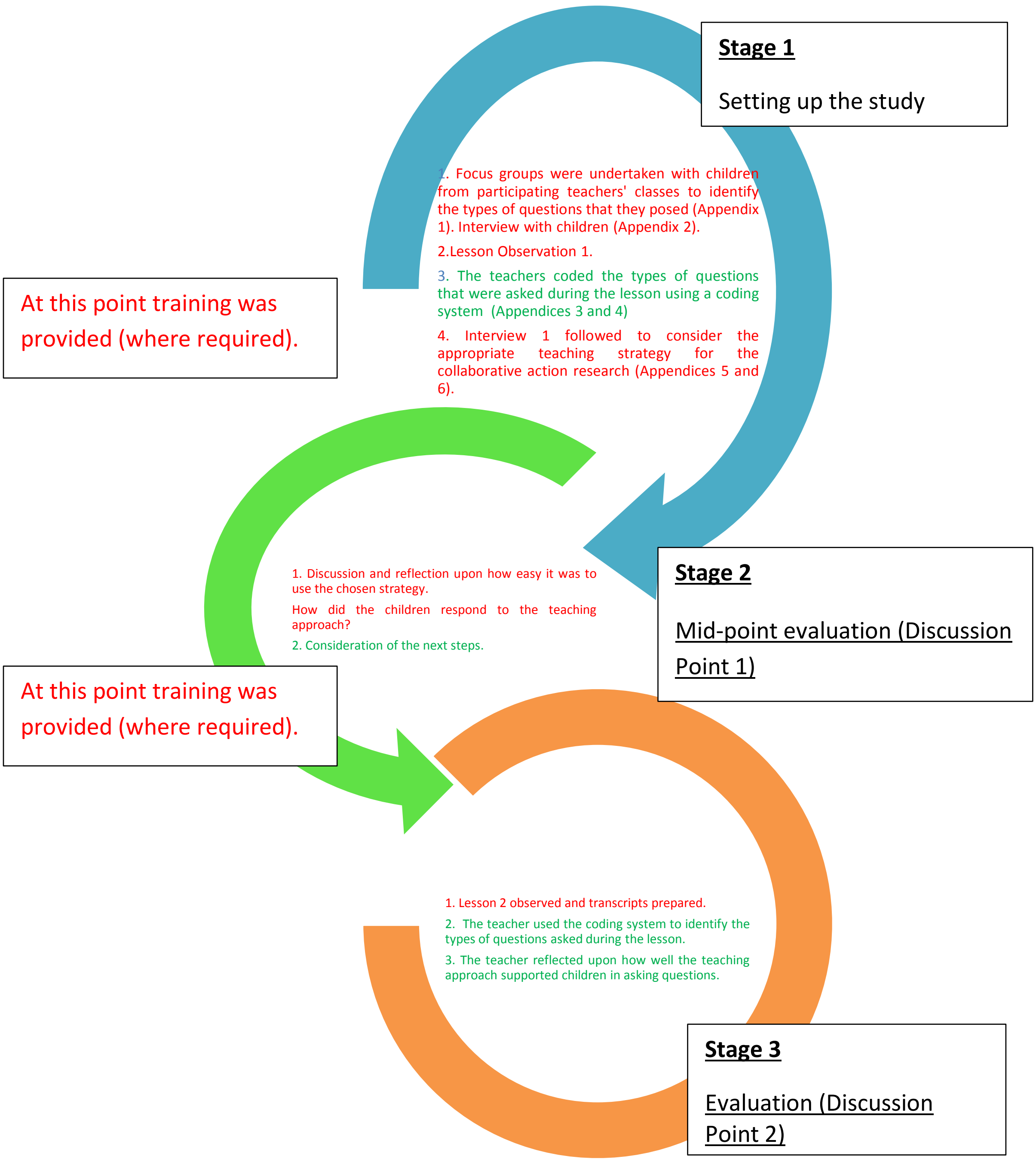


Figure 3.2 outlines the process that was employed during the research. Setting up the study (Stage 1) began with a focus group task with children and analysis of a science lesson (Lesson 1). Following this, an interview with the participating teachers was undertaken in order to discuss how questions were used. Here transcripts from the focus group task and Lesson 1 were discussed and the research questions were established with both of the two participating teachers. Stage 2 happened half way through the research and teachers had the opportunity to reflect upon how well the chosen teaching approach was being employed and to consider the next steps for them (this may have entailed further training input or a chance to refine the teaching). Finally, during Stage 3, transcripts from Lesson 2 were discussed and the teacher was able to evaluate and reflect upon how well the approach had worked. In total, teachers had the opportunity to engage in discussions about teaching on three occasions. During discussions, teachers reviewed, evaluated and reflected upon how they might improve their practice in the light of any new knowledge gained.

During the action–reflection model in Figure 3.2, teachers were co-constructors of knowledge as they were actively engaged in the development of the project, data analysis and generating the next steps for the research. This process follows the iterative nature akin to qualitative research and interpretivist theory whereby the analysis of data often results in further questions resulting from insights that may not have been anticipated. This approach echoes the work of Carr and Kemmis (1986) who maintain that collaborative research should support teachers in ‘self-reflective enquiry in order to improve their understanding of their practices’ (p.162). This supports the ideas of Somekh (1994) who argues that:-

> ...analysis and interpretation should be given at least equal credence and status with those of their ‘outsider’ partners from the university, and if possible precedence over them, (p. 368).

My role in the research was to act as a facilitator by providing a theoretical understanding of teaching strategies required to support the development of raising questions in science lessons, as well as supporting the process of reflection. Avgitidou (2009) maintains that members of higher education should conceive of their role as not only creators and transmitters of knowledge but also facilitators of 'knowledge creation' by individual teachers, thus supporting with the process of reflection. This positioning was especially pertinent because collaborative action research in this instance shares the features of interpretivisim whereby the aim is to 'understand what meanings people give to different situations' (Check and Scutt, 2012, p.15).

Indeed, Somekh (1994) asserts that collaborative action research is distinctive in that as an approach it rejects the notion that knowledge can be de-contextualised from its context and practice. She goes on to argue that knowledge constructed without the active participation of teachers can only be partial knowledge because the research outcomes can be influenced by the researcher's values and beliefs. Therefore, by analysing transcripts of lessons with the class teachers it is more likely that there will be a mutual understanding of the lesson. Since events arising from action research result from complex variables and teachers possess specific knowledge of the classroom, the methodology can provide special insights when it comes to interpretations of events (House, 1991).

As teachers were involved in the research process, they were well positioned to understand and apply meanings to the data collected and interpret the use of questions and how choices were influenced by the complexities and dynamics of a school setting. Although the 'voice' of the teacher was valuable in understanding the lessons, the data presented were not designed to be simple illustrations of the lesson. The aim was not to accept unquestioningly the respondent's views of events but to support with the process of reflection in order to probe ideas to ensure that views were not distorted or misrepresented in the narrative. To achieve this, questions were coded alongside teachers using a coding grid (Appendix 3 and 4) and interviews were used to provide a platform to discuss teaching.

3.9: Instruments of data collection

Case studies require multiple sources of data in order to answer the research questions. May (2011) argues that multiple methods are essential to a case study and that rich descriptions should be obtained through various mechanisms. Therefore, a broad range of devices to explore the contextual meanings that occurred during lessons was utilised. Moses and Knutson (2012) term this 'epistemological pluralism' in that there is 'a willingness to employ different tools to understand the social world that it aims to investigate' (p.200).

During this research different data collection methods were used. Interviews were employed to establish teachers' confidence levels when posing questions during Stage 1. To support the discussion, the transcripts from focus groups were also referred to. During Stages 2 and 3, teachers had the opportunity to reflect upon how well their chosen approach changed questioning skills through conversational interviews. To support teachers' reflections, transcripts from lesson observations were used to evaluate the effectiveness of the teaching approach. The Year 3 teacher, Jack, decided to make field notes to document their perceived effectiveness of science lessons. The notes were often written on lesson plans. Each of these methods of data collection will be discussed in the following sections.

3.9.2: Pupil Focus groups

During Stage 1 (Figure 3.1) focus groups were used in order to ascertain how confident children were at posing questions when provided with a science artefact (a Cartesian diver, shown in Figure 3.2). The transcripts of the focus group task served as a discussion point with the class teachers with regards to children's perceived experiences of questioning in science lessons and whether the questioning abilities of the focus group children were representative of the rest of the class. The focus groups also provided a baseline measurement of children's questioning skills because a coding sheet was used to identify the types of questions they were posing. The focus group was not a typical focus group because it was directed by a task.

The use of focus groups is compatible with the qualitative research paradigm because they are data rich, flexible and the discussion develops as children contribute ideas (Punch and Oancea, 2014).They also encourage genuine answers in a more spontaneous manner that could not be achieved during one to one interviews. My role was to provide the artefact and to facilitate the discussion. Throughout the focus group task, a series of planned questions relating to their questioning skills was posed (see Appendix 2). The data from both of these activities was shared with the class teacher during Interview 1.

The children who participated in the focus group task were selected randomly from a list which was composed of the names of children whose parents had agreed for them to take part in the task. The children had also given their consent. There were six children in each focus group. The focus groups took place in an open-access area of the school that children often worked in with a teaching assistant for group work sessions because Punch and Oancea (2014) argue that it is important that children are interviewed in a natural setting that is sympathetic to their everyday world in order to limit anxiety. The focus group task took place during the normal school day; in 'reading time' so that children were not missing lesson time or playtime. The focus group task lasted for about half an hour.

Figure 3.3: The Cartesian Diver that was used with children

In the Cartesian Diver there were three types of condiment; tomato sauce, brown sauce and mayonnaise. Each of these behaved differently when pressure was applied to the sides of the bottle. I chose to add different types of sauces (divers) in order to stimulate observation skills and to engage children in the activity. A Cartesian Diver was chosen for the focus group task because it was easy to set up and could be seen and manipulated in different ways; children can squeeze the bottle gently or can apply more pressure to the sides of the bottle in order to make the 'diver' go up and down. In addition to this, the Cartesian Diver was utilised because the literature suggests that in order to encourage children to ask questions they need to be provided with a curious item or problem that needs solving (Chin, 2004). The activity was open (there was no one way of exploring the artefact) so it was anticipated that children would be stimulated to talk about the artefact; which is in the spirit of enquiry based learning.

Children worked in pairs and were provided with one Cartesian Diver so that they could talk about what they were observing. Initially, children were provided with time to observe and explore the artefact before being asked what questions they would like to know the answer to in relation to the Cartesian Diver. It was important that the children knew that I was genuinely interested in the questions they had. Harlen and Elstgeest (1990) maintain that children should be encouraged to raise any questions because if they are required to ask only certain types of questions then this may deter them from raising questions in the first instance. As a result, children appeared keen to actively engage in the focus group task and tried to generate questions based upon their explorations of the Cartesian Diver. The focus group discussion was recorded with a digital audio recorder so that I was able to listen to the conversations and identify the types of questions that children were able to ask about the diver using a Coding Grid (Appendix 1).

A limitation of using a focus group, however, is that my personal views and opinions could have influenced the responses provided. In addition to this, Hyden and Bulow (2013) argue that ideas may be suppressed by dominant group members; therefore, I was mindful of these variables when children were talking.

3.9.3: Teacher Interviews and discussion points

Interviews are a prominent tool used in qualitative research in order to explore perceptions, meanings and construction of events and experiences (Punch and Oancea, 2014). Interviews, according to Cohen *et al.* (2003), recognise the social context of research and the 'centrality of human interactions' for knowledge production (p267). The purpose of the interviews conducted in this research project was to explore the key themes of why teachers ask certain questions, how they structure their lessons and the challenges that they believe science teaching poses to them personally. Tuckman (1972) recognises that interviews provide access to what is inside a person's head and make it possible to measure what a person knows and what they think. To achieve this, different types of interviews were conducted over the duration of the research period (see Table 3.1). The interviews undertaken in this research ranged from closed, structured interviews (Cohen *et al.* 2003) whereby set, pre-determined questions were asked and recorded on a schedule (Stage 1) through to completely informal interviews or discussions (Turner, 2010) where there were no predetermined questions and a conversational manner was adopted (Stages 2 and 3).

The initial interviews in Stage 1 served to identify the direction that the participating teachers wished the action research to follow as well as providing me with an understanding of their beliefs about science teaching and learning. The interviews conducted during Stage 1 also enabled me (alongside the teacher) to use the data to formulate specific goals for each teacher. During Stage 2 and 3, the aim was to provide the teachers with the opportunity to discuss and reflect upon their teaching.

Table 3.1: Interview type and aims

Stage of research	**Purpose of the interview**
Stage 1	<u>Closed interview</u> Questions were pre-determined and served to provide a baseline measurement of teacher's perceptions relating to science teaching and pedagogy (see Table 3.2 for questions). The questions used a closed-response format. <u>Structured interview</u> A structured interview was used to check responses from the closed interview, to explore responses in more depth and to identify research aims and questions that the teachers wished to explore. Questions were pre-determined so that it was possible to collect the same general areas of information from each teacher. During the structured interview, open-ended questions were posed so that teachers were able to contribute as much detail as they wished. The

	format of the interview also allowed the interviewer to ask probing questions (Turner, 2010).
Stage 2	Conversational interview Teachers had the opportunity to discuss and reflect upon their teaching and the impact of the puppet or Thinking Dice on questioning skills. During the conversational interview, questions were constructed in response to the ideas and comments provided by teachers.
Stage 3	Conversational interview Teachers had the opportunity to reflect upon the action research process and to consider how successful the Thinking Cubes or puppets had been in developing questioning skills in the classroom Closed interview The same closed interview (Table 3.2) was employed to measure any changes in teaching practices and viewpoints.

During Stage 1, teachers were asked to respond to a series of closed-response questions (see Table 3.2) designed to provide a baseline measurement to gauge the intensity of their feelings about issues relating to subject knowledge, teaching and questioning skills. The same questions were asked during Stage 3 of the research to identify a possible change in perceptions. The questions were formulated from the work of Hacking *et al*. (2011) who developed an assessment tool to measure teacher confidence and self-efficacy for engaging children in class discussions. The closed-response question format, used by Hackling *et al* (2011) to measure teacher confidence and efficacy, had been used in a number of research projects previously so it was assumed that the questions were reliable and valid.

Table 3.2: Closed-response questions employed to gauge teacher's perceptions of teaching strategies and questioning skills

Aspect	Agree strongly	Agree	Unsure	Disagree	Disagree strongly
I can engage children in hands on science activities.					
I am effective at establishing a classroom climate whereby students feel confident to pose questions.					
I can pose open and closed questions to support the science activity.					
I am confident in responding to children's scientific questions.					
I am able to use a range of techniques to establish children's prior knowledge.					
I can use my subject knowledge to ask the right questions in order to move children's learning forward.					
I encourage children to pose questions that they can investigate.					
I am confident at planning for opportunities for classroom talk.					
I have a good understanding of science concepts required to teach primary school children.					

The questions in Table 3.2 were written using a five point Likert rating scale so that I could begin to gauge the intensity of feeling. The rationale for adopting a closed response format at the beginning of the research was to serve as a means of quickly identifying patterns in the data, to identify any continuing professional development needs and to personalise the research question for each teacher. Questions in Table 3.2, therefore, served as a baseline measure. The same questions were asked at the end of the research process to see if perceptions and practices had changed over the duration of the research. To ensure the accuracy of the responses provided by teachers on the closed-response sheet a structured interview followed whereby questions were asked to further develop the ideas and feelings of teachers around the key aspects of teaching strategies, questioning skills and subject knowledge, as shown in Table 3.3.

Table 3.3: Structured interview questions to explore individual teacher's feelings about teaching and learning primary science

Question
• Do you have any A'levels in science? • Do you feel that having a science background makes a difference to your teaching? • Consider the phrase 'primary science' - What does it mead to you? • What is the role of the teacher in a science lesson? • Tell me about your philosophy for teaching. • What subject specific pedagogies are you aware of that may engage children in their learning? • Which do you use? • What is the place of questions in science? • How do you use questions in science? • Are you aware of the different types of questions that can be used when teaching? • How often do chidlren have the opportuntiy to answer their own questions? • Are there any merits in children being able to answer their own questions? • What (if any) are the challenges of children posing and answering their own quesitons? • Do you plan for different types of questions in science? • Do you plan science in teams? • As part of being a relefctive teacher, how would you like to improve your teaching of science?

Structured interviews were used because there was a need to collect key information and to construct an understanding of the values and philosophy of the participating teachers. During this interview a research question was formulated with the teachers.

During Stage 2 and 3 teachers were provided with the opportunity to discuss their teaching and lessons. The format was conversational and teachers were simply asked to consider how effective the teaching approach was. The conversational style of interview provided teachers with the chance to consider what was working well and what extra support may be required.

The teachers decided upon the time and place for the interviews; which lasted between 20 and 45 minutes. Both teachers chose to be interviewed (or discuss their teaching) after school in their classrooms so that there were no distractions and there was easy access to any plans, display boards or notes that they wished to refer to. The interviews were recorded using a digital audio-recorder to support with the analysis process at a later date and, to ensure that the 'flow' of the conversation was not impacted upon. Cohen *et al.* (2003) assert that an interview is a social interaction and if time is spent transcribing during the process then the method becomes a data collection exercise as opposed to a conversation. Had I chosen to write as the teachers were talking then arguably there could have been a bias in the data collected as I may have unconsciously selected or focused on things I felt to be important during the recording process. However, Bell (2010) argues that the researcher will have some influence on the interviewee and data collected because interviews are an interpersonal activity whereby humans interacting with humans.

3.9.4: Lesson Observations

Observations are on a continuum from highly structured, which utilise structured observation schedules, through to unstructured naturalistic observations that require the observer to take field notes in order to illuminate issues under investigation. Observations, according to Cohen *et al*. (2003) enable a researcher to 'gather live data from live situations' and provides the opportunity to collect data on the interactional setting (p.305). By working alongside teachers it is possible to begin to interpret events rather than relying on the researchers' own inferences. The 'observer-as-participant role' was adopted for this research because I was able to record what was happening but there was limited contact with the children on my part (Cohen *et al.,* 2003).

Lessons were videoed on two occasions during the research process; at Stage 1 and again at Stage 2 (See Figure 3.2). During Stage 1, the aim was to identify the types of questions that were being asked and to help participating teachers to formulate a research question. In Stage 3, the aim of the lesson observation was to ascertain if there had been a change in teaching and subsequent questioning skills.

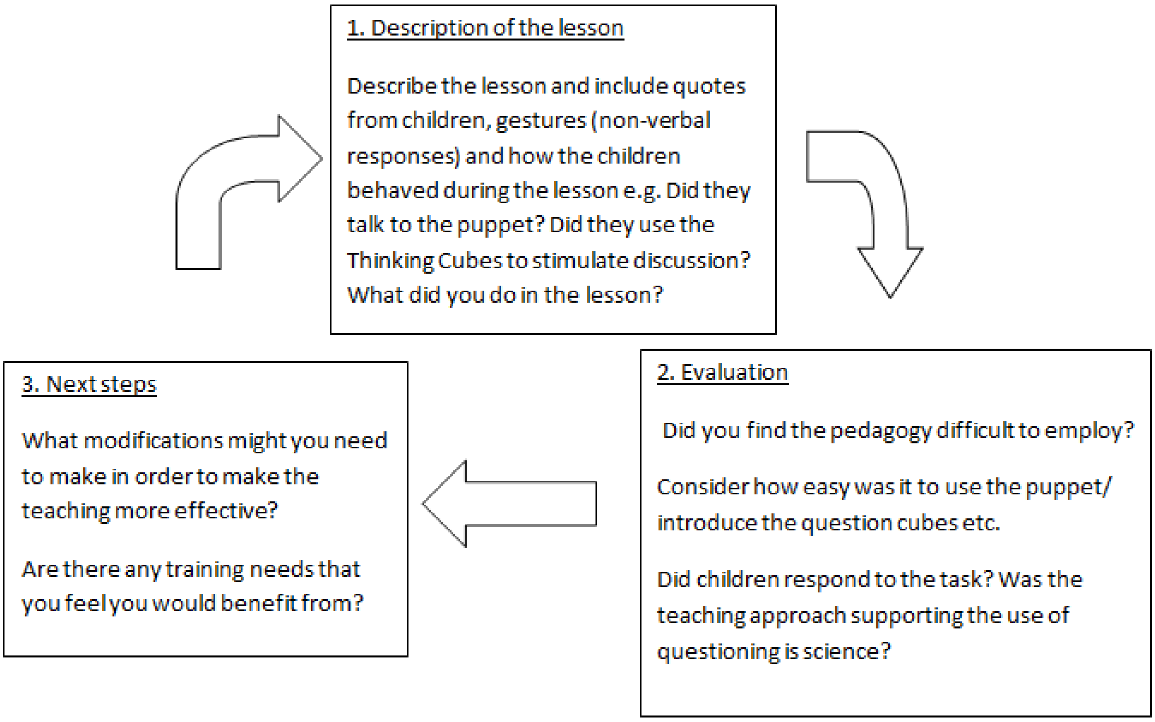
Although I had worked with teachers for a number of years as a university tutor and trusting relationships had been formed, it needs to be acknowledged that my presence in the classroom may have resulted in a change in the dynamics of the group work and/or the teaching approach (teachers may have felt under pressure by my presence). Another constraint to the research could have been the use of videoing. A drawback to using a video to record a lesson is that it can change behaviour. However, the children and the teacher were accustomed to having lessons videoed because the school had invested in recording equipment in order to record lessons as part of the staff's professional development. During whole class inputs, the video was positioned so that the recorder was aimed at the teacher and the interactive whiteboard. Regardless of the position of the camera, it was possible to hear the interactions and questioning sequences and these were transcribed from the video and used in the analysis.

3.9.5: Supporting the process of reflective thinking

During each stage of the research process teachers reflected on their teaching and the impact of the chosen approach on questioning skills. Through discussion, teachers were supported in identifying the next steps in the research process. As teachers in the study were in the early stages of their careers, they were familiar with reflecting upon their teaching after lessons as this was expected of them during their training and during their induction year. However, to further support them in their journey to becoming self-reflective practitioners they were introduced to some of the principles of reflection as identified in Figure 3.4; teachers were provided with paper copies of Figure 3.4 to support them with the process of reflection during Stage 1 of the research.

Figure 3.4 was developed from the work of Pollard (2014) who identifies the relationship between classroom practice and enquiry and the need for teachers to make judgements and evaluations about their practices based upon evidence collected. The process is cyclical (as shown by Figure 3.4) whereby teachers monitor, evaluate and revise their own practice continually.

Figure 3.4: The reflective cycle



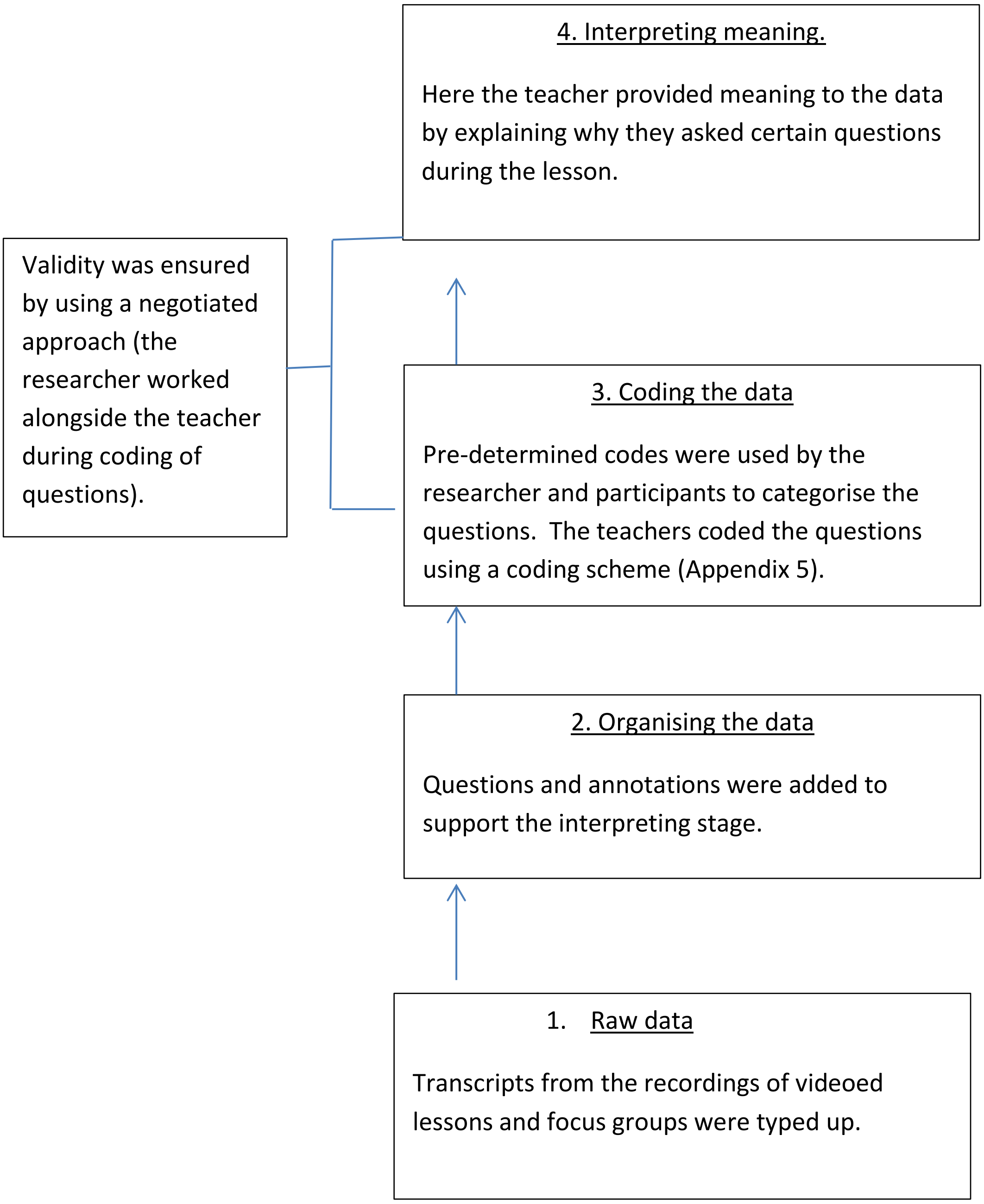
The aim of using reflective notes was to collect qualitative data which was personal and subjective in nature but provided teachers with the opportunity to reflect on their teaching and explore their feelings regarding various teaching approaches. The data collected during the reflective process was largely unstructured information (e.g. a reflection of the choices made during lessons). It does, however, need to be acknowledged that the process of partaking in a professional dialogue about reflections involves critically thinking about teaching and I was mindful of how this process was conducted so as not to damage the confidence of the teachers.

Teachers were encouraged to document their observations, feelings and reflections of events observed in the classroom in a way that suited them (there was no set approach or expectation). Due to the busyness of classrooms, some of the teachers only jotted down words and/or phrases on plans in order to serve as an aide memoire when reflecting upon their teaching at a later stage. It was hoped that the process of writing 'jigsawed' with the iterative nature of the action research model, which alternates between enquiry and action and may be conceived of and illustrated by a series of stages. Therefore, descriptive accounts of lessons (e.g. how children respond to teaching approaches designed to support questioning in science) provided 'ongoing' analysis and indicated if any additional support was necessary to 'fill in the gaps' in knowledge (in terms of a teaching strategies or subject knowledge).

3.10: Data analysis

The analysis of the qualitative data collected from the two participating teachers was undertaken using an adapted data analysis process for qualitative research. Figure 3.5 has been adapted from the work of Creswell (2009 p. 185).

Figure 3.5: The procedure followed for analysing the data from the focus groups, observations and interviews



Two lessons from each of the participating teachers were video recorded. The lessons were then transcribed by the researcher so that there was a familiarisation with the data; at this stage, questions and notes were added to the transcripts to better understand the pattern of questioning that was observed during the lesson. After the initial scrutiny of the data, the transcripts were shared with the teacher.

A coding scheme, developed from the literature and linked to questioning taxonomies in science education, was used to identify the types of questions that teachers posed during lessons. As there was an overlap in the question taxonomies, several authors are linked to each question type. Semantic tapestry questions, from Chin's taxonomy, were omitted from the coding scheme for this research. Semantic tapestry questions aim to link ideas into a conceptual framework using 'multi-pronged questions' and it was felt that this might be too challenging for primary science teachers when beginning to develop their questioning practices. Had the research been of a longer duration, then multi-pronged question stems may have been incorporated as teacher confidence increased. Table 3.4 shows how the literature links to the coding scheme as well as how each question type was coded.

Table 3.4: The coding scheme used to categorise teacher questions

Question type and code	**Description**	**Example**	**Linkage to literature**
Closed (C)	Often requires a one word answer and is used to check for understanding or recall of facts	How many bones in the body? So you mean...? What is...?	Carr (1998) Yipp (2004) Koufetta-Menicou and Scaife (2000)
Open (O)	Requires a more open response in the form of a sentence or explanation. There is more than one possible answer	What do you think might happen if...? Can you tell the class about...? So what does that have to do with...?	Carr (1998)
Explanatory (E)	Requires a more detailed response on the part of the person being questioned. Often asked once a child has provided an answer	Can you give an example of...? Can you explain how that happens? What do you mean by...? Why ?	Chin (2007) Koufetta-Menicou and Scaife (2000)
Classroom organisation (CO)	Links to classroom management issues	Can I see hands up of those people who have an answer? Have you written the date? Do you know what to do?	Not linked to questioning taxonomies in science education but included because classroom organisation questions were posed frequently.
Productive (Pr)	Questions support children in being active in order to find the	How would you test...? What do you notice…? How many/how long?	Elstgeest (1985) Yipp (2004) Chin (2007)

	answer to questions. Involves questions that lead to some sort of investigative work	What if …? Can you find a way to…? If… then…?	Koufetta-Menicou and Scaife (2000)
Comparison (Comp)	Questions require children to be use careful observation skills in order to answer a question	In what ways are they the same/different?	Elstgeest (1985) Yipp (2004) Koufetta-Menicou and Scaife (2000)
Person Centred and opinion questions (PC)	Questions that includes the pronoun 'you'. The question provides limited jeopardy on the part of the learner	So what do you think the problem is? Why do you think it ...? What is your opinion?	Harlen and Qualter (2014)
Problem Solving (PS)	Supports children in applying their conceptual understanding to another situation	Can you find a way to...? How would you use...? How would you apply what you have learned to develop...?	Elstgeest (1985) Chin (2007)
Defining questions (D)	Asks for clarification	What do you mean…? Do you mean that…? So…? In other words…? Tell me more about…?	Chin (2007) Carr (1998) Koufetta-Menicou and Scaife (2000)
Information Seeking (I)	Recalling facts – open ended but of low cognitive demand	Do you remember what we did last week? How would you summarise? How would you describe?	Yipp (2004) Chin (2007) Koufetta-Menicou and Scaife (2000)

Transcripts were analysed alongside each participating teacher because Borko, Jacobs, Eiteljorg and Pittman (2008) argue that learning about teaching is best constructed through discussions about practices. This constituted a negotiated approach in order to negate the impact of the researcher coding in isolation and according to their own bias and viewpoint. Indeed, coding with the teacher, generated discussion with regards to the category or intended purpose of a question.

Transcripts of the questioning sequences and dialogue were focused on categorising the question types posed over the duration of the lesson. The coding scheme was designed in order to engage teachers in the co-analysis of their lesson transcript using this coding scheme (Table 3.4). The transcripts of the lesson also served as a discussion point because the teachers were able to justify why they asked certain questions and to say how they felt during the lesson. When the teacher coded questions they sometimes argued that some questions were linked to more than one category (e.g. closed and person centred) so a polythetic classification approach (allowing a question to be assigned to more than one category) was applied. This is, according to Graesser and Person (1994) and Roth (2000) an appropriate approach to adopt when dealing with the complexities of human discourse. Therefore, all questions were coded as closed or open in the first instance. Coding was also added if the question was person centred. Table 3.5 shows an example of part of a lesson that was analysed alongside a teacher.

Table 3.5: Transcript coding example of Jack's lesson in January 2014

Line	Speaker	Words spoken	Code	Comments
1	Teacher	We'll be carrying on with our learning in science. Let's have a quick reminder of our learning in science this term.	Not a question but open ended statement.	Recapping on prior learning – making links between sessions. Used to assess knowledge to date.
2	Sam	That North and North can't sick together and South and South can't stick together but North and South stick together.	Recalling prior learning	
3	Teacher	Are you going to use scientific vocabulary? You are absolutely right in what you said but tell me again.	C CO.	
4	Sam	North and North can repel and South and South repel but North and South attract.		Few hands were up – children given a chance to talk in pairs – value of paired shared talk.
5	Teacher	What have you learned? (directed at another child)	O I	Low cognitive demand – little jeopardy on child. Seeks information
6	Jess	North and South attract because they have magnetic metal inside them, which literally means that when you push them they will attract and turn around.		
7	Teacher	Yes, if you put magnets on a smooth table, they will spin around.		
8	Teacher	What do we mean by magnetic materials?	PC I	
9	Tia	They attract		
10	Teacher	What materials are magnetic?	C I	
11	Tia	Metals		
12	Teacher	What metals?	C	

			I	
13	Ellie	Steel		Develop Subject knowledge
14	James	Iron		

A coding sheet (Table 3.6) for pupil questions was used to code children's questions and was also developed from the literature (see Table 2.3). It was anticipated that Lessons 1 and 2 would be compared in order to provide the data required to answer research questions 3 and 4 (How does the use of a puppet or Thinking Dice support children in asking and answering their own questions in science?).

Table 3.6: Coding sheet for children's questions

Question types and example of questions	Function of question
Basic information questions What does the dictionary say about salt? What does the sachet contain?	To generate questions in response to cues or to seek information.
Wonderment What would happen if…?	Application of an idea – requires children to be active and to test an idea.
Philosophical questions I wonder why that happens?	Does not require another person to answer; just a think out loud question.
Procedural or Management questions Who would like to count? What do we do next?	Requires clarification of a procedure or task. Children negotiating roles during experimental work.
Comparison questions Which goes fastest? In what ways are they the same/different?	Use of observational skills to compare variables.
Explanatory and exploration questions Why does the sachet float?	Children needing an explanation based upon their observation of events that they have observed or items they have been exploring.

3.11: Piloting the coding scheme

As part of the focus of the observation was known (charting the incidence of different question types) in order to compare one situation with another (Lessons 1 and 2) then it is an efficient use of time to use a schedule with pre-determined categories (Morrison, 1993). However, a drawback to employing a structured scheme is that it needs careful piloting in order to collect valid data. Therefore, I practised using the question coding scheme using a video clip from a training web-site 'From Good to Outstanding' (Flashback Productions, 2009). I transcribed the dialogue and used the grid in order to check that the grid was suitable to identify question types posed during a lesson. The scheme appeared 'fit for purpose' because it was possible to code questions using the pre-determined categories.

3. 12: Reliability and validity

A coding system should have meaningful and discrete categories. If the coding system is too simplistic, this may result in a limited insight of what is being observed. The coding scheme for this research began with the theoretical framework as presented in Tables 2.2 and 2.3 of the literature review.

The data collected during this research process was socially situated and as such, the research findings need to be accepted with some self-awareness because there was a focus on people and their interpretations of events. Data from multiple sources (transcripts of lessons, interviews and coding of questions) were analysed and discussed alongside the teacher to ensure factual accuracy and to therefore, enhance the credibility of the findings and assertions made. To ensure a greater degree of reliability, the research needed to be undertaken in a careful and critical manner when interpreting data, which was qualitative and subjective.

While assigning frequencies to classification is an aid to understanding patterns (i.e. how many closed-response questions were asked) this does not make the research quantitative. The goal was to be descriptive rather than predictive in order to explain and understand the complexities of questioning. This links to the interpreting meaning stage of the analysis process whereby the participating teachers explained the data and answered questions.

Validity is, according to Creswell (2009), determined by the degree to which the findings are accurate from the standpoint of the researcher and participants. To ensure validity, the research participants were encouraged to check the transcripts of observed lessons and subsequent interviews to ensure that the meanings were accurate. In addition to this rich descriptions were provided (transcript extracts) to enable an insight into the data collected (Creswell, 2009).

3. 13: Ethical considerations

This research was approached from a constructivist epistemology and the collection of qualitative data, therefore, it was important that the research was undertaken in an ethical manner. Issues of informed consent, confidentiality and anonymity were deliberately considered and as such ethical approval was sought and granted by the Ethics Committee at Southampton University before the research commenced (Ethics reference number: 7469, Appendix 8 and 9). To ensure that there was informed consent, teachers were provided with information sheets, attended a meeting so that they could ask questions about the research and were requested to sign a consent sheet (Appendix 10). The children and parents from the participating teachers' classes were also provided with information sheets detailing the aims of the research (Appendix 11). Parents and children were asked to sign consent sheets. In order to support children in providing informed consent, the information sheets and consent forms were in a child friendly format. Children were selected for the focus groups from those who had consented to partaking in the focus groups and whose parent had signed the consent form. Consent was checked throughout the research process. In line with British Education Research Association (BERA) guidelines, full consent was gained prior to the interview and checked again when the interviewee was de-briefed after interviewing in Stages 1, 2 and 3 of the research process. After the interview, the interviewee also had the opportunity to check the responses for factual accuracy. At this point it was made explicit that the interviewee still had the right to withdraw from the study, which BERA (2004) identify should be a right throughout the research.

Protection of the participating teachers' and children's identities was ensured during the research process. The children and teachers were provided with pseudonyms (the Year 3 teacher was named Jack and the Year 6 teacher was provided with the pseudonym Rob). The school name is not identified in the reporting of the research thus further protecting the identity of the participating teachers. The confidential nature of the data (videoed lessons and transcripts) was ensured by not sharing the findings with other members of staff at the school. The transcripts were kept on a secure password protected computer.

Ethical issues were also considered at the data collection and analysis phase to ensure that the findings were reported accurately. To achieve this aim, the teacher was involved in the coding of the transcripts of observed lessons and was encouraged to evaluate and reflect upon their teaching. In order to retain the self-esteem of the participating teachers, no critical comments were made that could be construed in a negative way. Teachers were provided with the opportunity to read the results section that related to their practice to ensure that their representation was accurate (Rob was the only teacher who elected to do this).

It needs to be acknowledged that the school was chosen for the case study due to ease of access; the author had previously worked in the school and knew the staff well. This may have impacted on the responses provided by the participant (the teachers were aware of my positioning). There were, however, a number of variables that may have impacted upon the collaborative nature of the research. As I am a member of university staff there may have been a conferred status in the viewpoint of the teacher in terms of a power differential. In order to limit this, there was a conscious decision to ensure that each teacher had an equal role in the research and there was the expectation that I would learn from them and support them in answering their own research questions. This links with the views of Somekh (1994) who maintains that 'although equality is an almost impossible ideal, both should value each other's research questions' (p.363). In addition to supporting the classroom teachers in identifying the focus for the research, I had already spent time working closely with the teachers who would be involved in the study so that trusting relationships had been fostered.

3.14: Summary

In this chapter I argue that in order to understand how and why teachers pose questions during lessons a qualitative, interpretative approach is required because teaching is a social process and knowledge and insight is gained by interacting and discussing teaching and learning with teachers involved in the process. In order to collect the data required, a case study approach was employed so that a narrative of teaching and teacher learning could be documented. The design of the case study was based on a collaborative action research model in order to support teacher reflection and enactment (Clarke and

Hollingsworth, 2002). During the collaborative action research process observations, interviews and discussions were utilized so that teachers had the opportunity to reflect on their questioning skills and the effectiveness of the chosen teaching approach. Teachers co-analysed transcripts of their lessons because learning is best developed by discussing practice (Borko *et al.*, 2008). Co-analysis also ensured that the data was factually accurate. To ensure validity, teachers were proved with the opportunity to read through the findings chapter. Ethical considerations in terms of consent, anonymity and the right to withdraw underpinned every stage of the research process.

Chapter 4

Case Study 1

Jack and his Year 3 class: using puppets to develop questioning skills

4.1: Introduction

This chapter provides a description and analysis of the teaching approaches and questioning skills adopted during Jack's science lessons. The analysis undertaken answers the three research questions which are firstly, to establish how Jack's teaching practices changed as a result of collaborative action research. Secondly, to identify if collaborative action research changed Jack's questioning skills and finally, to explore how the use of puppets influenced children's questioning skills during science lessons.

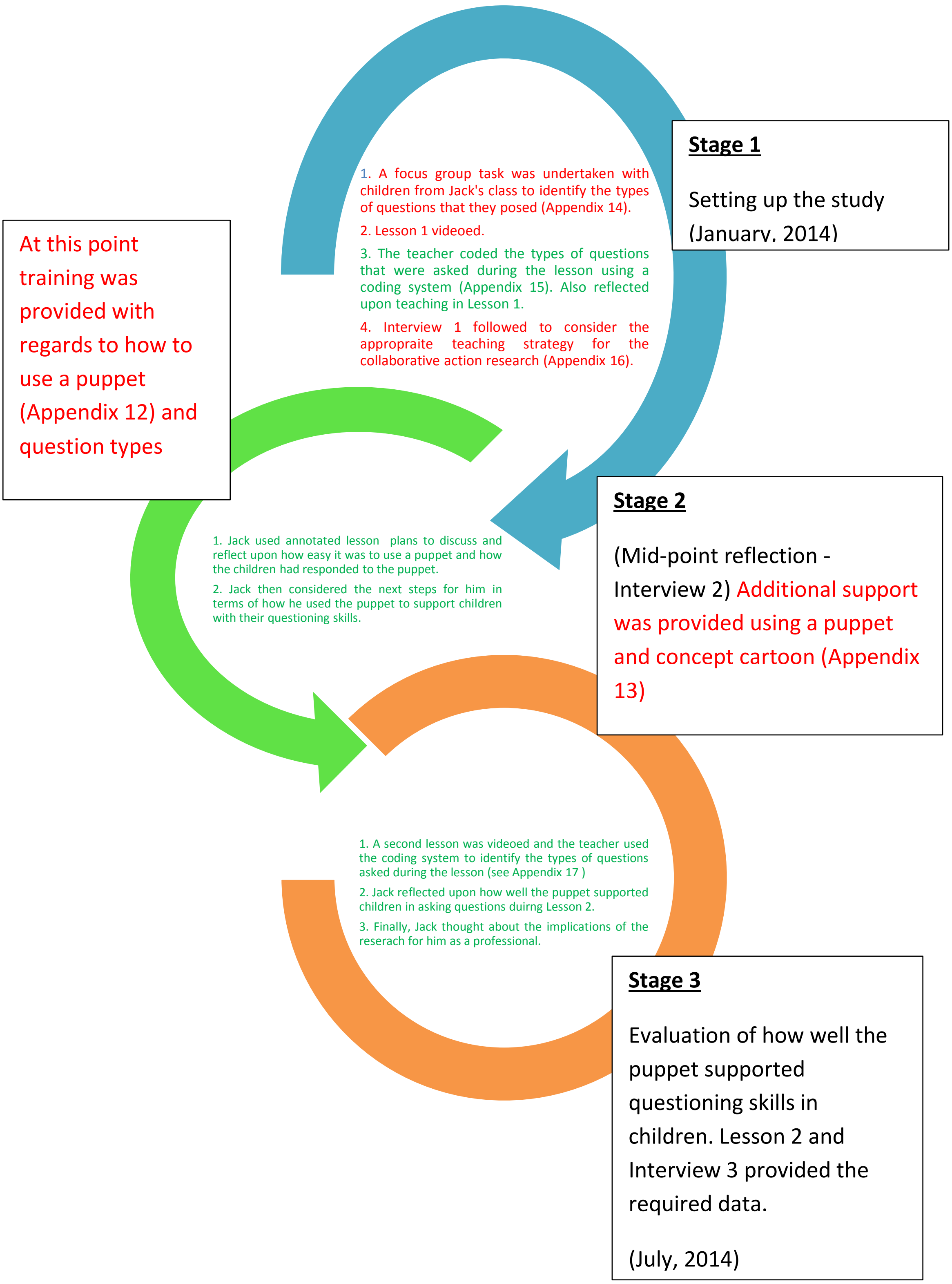
In order to provide the evidence to answer the research questions, this chapter will begin by presenting a brief biography of Jack and his class. This is followed by a flow chart (Figure 4.1) detailing the stages of the action research process for Jack. The chapter will then compare Lessons 1 and 2 to search for changes in teaching strategies and questioning.

4.2: Jack and his class

Jack became a primary school teacher in 2011 after completing a Post Graduate Certificate in Education; his first degree was in Sound Design Technology. He has taught a Year 3 class (children aged between 7 and 8) for the past two years.

Jack's class consisted of 32, mixed ability children. In his class there were fourteen girls and eighteen boys who were from a mainly white ethnic background. The children were taught in mixed ability groups for science and usually engaged in science lessons for an afternoon each week. The class was taught almost exclusively by Jack; the school employed a teacher to deliver physical education sessions during Planning, Preparation and Assessment (PPA) time. Figure 4.1 presents the action research cycle that Jack engaged in. The red text relates to the researcher input and data collection points. The green text shows the teacher actions.

Figure 4.1: The action research cycle for Jack



4.3: Research Question 1: How do primary school teachers' questioning practices change as a result of collaborative action research?

At the beginning of the research process Jack's teaching strategies and views about science were identified. Table 4.1 summarises the key themes that emerged from interviews and observed lessons during Stages 1 and 3 of the research process. The red annotations show Jack's views and teaching strategies at the beginning of the research process. The green script relates to Stage 3 and how the action research impacted upon questioning skills.

Table 4.1: Summary of teaching strategies over the duration of the action research cycle

Theme	**Main point**
a) Jack's views of science	Science should entail a practical element to develop children's conceptual understanding of science. This remained unchanged throughout the research.
b) Structure of Jack's lessons	Lesson 1 began and ended with a number of closed-response questions to assess children's understanding. Children engaged in practical work but this was 'controlled' by Jack because he had decided how children were going to undertake investigative work. The structure of Lesson 2 was broadly the same (he was still using closed-questions to assess knowledge during the input and plenary) but Jack was now planning time for children to talk in lessons by using a puppet (along with a concept cartoon). There were more opportunities for children to plan their own investigations.
c) Challenge of classroom talk for Jack	Jack reported that he was unsure of how to plan for classroom talk. Children, therefore, had limited opportunities to discuss science concepts and were not provided with the opportunity to pose their own questions. During lesson 2 Jack was asking more open-ended questions which included the question stems 'how' and 'why.' This questioning approach resulted in children providing more expansive answers. Jack reported that the use of the puppet, along with concept cartoons, encouraged children to talk about science concepts and because the puppet (Ricky) was the weakest scientist in the class, children were confident to explain the concepts to Ricky using appropriate scientific language. There was a move from IRE towards IRRE moves during the questioning sessions in Lesson 2 and children were beginning to engage in cross discussion and cumulative talk.

4.3.1 Stage 1: Strategies adopted by Jack at the beginning of the research cycle

a) Jack's views of science

During Stage 1 of the research Jack was asked to respond to a number of questions relating to his attitude towards teaching. The findings are shown below in Table 4.2

Table 4.2: Jack's perceptions of his teaching and questioning skills

Aspect	Agree strongly	Agree	Unsure	Disagree	Disagree strongly
I can engage children in hands on science activities.					
I am effective at establishing a classroom climate whereby students feel confident to pose questions.					
I can pose open and closed questions to support the science activity.					
I am confident in responding to children's scientific questions.					
I am able to use a range of techniques to establish children's prior knowledge.					
I can use my subject knowledge to ask the right questions in order to move children's learning forward.					
I encourage children to pose questions that they can investigate.					
I am confident at planning for opportunities for classroom talk.					
I have a good understanding of science concepts required to teach primary school children.					

The one area that Jack reported to agreeing strongly with was his ability to support children in 'hands on' learning. However, during Interview 1 (Stage 1) Jack reported:

> I am concerned that they [the children] are not using enough practical science approaches so are not really constructing their understanding enough. When I first started teaching I thought that science should be open... here is an idea, now off you go but that doesn't seem to work with Year 3. I feel that with Year 3 I am trying to find a balance between really open-ended and very scaffolded investigations. I want to be steering children but I find myself dragging them to where I want them to be (Interview1).

Jack identified in the above extract that science lessons should entail a 'practical element' in order to develop children's understanding of basic concepts. He reported that his subject knowledge (he has Advanced Level school biology) supports him in providing children with opportunities to learn via investigative work rather than using transmission approaches. Jack's view of undertaking practical work to develop conceptual understanding may demonstrate his view of science as predominantly based on experimentation. However, there needs to be a recognition that children need to 'think scientifically' if they are to 'work scientifically'. Working scientifically entails students being engaged in negotiation and discussion about how to set up an investigation and there should be a linkage between their questions and/or predictions to concepts being developed through the practical work (Sharp *et al.* 2011). The comment that children could be given an idea which they then investigate may indicate that Jack is not fully aware of the process skills such as being able to predict, ask questions and observe systematically in order to gather, record and present data. These process skills need to be developed before children are able to become more autonomous learners during lessons. To refine children's predictions it was suggested to Jack that productive questions could be asked (what do you think will happen if…? or why do you think that…?) because these questions may help to focus children's thinking.

b) Jack's reflections on the structure of his lesson (Stage 1)

Lesson 1 was part of a unit of work linked to magnetism and required children to plan an enquiry to identify which was the strongest magnet. During the lesson children were introduced to a problem via a video link of a puppet sorting cans. Some of the magnets did not pick up the cans and children were asked what the problem could be before being required to plan an investigation to find out which was the strongest magnet. To support children with their planning they were provided with the opportunity to go around the room to 'explore the magnets' and to observe any differences.

Jack started Lesson 1 with a five minute recap to assess prior learning. During the introduction of Lesson 1 there were a number of closed-response questions posed such as: what do we mean by a magnetic material? what materials are magnetic? are all metals magnetic? Jack explained that this was undertaken in order to check children's understanding of magnetism because in the lesson they would need to apply this subject knowledge in order to problem solve. Indeed, teachers should sometimes pose low cognitive demand questions in order to support children's thinking at a higher level (Martin, 2006); in this instance being able to apply their knowledge of magnets to find out which is the strongest.

The findings of the investigation were discussed and shared during the plenary of the lesson. However, children did not explain what their results were showing or if there were any surprises. Jack identified that on reflection he could 'have provided opportunities for children to compare their findings' (Interview 1). This would have been a useful exercise because children came to different conclusions when attempting to identify the strongest magnet. Comparing findings, according to Osborne *et al.* (2004), provides learners with the opportunity to present their evidence through talk. I suggested that the children could have asked the other groups questions about their methods and findings, rather than the teacher leading the discussion. However, when this was suggested as a strategy, Jack felt that the children would need to have this modelled to them first.

c) The challenge of classroom talk

During Interview 1 Jack was asked about his ability to plan for opportunities to encourage children to pose their own questions or to discuss concepts (Table 4.2). Jack reported that he felt unsure of how to plan for classroom talk and questioning so did not feel that he was equipped to encourage children to pose their own questions. During Lesson 1, it appeared that Jack was acting as a monitor in the lesson because he was setting the task and had decided how practical work was to be executed (Tabak and Baumgartner, 2004). There were no opportunities for children to ask questions relating to the strength of a magnet. It could be asserted that Jack could develop his practice beyond 'doing' science and move towards 'talking' science (Lemke, 1990) because if children are encouraged to engage in talk activities then they will be more inclined to respond and learn from the views of others (Watts and Alsop, 1995). Encouraging children to talk to each other could have been developed part way through Lesson 1 when children were shown a video clip (a recording produced by the Year 3 teaching team in the school) of a puppet called Roger working at a recycling plant in an attempt to link subject knowledge to the application of a problem. The children were told that 'Roger is rubbish at science and to watch carefully to see if they could think about how to help Roger' (Jack, Lesson 1). The video showed

Roger trying to pick up a tin of baked beans with a magnet. If the magnet did not pick up the tin then a different magnet was tested. The children appeared really engaged, however, when they were asked to explain what Roger's problem was there was confusion, as indicated in Table 4.3.

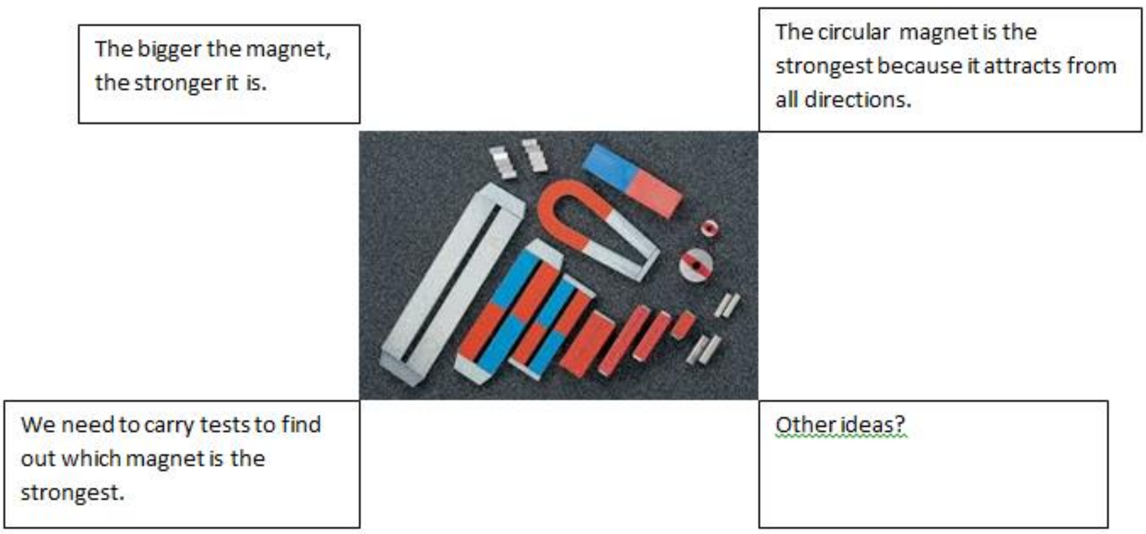
Table 4.3: Interaction sequence indicating a child's confusion

Number from Transcript	Name	Transcript
45	Teacher	Watch the exciting bit of the video again – look, it [the puppet] has lifted it up but it [the magnet] has dropped it [the can]. So do you think it [the can] was magnetic?
46	James	I think the magnets might be different.
47	Teacher	He used all the magnets on all the cans but only one magnet picked it up.
48	James	I think the cans are heavy so can't attract.
49	Teacher	Are the cans heavy, does that mean they can't be attracted to a magnet?
50	James	You can see they are heavy.

Although Jack wanted children to apply their learning to a problem, James appeared to have insufficient subject knowledge as indicated on Line 48 where he reported that if cans are heavy then they cannot attract (rather than understanding that magnets can be different strengths). Jack identified that 'it took a long time for children to comprehend what they needed to do' (Interview 1). On Lines 47 and 49 Jack was using defining questions/statements to help children to consider the variables under investigation but for the questioning to be fruitful he could have modelled the activity to the children with real cans. In addition to this, when James said that the magnets might be different (Line 46 on the transcript), Jack could have asked 'how' or 'why' and paused and allowed children to discuss how the magnets might be different with a talk partner. This may have created the climate whereby children could share their ideas with a supportive peer and would have involved the whole class rather than being a conversation between one child and the teacher. If children are encouraged to discuss ideas then they are more likely to be engaged in the lesson (Osborne *et al.*, 2004). Also, by asking other children for their view(s), it may have been possible to identify the variable that children were to investigate (the strength of different magnets) more readily.

Jack planned time for children to explore different magnets and told them 'get to know your magnets' (Jack, Lesson 1). When looking at the videoed lesson, Jack reflected that 'children's explorations were not focused and that 'children were off task and were not doing what I expected them to do' (Interview 1). Instead, children were observed to place magnets North to North or South to North rather than attempting to measure which magnets were strongest. I suggested that he could have used a concept cartoon (Figure 4.2) to provide a discussion focus for the children's exploration.

Figure 4.2: An example of a concept cartoon that may result in discussion and/or cognitive conflict.



Concept cartoons provide an effective stimulus for talk and may support children's ability to justify and reason when exploring ideas and concepts (Naylor and Keogh, 2000). When talking about the science presented in the concept cartoon, children's thinking could have been developed through interactions with peers (Vygotsky, 1978). This was identified by Jack as being an issue when he reported that, 'I'm not sure what is going on in their groups – it would be interesting to focus on the talk' (Jack, Interview 1). Indeed, through listening to children's conversations, it is possible to identify their understanding and confusions.

Following the use of a concept cartoon a suggestion of using a puppet was made as a way to support children in developing their reasoning skills in response to questions posed by the puppet. This was suggested because Jack had identified that he was keen to use puppets to provide a problem for children to solve. As Jack reported that he was not confident in planning opportunities for talk, the concept cartoons were suggested as a tool to help him to formulate a problem for the puppet so that he could generate discussion rather than needing to formulate his own problems for children to solve.

4.3.2 Stage 2: Reflections on teaching at the mid-way point of the action research process

The main issue that Jack discussed at this point was the extent to which using a puppet was successful for engaging children in the learning process, and encouraging them to make their thinking and reasoning more visible through talk.

Jack had kept written notes relating to key ideas that he wished to discuss during Interview 2. Jack commented that the use of a puppet had been well received by his class and that they responded sensitively when the puppet looked either confused or excited. This response is documented in the research with Low and Matthew (2000) maintaining that puppets are valuable in engaging children in talk and that children respond well to others who are experiencing difficulties. The puppet had been introduced to the children as being a keen scientist who was often confused by concepts and required help in understanding the science. Jack felt that because the puppet had been introduced as the weakest scientist in the class, this provided the impetus for children to 'help the puppet' and that subsequently their explanations to the puppet had become clearer and more expansive than if they had been answering 'his' questions. Jack commented that:

> 'Because the puppet found science challenging, the children took care to ensure that they used scientific language correctly and that they reasoned and justified their thinking and this seemed to clarify their thinking' (Interview 2).

Jack also reported that the puppet had been used successfully to help dispel misconceptions. He felt that this had been achieved because he was able to use the puppet to seek clarification of children's thinking by saying to the children 'Ricky is still confused, can you explain that to him again?' Here Jack was applying a pattern of talk that is not the 'norm' in the classroom; using the puppet to show confusion (Martin, 2006). Based on Jack's reflections, it seemed that the dynamics of the classroom environment were changing because Jack (the authority figure) was no longer posing all the questions or problems. Therefore, the teaching was moving from being 'teacher-centred' and was becoming more 'learner-centred'. This was achieved by Jack acting as a fellow investigator (through the puppet) and enabled him to think out loud when contemplating concepts. Collins *et al.* (2008) argue that if reasoning skills are modelled to children then science becomes more accessible to children and they become more willing to engage in lessons. Jack had noticed that more children were willing to answer questions, especially if they were posed by Ricky.

4.3.3 - Stage 3: Evaluation of how collaborative action research impacted upon practices

In order to evaluate a change in Jack's teaching approach, data from Interviews 2 and 3 and transcripts from Lesson 2 were analysed. Lesson 2 (Stage 3) was observed in July 2014 during the penultimate week of term. During this lesson children were considering the properties of rocks and were asked to apply their learning from previous lessons to decide which rock would be most suitable to build a statue from. The type of investigation that children were engaged in was the same as Lesson 1 and required them to make comparisons between variables. This was expedient as the lessons were similar in terms of the way in which children were being required to work and think scientifically so comparisons between questions asked could be made without the confounding variable of the type of investigation impacting upon the outcomes.

a) Jack's view of science

During Interview 3 Jack was asked to complete the same closed-response questions that he responded to during Stage 1 of the research process in order to evaluate any changes in attitude and skills. The findings are shown in Table 4.4.

Table 4.4: Jack's perceptions of his teaching and questioning skills

Aspect	Agree strongly	Agree	Unsure	Disagree	Disagree strongly
I can engage children in hands on science activities.					
I am effective at establishing a classroom climate whereby students feel confident to pose questions.					
I can pose open and closed questions to support the science activity.					
I am confident in responding to children's scientific questions.					
I am able to use a range of techniques to establish children's prior knowledge.					
I can use my subject knowledge to ask the right questions in order to move children's learning forward.					
I encourage children to pose questions that they can investigate.					
I am confident at planning for opportunities for classroom talk.					
I have a good understanding of science concepts required to teach primary school children.					

Pre action research

Post action research

Jack reported to being more confident at posing open and closed questions, using a range of techniques to establish children's knowledge and was more confident when asking questions and planning opportunities for talk. At the end of the research he reported that he was still unsure about how to best support children in posing their own questions that could be investigated (this aspect will be discussed in Section 4.5).

b) Structure of Jack's lessons

During Interview 1 (Stage 1) it was suggested to Jack that he could use a concept cartoon to support discussion and/or stimulate cognitive conflict by providing children with a problem to solve. Jack mentioned that he had been using concept cartoons on a regular basis to support talk (Interview 2). At the beginning of Lesson 2, Jack used a concept cartoon (Figure 4.3) to encourage children to consider which rock was 'best' to write with.

Figure 4.3: Rock concept cartoon

I think granite because it is hard.

I think chalk because it is the right colour.

Sandstone is the best because it is rough and won't slip.

The concept cartoon had been devised by Jack but did not generate a reasoned discussion on the part of the children – they already knew what the answer was, as overheard by the limited discussion that children had during 'talk time':

> Sinead: Chalk is best because I can write with it.
>
> Bradley: Chalk

When asked why he had used this particular concept cartoon Jack said that he thought that the concept cartoon would enable children to have a clear focus for their observations when comparing rocks. He continued to explain that the concept cartoon was used because he wanted to remind children of the properties of rocks and to make links to the problem that he was going to introduce later in the lesson. Therefore, Jack was ensuring that children had sufficient subject knowledge before they applied their learning to a new situation.

Jack planned 'talk-time' in his lesson and children were provided with opportunities to discuss how they would find out which rock would be suitable for the statue. The children suggested a number of different ways in which they could discover the best rock for the statue e.g. dropping rocks from the same height to see which breaks first, putting the rocks into beakers of water and observing which one appears to break down first or undertaking a scratch test to find out which rock is strongest. In Lesson 2 children provided well thought through reasons for their choice of investigation as shown in the following extract;

> Heidi: We could put the rocks in water. I think the chalk would go powdery and bits would come off. This will help you know how it interacts to rain. The one that basically reacts most to water won't be the best rock. We don't want puddles of white water on our playground!

The above extract was highlighted to Jack and although the maturity of children over the research period may have accounted for the reasoned thinking, Jack said that 'children are definitely thinking very carefully about concepts and how to plan an investigation' (Interview 3). The reasoning was in contrast to Lesson 1 (Table 4.5) where children struggled to identify how they could find out which was the strongest magnet.

Table 4.5: Interaction sequence of children's ability to plan for an investigation during Lesson 1

Transcript number	Name	Transcript
62	Teacher	Has anyone moved towards some ideas for an investigation?
63	Erin	Um, well, I'm not sure what you mean.
64	Teacher	Have you some ideas of how you might help to solve Roger's problem?
65	Erin	It's a bit tricky to explain.
66	Teacher	Can you demonstrate it?
67	Erin	Not really.

The use of the plenary was discussed with Jack because in both observed lessons children read their results from books. It was suggested to Jack after Lesson 1 (Stage 1) and again at the mid-point reflection point (Stage 2) that he could use the plenary to support children in posing comparison type questions. Jack only asked 'which rock is best?' but because all children had undertaken a scratch test they had the same result. The use of evaluative practice was not evident in the lesson. Had children been afforded the opportunity to test rocks in different ways, they may have produced different results which could have been compared.

c) Classroom talk

The questioning pattern was beginning to change as evidenced in Table 4.6. Instead of being IRE more children were responding to the initial question so the pattern was a move towards the IRRRE (Initiation-Response-Response-Response-Evaluation) questioning sequence.

Table 4.6: Questioning sequence in Lesson 2 showing a move from IRE

Transcript number	Name	Transcript
32	Teacher	You want to commemorate someone forever, what do you need to think about?
33	Sam	I think granite, because it is hard and it will stay there for a long time. I think chalk would be the worst because … well, usually if you put another piece of chalk next to it, it rubs and then it breaks apart.
34	Molly	I would say granite because it is hard and not good for the job. The worst would be chalk because it falls apart.
35	Alan	So does the sandstone…that is quite crumbly and might wear away quickly.
36	Teacher	Interesting, so you are concerned by the statue being worn down. What sort of things would wear the statue down?

It was suggested during Stage 1 that in order to move away from IRE, Jack could pose a question and then encourage another child to answer before giving feedback so that more children are involved and there is ‘cross-discussion’ (Lemke, 1990). From the above dialogue, it appeared that Jack was beginning to change his questioning approach. Although children were not yet engaging in cross-discussion, as the responses were independent of each other, the IRE questioning sequence was not as prominent. Jack posed an open-question (Line 32) and a number of children responded to his question before feedback or further questioning was used (Line 36). There were four occasions during the lesson whereby the children attempted to engage in cross-discussion. Another example is shown in Table 4.7.

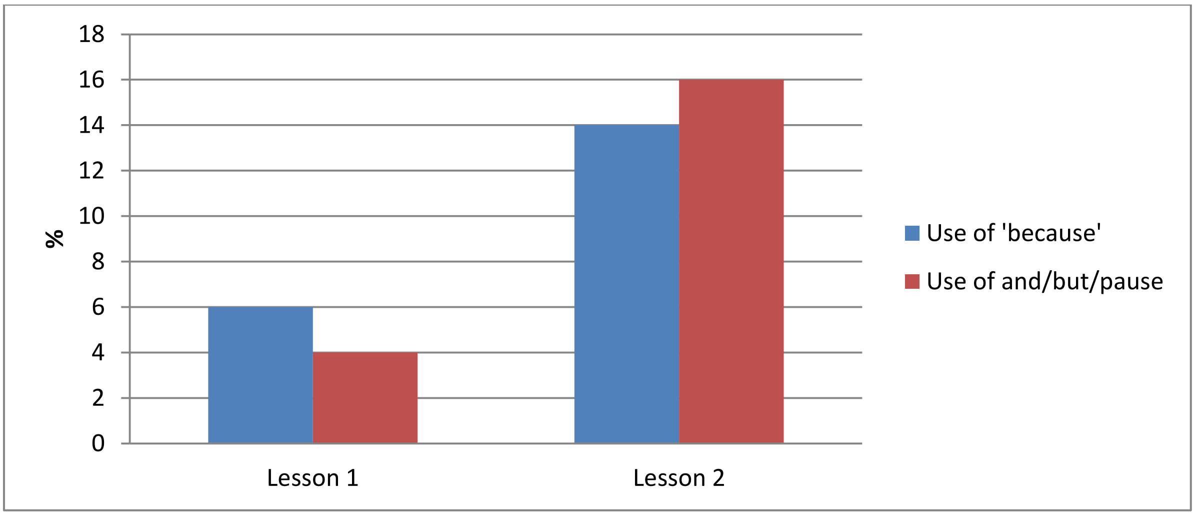
Table 4.7: Example of talk pattern in Lesson 2

Transcript Number	Name	Transcript
12	Teacher	Who can tell me how they know this rock is chalk? (Children then talked on table groups).
13	Bradley	I found it on the beach before and I just recognise it.
14	Tamsin	Um, on black paper you can see it. You can see what you are writing.
15	Vicky	It is the colour. Chalk is white. It is also crumbly.

On Line 13, Bradley was relating the science concept (identification of chalk) to his knowledge of everyday observations. Tamsin was adding information based upon her understanding and Vicky was able to develop the themes by adding her observations relating to the properties of chalk.

In Lesson 2, children also provided expansive answers rather than one word utterances. The children were using words such as ‘because’ or paused when thinking about their answers. A comparison of children’s responses in Lesson 1 and 2 are shown in Figure 4.4. The use of words such as ‘and’, ‘because’ and ‘but’ appeared more spontaneously in Lesson 2; the children did not need to be encouraged to say ‘because’ as it had become part of their answering approach as shown by their responses in the transcript (Line 33, Table 4.6).

Figure 4.4: The use of ‘because’, ‘and’, ‘but’ or pauses used by children during responses to questions in lessons 1 and 2



Analysis of the transcript of Lesson 2 identified that the use of because/and/but or a pause tended to follow questions that incorporated ‘why’ and ‘how’ questions which probe thinking and encourage analysis (Koufetta-Menicou and Scaife, 2000). In Lesson 1 there were more low cognitive demand questions that tended to involve the question stem ‘what’ or the phrase ‘who can tell me…?’ which resulted in very short answers. See section 4.5.1 for further discussion of children’s utterances in response to question types.

Children were also observed to challenge each other’s thinking (this was not evident during Lesson 1). When children were asked how they could identify sandstone Erin and Ashley were confident to challenge the thinking of others as evidenced in Table 4.8.

Table 4.8: Children challenging each other's thinking during Lesson 2

Number from Transcript	Name	Transcript
15	Teacher	How did you know it was sandstone?
16	Vicky	I didn't know at first, and then I noticed that sandstone is made of brick.
17	Erin	No, bricks are made of clay.
18	Ashley	No, you can see sand grains in some bricks so not all bricks are made from clay.

Jack commented that the use of a puppet had changed his teaching in that he now thought carefully about how he planned his lessons. He continued that 'using him [Ricky] in tandem with the concept cartoons was very productive as it gave the lesson a real focus' (Interview 2). To support this assertion Jack offered an example from a lesson that he had recently delivered whereby a concept cartoon had been used to discuss scientific ideas relating to materials (Appendix 18). On the lesson plan, Jack had considered how he would use Ricky to develop classroom talk. The children were required to discuss ideas presented in a concept cartoon and to explain to Ricky why he was wrong. In his reflective notes, Jack had written;

> Ricky had some ideas for uses of materials i.e. a chocolate teapot. The children explained why the characteristics of his material were unsuitable and made more appropriate suggestions (Jack, reflective notes, March, 2014).

Jack had also written that 'Ricky was effective at encouraging children to think very carefully and was good for challenging children's understanding, misconceptions and vocabulary'. When discussing this, Jack asserted that children had become much better at providing clear explanations and justifications for their ideas. Jack commented that the use of a puppet provided a 'tool to support children with their ability to reason and to use scientific language' (Interview 2*)*. He also reflected that the use of the puppet gave his lessons a real focus and purpose for children's explanations because the puppet had presented children with a problem that needed to be solved. He was surprised at how the children had accepted the puppet as a member of the class and that they were very responsive to his facial expressions. Indeed, research indicates that children often relate to another's difficulties and are keen to help modify confused concepts (Naylor and Keogh, 2000).

Jack reported that the format of his lessons now tended to involve a concept cartoon (as shown in Figure 4.5) followed by the children talking and explaining the science to Ricky. During an unobserved lesson children had considered that they need water and that plants do to. Children were then required to consider where the plant got its water from.

Figure 4.5: The concept carton used by Jack in a plants lesson (see Appendix 19)

This indicates that Jack was now thinking about how to use a concept cartoon alongside Ricky to encourage children to talk about their ideas, think about why Ricky might be confused and to use scientific language accurately. An example from Jack's planning file was provided as evidence for a change in Jack's planning approach which now incorporated a consideration of how he would provide opportunities for talk (see Appendix 19).

Indeed, Jack said that the use of a puppet helped children to elaborate on their thinking and that their thinking was better justified after children had been provided with the opportunity to discuss ideas in groups before sharing their ideas with the rest of the class. This links to the work of Vygotsky (1978) and the importance of establishing the social nature of the school environment for verbal interactions to occur. When Jack talked to the children about their learning in science, one of the children said;

> 'I am better at explaining science to Ricky…it makes me think a lot. You have to be really careful about what you say to Ricky. He sometimes doesn't know the science

words so you have to explain them to him. He says he doesn't understand and we have to help him' (Year 3 child, Stage 3).

During Interview 3 Jack said that he now had a better understanding of the impact of different question types and felt better prepared to plan for questioning during the lesson. Indeed, Pollard (2014) argues that teachers are most likely to change their practices if the ideas for change resonate with their experiences. Through action research, it could be argued that Jack was able to evaluate his questioning skills and had time to reflect upon his practice. Evidence suggests that Jack is now beginning to think strategically about how the puppet can be used to develop children's understanding.

4.4: Research Question 2 - Is there a change in the type of questions posed as a result of the collaborative action research?

This section will begin by summarising the key themes relating to Jack's questioning skills (Table 4.9) before discussing the types of questions posed during Stage 1 of the research. This will follow a comparison of questions asked in Lesson 1 and 2 in order to establish if the action research impacted upon Jack's questioning. Table 4.9 summarises Jack's questioning skills during Stage 1 and Stage 3 of the research.

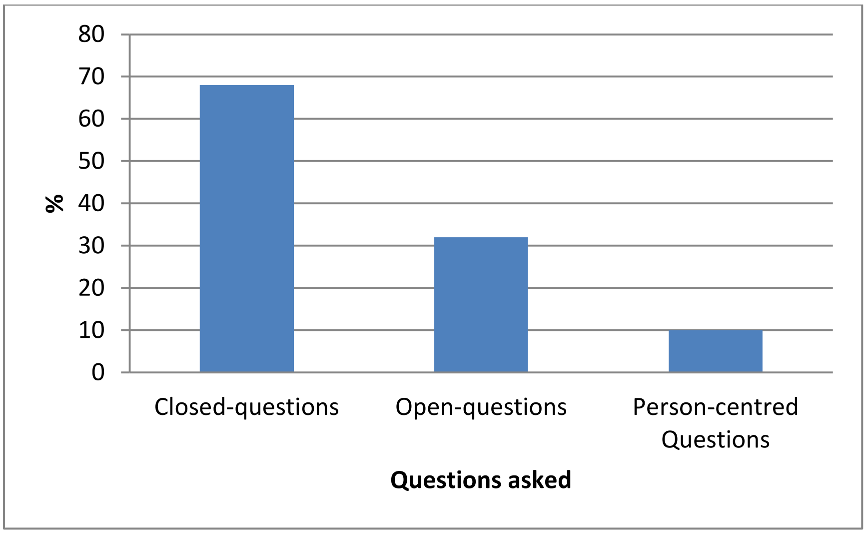
Table 4.9: Summary of Jack's questioning skills at Stage 1 and 3 of the research

Stage 1	**Stage 3**
• Jack was mainly posing closed-questions to elicit facts or to check that children were supported in undertaking investigations. • When Jack posed open-questions these were of low cognitive demand. • The questioning pattern was primarily in the IRE format.	• Jack used a wider range of questions during Lesson 2. • He asked more open-questions and children provided more reasoned and elaborate answers and used their observation skills to help them answer questions. • He was not, however, using the plenary to support children in providing reasoned arguments.

4.4.1 - Stage 1: Jack's questioning skills at the beginning of the research

Evidence for Jack's questioning skills was provided by transcripts of Lesson 1 and data from Interview 1 (Stage 1). Questions from Lesson 1 were coded with the teacher using a coding scheme (Appendix 5). Figure 4.6 identifies the percentage of open, and person-centred questions asked by Jack during his lesson.

Figure 4.6: Closed, open and person centred questions posed during Lesson 1



The majority of Jack's questions posed during Lesson 1 were closed-response questions (68%). Table 4.10 shows the percentage of the types of closed-questions that Jack asked during Lesson 1.

Table 4.10: Closed-question types posed by Jack during lesson 1

Closed question types	**Percentage**
Information seeking questions	34%
Classroom organisation questions	30%
Productive questions	36%

Jack asked information seeking such as 'which metals are magnetic?' and classroom organisation questions (What are you going to use to measure the distance?) at the beginning of the lesson and productive questions lessons later in the lesson. The classroom organisation questions were used in order to ensure that children were supported with their investigation. Although 36% of the closed-response questions were coded as being productive they were not asked while children were engaged in the actual investigation and did not require them to use higher ordered thinking skills as advocated by Elstgeest (1985) to find answers to their questions. Instead, the productive questions such as 'how will you measure?' were asked to support children with the investigation.

Jack argued that children were not accustomed to planning their own investigations and productive questions such as ‘is that going to give you a measure?’ Or ‘what do you need to do now?’ helped to develop process skills.

In addition to asking closed questions, 10% of the questions were also coded as person-centred questions and Jack said that he used the word ‘you’ in order to encourage more children to ‘have a go at answering his questions’ (Interview 1).

Thirty two percent of the questions posed during Lesson 1 were open-questions but these tended to be low cognitive demand questions such as ‘what did we do last week’. There were few ‘why’ or ‘how’ questions asked that required children to explain and justify their reasoning. Indeed, only 5% of the open-ended questions were defining questions such as ‘you think the bendy magnet was best because…?’ or ‘can you tell me more?’ were posed with the aim of encouraging children to provide more detailed answers. Jack was not surprised that most of his questions were closed or of low cognitive demand because he had not really given much thought to the types of questions that he was asking. He recognised that he needed to know more about question types so that he could model these to his class.

When Jack studied the transcript, he noticed that children provided short answers and referred to the following section of the lesson transcript in Table 4.11 to exemplify his thinking:

Table 4.11: Interaction sequence to explore a child's observations of real life science during Lesson 1

Number from transcript	Name	Transcript	Question type
21	Bradley	I saw a big crane with a magnet once and I saw a can fly up.	
22	Teacher	Why do you think it flew up?	Open
23	Bradley	It's magnetic.	
24	Teacher	Did all the cans fly up?	Closed
25	Bradley	Um, some of them.	
26	Teacher	What about the other ones?	Closed
27	Bradley	Um, they stayed on the ground.	
28	Teacher	How interesting! Now I wonder why that happened…	Not a question but 'open' in terms of the response that could be provided
29	Bradley	Because the magnet is big.	

From the dialogue presented in Table 4.11, Bradley was only able to provide simple answers. The reason for this could have been that Bradley did not have secure subject knowledge or due to the questioning pattern used by Jack which was IRE whereby Jack raised mainly closed-questions. Jack reported that his questions to Bradley were designed to elicit a particular response from him (that some metals are magnetic). The dialogue was only between Jack and Bradley and Jack was aware that other children appeared to lose interest during the discussion. It was, therefore, suggested during Interview 1 that Jack could have encouraged the rest of the class to respond to his question on Line 28 of the transcript.

When the transcript of the children's utterances from Lesson 1 were analysed during Interview 1, it was noticed that the average length of a child's answer was very short (comprised of only seven words). If closed-questions were asked, the average length of response was only three words. Jack and I, therefore, discussed the importance of encouraging children to use words such as 'because' or 'so' after they have given an answer so that they had to justify their thinking. We agreed that in order to achieve this effectively then the pace of the lesson may need to slow down; as advocated by Budd-Rowe (1986) who asserts that children need at least three seconds thinking time between asking a question and giving the child time to respond if the responses are to be more reasoned.

It was agreed that in order to develop children's ability to ask productive questions that could be investigated through scientific enquiry, there would need to be a concerted effort to teach children the skill of observation. This was identified because children, during the focus group task, only looked superficially and needed support in undertaking close observation. During the focus group task, children had to be asked questions in order to scaffold their observational skills as shown in Table 4.12

Table 4.12: Development of observation skills

Name	**Transcript**
Researcher	Right, what do you notice then, what is happening?
Katie	So when you have the bottle upright [modelled to show what upright means] do both the sauces [mayonnaise and tomato] go down and back up?
Researcher	What do you think will happen when we squeeze the bottle?

The process skill of observation is recognised in the literature as being important because it is from observations that children can sort, group, classify and may display curiosity and subsequent questions (Johnston, 2009; Monteira and Jimenez, 2015). In Table 4.12, children were being directed to look carefully at the Cartesian Diver in order to support them in raising subsequent questions.

4.4.2 Stage 2 – Reflection on questioning skills at the mid-way point in the action research cycle

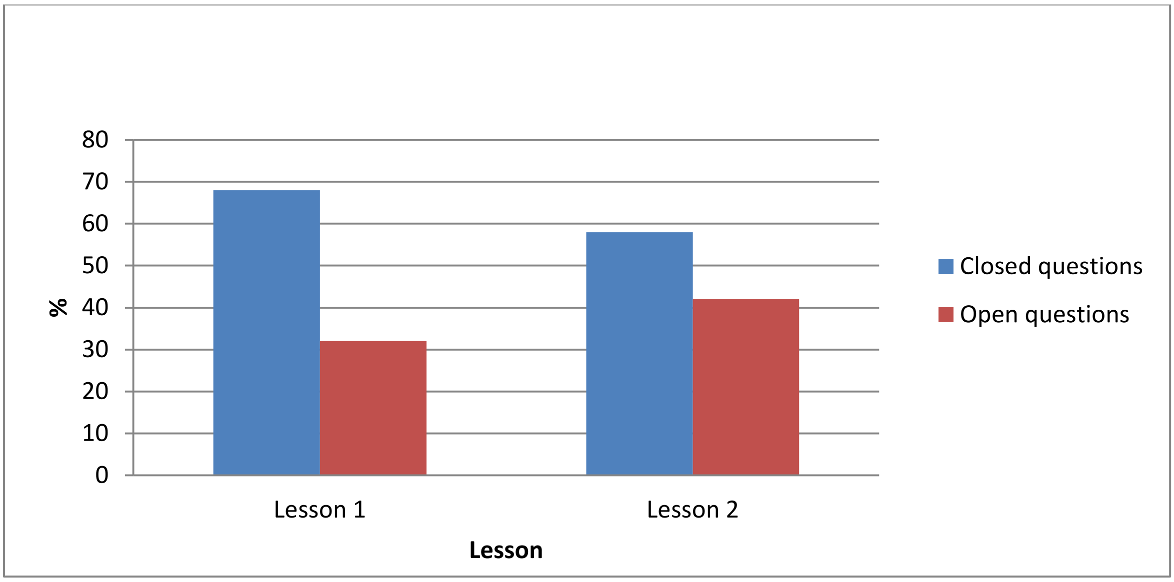
The main issue discussed was how well the puppet was being used to develop Jack and his classes' questioning skills. When asked if the puppet had changed his questioning practices, Jack reported that it allowed him to 'challenge thinking and made him think about the questions he asked but was not yet making a difference to children's questioning skills' (Interview 2). Jack conceded that his questioning was beginning to change and that he was starting to give children longer to answer. As he had identified that children were not yet raising their own questions, we discussed the importance of modelling different questions to children to make them aware of the functions of questions.

For the next cycle of the research, Jack decided that he would aim to develop children's questioning skills during the plenary of the lesson. This was considered as a target area because the plenary in Lesson 1 had many opportunities for children to ask each other questions about the results gathered and to make comparisons; it was felt that this may be a successful approach in encouraging children to begin to ask questions and Jack was directed to the comparison question stems on the coding sheet.

<u>4.4.3 - Stage 3: Evaluation of Jack's questioning skills</u>

After observing Lesson 2, the questions were coded with Jack and a summary transcript of questions posed was generated so that comparisons between Lessons 1 and 2 could be made (Appendix 17). Initially all questions were coded as either open or closed and the findings are shown on Figure 4.7

Figure 4.7: Percentage of open and closed questions posed during Lessons 1 and 2



When analysing the question types (Figure 4.7), it was noted that Jack was asking fewer closed response questions that required children to simply recall information. There appeared to be an increase in 'student talk' and even when children were being asked closed-questions; their answers tended to be expansive with children applying their skills of observation to support them in giving more detailed answers. The length of children's utterances had become more elaborated and on average, were now twenty three words (compared to only seven in Lesson 1). The following extract shows how children were using their observation skills to help them provide more detailed answers:

> Teacher: Have you ever seen an example of where rocks have been worn down by rain? (Transcript Number 40)
>
> Jade: Well, once when I was out in the rain and was under the umbrella, I saw chalk in the rain and it kind of had drips going down it. The drips were kind of white because all of the powder of the chalk had come off (Transcript Number 41).

It was also noted that Jack was asking more open-ended questions during Lesson 2 (42% of the questions compared to 32% in Lesson 1). There were more 'how' questions posed during Lesson 2 (18%) compared to Lesson 1 (1%). For example, in Lesson 2 children were asked 'how do you know which rock is granite?' or 'how do you know which rock is best to build a statue?' Posing 'how' questions encourages children to develop their reasoning skills and thinking skills. 'How' questions are also open-ended, so children are more likely to respond as there is less jeopardy on the part of the learner of being wrong (Elstgeest, 1985). This links to the work of Harlen and Qualter (2014) who argue that open-ended questions create an atmosphere whereby children feel confident to share their thoughts and opinions because the questions are not reliant on simply exploring facts. Jack also asked a wider range of question types during Lesson 2 (see Figure 4.8).

Figure 4.8: Questions asked by Jack during Lessons 1 and 2

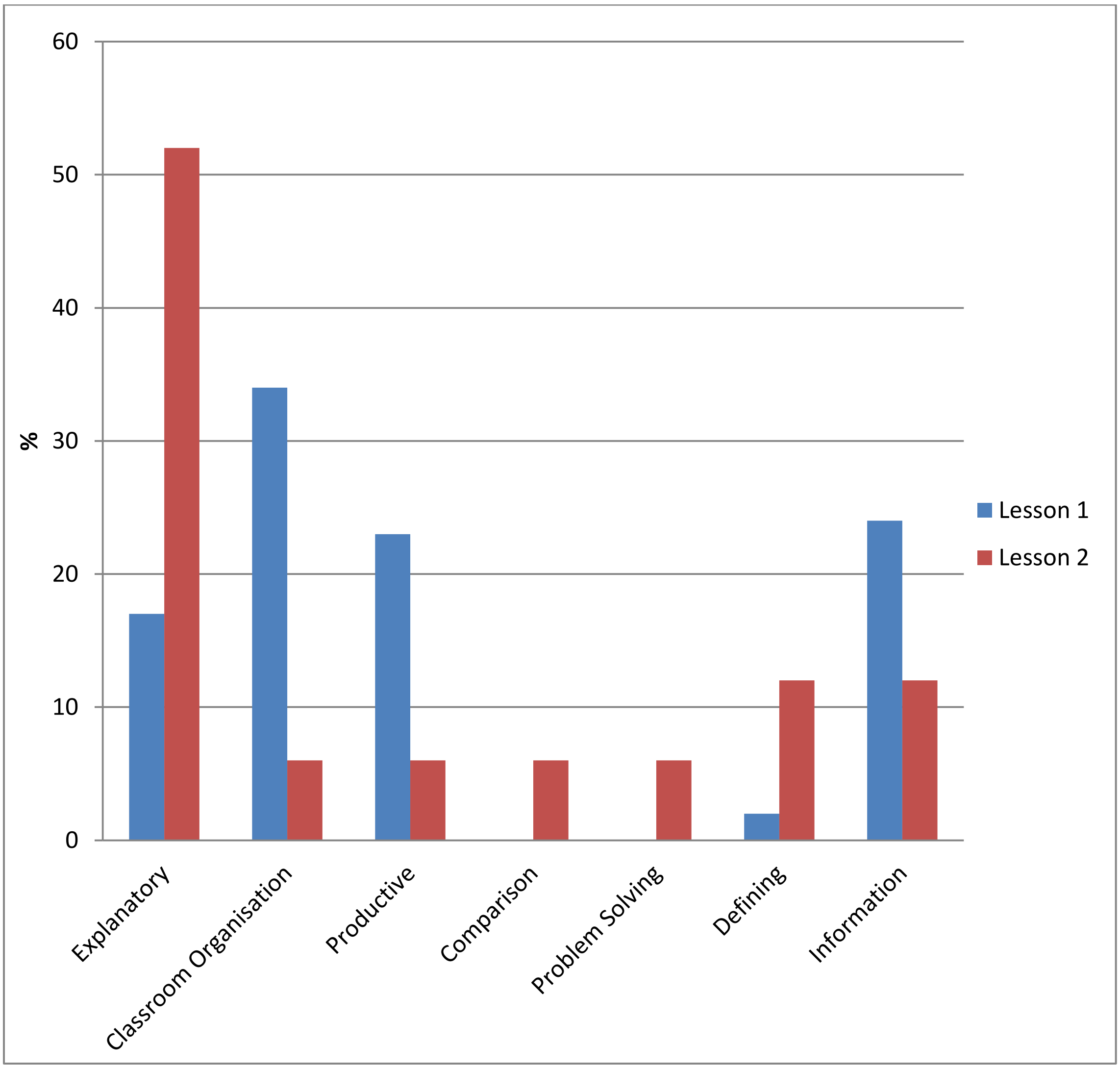


Figure 4.8 shows that Jack posed fewer classroom organisation questions in Lesson 2 as he did not need to ask questions to check that the children understood how to undertake the investigation. Alternatively, it could be assumed that they had a year to learn how to work during science lessons so required less scaffolding to plan investigations. In Lesson 1, there was a high proportion of classroom organisation questions linked to how to compete worksheet and a number of questions about to how to measure correctly. Jack used the full range of questions in Lesson 2 which included problem solving and comparison questions. Table 4.13 shows an example for each of the different types of questions that Jack posed during lessons 1 and 2. In Lesson 2 he was asking more explanatory questions and fewer information seeking questions that relied upon recall of facts.

Table 4.13: Questions posed by Jack during lessons 1 and 2

Question type	**Frequency (%) and examples of question types in each lesson**	
	Lesson 1	Lesson 2
Productive	23% Can you demonstrate the methods used?	6% Can you find a way to test the rocks?
Comparison	--	6% Why is the granite better than the chalk?
Problem Solving	--	6% Chalk is soft. Will it make a good statue? How can we investigate this?
Information seeking	25% Is brass magnetic?	12% What sort of things wear rocks down?
Explanatory	18% When I see Roger what shall I tell him?	52% Why do you think the surface looks different?
Classroom management	32% Who has got the method done?	6% How did we get on?
Defining	2% What do you mean?	12% Why do you think that? Tell me more.

Jack commented that he asked problem solving questions because he wanted the children to think about how they could find out which rock was the 'best' for the statue. The word 'best' was used for one of the questions because Jack hoped that this would result in children providing different approaches to investigate the question (e.g. the strongest rock, the easiest rock to carve accurately, the least permeable etc.) and thus engage the class in evaluative thinking. However, he required all children to perform a scratch test during the lesson.

It is pertinent to note that children were using their skills of observation from a scratch test in order to answer Jack's comparison question in Lesson 2 (why is granite better than chalk?) because they looked carefully at the rocks before responding with; 'The chalk has got a bit missing, like a scratch line... that is because that bit of the chalk is on the granite'. The development of observational skills was an area for development for Jack (as noted in Section 4.5.2) when he mentioned that he tried to plan time in lessons for children to develop this skill.

The plenary of the lesson had not changed in format when compared to Lesson 1; children were still reading their results from sheets and were not asking questions of each other. In order to encourage children to ask comparison questions, Jack could have modelled asking questions to each group. However, because all the children were conducting the scratch test it was unlikely that there would have been a great deal of variation between the results collected. Although children were reading from their books when sharing their findings, Jack provided children with time to look at the data and to consider a response. Lewis (2012) argues that if given time, children will be better positioned to provide a reasoned response. This is important as children collect a range of information during investigative work and need time to process the findings.

Jack mentioned that he had tried to slow the pace of the lesson so that there was more 'wait-time' between the posing of the question and the time given for the children to answer during Lesson 2. Jack reported that by doing this the children had time to think and often provided more 'thoughtful answers'. In addition to slowing the pace of the lesson, Jack tried not to give the children feedback too soon and paused after a child had answered a question before responding to them. This sometimes resulted in a child continuing with their response as exemplified in the following response:

> Teacher: Which rock will make the 'best' material for the statue? (Transcript Number 33)
>
> Vicky: I think it is granite because it is hard and it will stay there for a long time. (Pause) I think the chalk would be the worst because (pause) well, usually if you put another piece of chalk next to it, it rubs and then it breaks apart (Transcript Number 34).

In the above discussion there were two occasions (pause points) whereby the child paused and where the teacher could have asked a question. However, had Jack responded or interjected then the child may not have provided such an expansive answer. Jack commented that previously he would have asked a question as shown in

Table 4.14. On Line 135 Jack asked another question in quick succession (Line 137) when the child provided a one word answer. Jack conceded that had he paused and waited when the child said ‘yes’ the child may have provided a more expansive answer.

Table 4.14: Quick succession questioning in Lesson 1

Transcript number	Name	Transcript
135	Teacher	What if one test was done on the table and the other on the carpet, would that be fair?
136	Molly	Yes.
137	Teacher	Is it the same – would you be able to skate faster on the table or the carpet? (Jack then provided an explanation instead of asking a child to respond).

The reflections indicate that pausing and increasing the wait time impacts upon the quality of the responses provided. Evidence indicates that increasing wait time also increases the length of the pupil utterances (Budd-Rowe, 1986; Lewis, 1992).

4.5 Research Question 3 - How does the use of a puppet support children in asking and answering their own questions?

4.5.1 Stage 1 – children’s questioning skills at the beginning of the action research process

To provide a baseline measurement of children’s questioning skills, a focus group task was utilised (see section 3.5.2 of the Methodology and Appendix 14 for the focus group transcript). During the focus group, children were presented with a Cartesian Diver artefact and given time to explore how it worked. The Year 3 children did not need to be encouraged to use the Cartesian Diver in an interactive way (they shook the bottles and tipped them upside down) however, none of them thought about applying pressure to the sides of the bottle. Therefore, after a while, the children were asked to squeeze the bottle to see if anything happened. They appeared curious at what had occurred and one child was heard saying ‘*Wow, it is magic*’. The children were then encouraged to look closely at the artefact and were asked a number of attention seeking questions (as discussed during the literature review, Figure 1.2) in order to develop their observational skills further. They were asked questions such as ‘what did you see happening?’ ‘which sauce went down the fastest?’ After this scaffolding, children began to guess which sauce would go down the fastest when the bottle was squeezed. Children were then asked to think of questions that they would like to know the answers to in relation to their observations of the Cartesian diver. In total, six questions were posed by the children. The questions were analysed using a coding scheme (Appendix 1).

Two of the six questions generated by the children were a repetition of the attention seeking questions that I had asked (which one went down the fastest? and which sachet floats?) and could be answered by simply observing the sachets. The other four questions posed by children are presented below and were ‘why’ questions, indicating that questioning was going beyond the generation of simple factual questions (questions that result in recall of facts) in that they were requiring information and/or explanations.

> Tom: Why does the brown sauce go down?
>
> Harry: Why does the ketchup go down?
>
> Erin: Why does it shoot back up again?
>
> Katie: Why do they dance?

None of the children posed productive or wonderment questions that entailed an ‘action’ in the form of an enquiry as defined by Chin *et al.* (2002) and Scardamalia and Bereiter, (1992) (see Figure 2.3 of the literature review). For example, the questions did not require children to undertake any measurements or to manipulate variables and observe the outcome; this may have been achieved had children posed wonderment questions such as ‘I wonder what would happen if you used different liquids in the bottle?’

When the transcript of the focus group activity was shared with Jack during Interview 1, the following dialogue ensued.

> Jack: I am not surprised by the types of questions that the children were asking.
>
> Researcher: Why?
>
> Jack: Children are more familiar with answering questions rather than asking them.

The comments made by Jack indicate that children do not ask questions because they view questions as something that the teacher does. During Interview 1 Jack reported that he was not confident at planning opportunities for children to talk or to pose their own investigations (see Figure 4.1) therefore, the structuring of lessons may result in limited opportunities for children to investigate their own questions.

4.5.2 Stage 2 - Reflections on children's ability to question

Jack had written reflective notes to support him with his thinking during Interview 2. Jack asserted that children were not asking questions during whole class inputs. In his reflective notes he had identified that Ricky was 'very good for developing children's understanding, challenging misconceptions and extending their vocabulary but the puppet was not helping children to ask questions'. He had posed the question in his notes; 'How can I use him more to support children's learning?' and had thought about actions he could employ such as leaving the puppet on the table for children to engage with. He noted that children were talking to the puppet but were not using the puppet to ask questions. It was suggested that maybe the puppet could be used to model comparison questions and then children could be encouraged to use the puppet to ask groups about their findings from investigations.

4.5.3 Stage 3 – Evaluation of children's questioning skills

Jack asserted that Lesson 2 was not 'the best of lessons' in relation to developing children's questioning skills. During Lesson 1, there was only one question posed by a child and this was linked to a classroom management issue (see Table 4.15). In Lesson 2, children were heard to ask a wider range of questions including philosophical and exploratory questions. The exploratory questions were based on what they had been observing during the lesson. This indicates that in order to support children in raising questions there is value in planning opportunities for children to observe artefacts (in Lesson 2 this linked to rocks). The questions posed by children are shown in Table 4.15.

Table 4.15: Comparison of questions asked by children during Lessons 1 and 2

Question types	Examples	
	Lesson 1	Lesson 2
Classroom management	Can we go around the room?	Can you see the small grains of sand?
Philosophical question	--	I wonder if you can dye sandstone?
Exploratory questions	--	How does this rock feel Ricky? Have you seen the broken paving stone? Oh look, he can scratch the chalk with his fingers, can you see?

Although children were asking a wider range of questions during Lesson 2, Jack maintained that in other science lessons, children were capable of asking simple questions that they were subsequently able to investigate. When discussing why this was the case, we agreed that there are certain types of investigations, such as fair testing, whereby it is easier for children to ask and answer their own questions using enquiry. Jack provided an example of a lesson plan that he had taught relating to plants (see Appendix 19). He self-reported that the class had asked a number of problem solving questions that they wanted to explore about what a plant needs in order to be healthy and the children were then required to set up an investigation. Jack talked about the types of questions that the children had asked such as;

> What would happen if you put the plant into orange juice?
>
> Could we use coloured water?
>
> What about using fizzy drinks?

White and Gunstone (1992) maintain that when children pose 'what if…?' type questions then deeper thinking ensues. The open-ended approach adopted during the plants lesson appeared to engage the children in their learning according to Jack and they were keen to find out the answers to their questions. The opportunity for children to pose open-ended, productive questions links to the literature in that when children are able to pose their own questions, this focuses their attention and plays a significant role in meaningful learning and the motivation to engage in the lesson (Chin, 2002).

4.6: Jack's reflections and development over the duration of the research

Jack's reflections in relation to his questioning skills are referenced throughout the chapter but Table 4.16 highlights how the use of a puppet (along with the concept cartoon) changed his questioning over the duration of the research. The table shows that Jack moved from using closed-questions during Stage 1, through to considering how he would plan his questioning sequences to enable children to provide more elaborated answers during Stage 3.

Table 4.16: Jack's reflection on his practice over the duration of the research process

Stage 1	**Stage 2**	**Stage 3**
Jack commented that he was not aware of the range of question types or how to use productive questions to support children's learning. He commented that he 'had not really considered questions before' (Interview 1) When coding questions from Lesson 1 Jack identified that he was using mainly closed-response questions that resulted in children providing short answers.	During Interview 2, Jack reported that the use of a puppet made him 'think about the different questions that were being asked during lessons and that the puppet was 'effective at encouraging children to think very carefully and was good for challenging children's understanding, misconceptions.' He continued to report that 'the puppet was good because it moved away from the idea that the teacher asks the questions.' Jack was cognisant that the puppet was not yet supporting children to ask their own questions when he reported that the puppet had 'not made a difference to children's question yet' (Interview 2)	When coding the questions from lesson 2 Jack noted that he had asked a wider range of questions and reported that 'using the puppet in tandem with the concept cartoons provided a focus to the lesson' (Interview 3) Due to asking more open-ended questions, children were able to provide more reasoned answers. Jack reflected that 'by slowing the pace, children have longer to think about their answers…they have more thinking time and the answers are longer' (Interview 3) He reported that during Lesson 2 children did not ask questions but reflected that they were able to achieve this when undertaking fair testing. He referred to his planning to explain how the puppet had been used to support children's questioning skills (Interview 3).

4.7: Key themes

Table 4.17: Summary of the impact of collaborative action research on Jack

Indicators of clear impact or consolidation of skills	Indicators of developing skills	Challenges/skills not addressed or no visible impact
Jack is asking more open-ended questions that require children to explain and reason. Children are providing more expansive answers as a result.	Jack is beginning to change his planning so that there are more opportunities for talk. Jack has shown that he considers how he will use the puppet (along with a concept cartoon) to stimulate children's thinking. Jack maintained that the pace of the lesson was beginning to slow so that children had more wait-time to formulate their answers. The questioning pattern was beginning to incorporate cumulative talk.	The plenary and general structure of the lesson has remained the same. Jack begins and ends his lessons with a number of closed-questions to assess children's understanding. He does not use the plenary of the lesson to encourage children to compare their findings. In general, children are still required to perform the same investigation. In the observed lessons children were not yet posing productive questions, however, Jack reported that they were able to achieve this when engaging in lessons where they were required to manipulate variables.

Column 1 of Table 4.17 summaries the impact of the research for Jack. Evidence of change in Jack's teaching was his ability to ask a wider range of questions which included comparison and problem-solving questions (see Figure 4.8). This was in contrast to Lesson 1 when Jack asked a high proportion of classroom organisation and information questions. During Lesson 2 Jack was observed to ask 'how' and 'why' more readily when using a puppet as evidenced in section 4.4.3. Posing 'how' and 'why' questions often challenges teachers and according to Martin and Hand (2009) only 1% of teachers used these question stems after 18 months of professional development. Jack changed his questioning over 2 academic terms and associated this change with the use of a puppet alongside a concept cartoon.

Jack developed his planning approach over the duration of the research. The use of a puppet and concept cartoon helped Jack to problematise the science, for example, asking children to find the 'best rock' for a statue (Lesson 2) as well as developing their skills of working scientifically. This was evidenced in lesson plans that Jack submitted as part of his reflections. During a materials lesson, Jack strategically used the puppet to sort materials in a naïve way so that children were able to challenge the way in which Ricky had sorted the materials. He reported that the use of the puppet helped him to ask 'why' more readily and changed how children responded to questions. Jack reported that the use of a puppet with a concept cartoon supported children's ability to justify and reason. This was exemplified by the increase in the use of 'because', 'so' and pauses provided by the children when they were answering questions during Lesson 2. Indeed, Harlen and Quarter (2014) argue that if open-ended questions are asked this changes the dynamics of the classroom to support children to share their thoughts.

Jack felt that the use of a puppet had changed the power dynamics of the classroom and that children were more willing to answer questions if the puppet had posed a question and/or problem. Research undertaken by Low and Matthew (2000) established that children respond well to others who are experiencing difficulties. The action research process developed Jack's practice because he was taught that different questions serve different functions and enabled him to plan his questioning in a more strategic manner. For example, when using a puppet (and concept cartoon) Jack had to plan questions that Ricky would ask the children in order to extend children's conceptual understanding. Jack also reflected that there was more 'wait-time' and that this provided children with thinking time so that their answers were more elaborated. Jack was beginning to move away from the IRE format and was beginning to move towards IRRRE in order to include more children in questioning sequences.

At the end of the research cycle, Jack had recognised how important it was to develop children's observational skills so that they could formulate questions. He also identified the value of using a puppet to support children's questioning skills during the plenary of lessons but this was yet to be integrated into his teaching.

4.7: Summary of the research cycle for Jack

During Interview 1, Stage 1, Jack mentioned that he was unsure of different question types so time was spent discussing the question typologies and Jack was provided with the coding scheme to help him when planning lessons. He was also aware that he needed to further develop his subject teaching approach to support children in raising their own questions. He had used concept cartoons and puppets previously and indeed used a puppet during Lesson 1 but he was unsure of how to problematise the science so that children engaged in meaningful talk. Therefore, the action research cycle began by focusing on how to use a puppet to generate higher-ordered thinking.

At Stage 2, Jack actively engaged in the process of self-reflection and routinely wrote notes and questions on his plans about how the puppet was being used; these were used to inform discussions about how to improve his teaching which, according to Loughran (2002), enhances meaning making from the lessons. A key issue for Jack at Stage 2 was that although children were developing their vocabulary and reasoning when 'Ricky' asked a question, they were not yet asking their own questions (Interview 1). Therefore, it was suggested that he formulate a problem so that discussion and questioning skills were fostered. He identified that it was difficult to achieve this so it was suggested that he use a concept cartoon to scaffold him in problematizing the science concepts via Ricky. In this instance it was possible to model how a puppet can serve as a scaffold to encourage Jack to conceptualise a problem in order to encourage talk (see Appendix 13).

In Stage 3 Jack was able to use a puppet, along with the concept cartoon to strategically consider the structure of his lessons and the questions that he asked (see section 4.5). Jack reported, via the closed response questionnaire, that he was more confident to ask 'the right question at the right time' and to 'plan for opportunities for talk'. He was also observed to ask a wider range of questions but was not using the plenary to ask a range of questions; instead relying upon closed response questions. Children did not pose their own questions during Lesson 2 but Jack discussed a lesson relating to plants and fair testing (Appendix 19) whereby children were observed to ask their own questions (Interview 3).

Chapter 5

Case Study 2

Rob and his Year 6 class: using of Thinking Cubes to develop questioning skills

5.1: Introduction

This chapter aims to provide a description and analysis of the questioning skills adopted during Rob's science lessons. The analysis answers three research questions which are firstly, to establish how Rob's questioning practices changed as a result of collaborative action research, secondly, to evaluate if collaborative action research impacts upon types of questions posed and finally, to explore how the use of Thinking Cubes influenced children's ability to ask questions during science lessons.

In order to provide the evidence to establish if collaborative action research contributed to a change in teaching approaches and questioning skills, this chapter will begin by presenting a brief biography about Rob and his class followed by a flow chart (Figure 5.1) detailing the stages of the action research process. The chapter will then compare Lessons 1 and 2 to search for changes in teaching strategies and questioning.

5.2: Rob and his class

Rob became a primary school teacher in 2011 after completing a Graduate Teaching Programme; his first degree was in Sports Coaching Science. He has taught a Year 6 class (children aged between 10 and 11 years) for the past two years. Rob's class consisted of 30 children. In his class there were thirteen boys and seventeen girls from a mainly white ethnic background. Science lessons were planned for on a weekly basis but as the class were preparing for end of year testing, science lessons were often revision sessions and short in duration (thirty minutes), designed to reinforce science subject knowledge. The red text relates to the researcher input and data collection points. The green text shows the teacher actions.

Figure 5.1: The action research cycle for Rob

Stage 1

Setting up the study (January, 2014)

1. A focus groups task was undertaken with children from Rob's class to identify the types of questions that they posed. (Appendix 20).

2. Lesson 1 was videoed to establish Rob's questioning skills and teaching strategies.

3. Rob coded the types of questions that were asked during the lesson using a coding system (Appendix 21).

4. Interview 1 followed to dicusss teaching strategy and questioning skills (Appendix 22).

At this point training was provided with regards to question types and how they link to different investigations.

Stage 2

There was a discussion of how effective the Thinking Cubes were at supporting children's questioning skills during Interview 2.

(End of March , 2014)

1. Rob used lesson plans to discuss and reflect upon how the children had responded to the Thinking Cubes.

2. Rob then considered the next steps for him in terms of how he used the Thinking Cubes to support children with their questioning skills.

Stage 3

An evaluation of how well the Thinking Cubes support children's questioning skills took place during Interview 3 (June, 2014)

1. Lesson 2 was videoed and Rob used the coding system to identify and compare the types of questions asked during the lesson (Appendix 23)

2. Rob reflected upon how well the Thinking Cubes supported children in asking questions.

3. Finally, Rob reflected upon the implications of the reserach.

5.3: How do primary school teachers' questioning practices change as a result of collaborative action research?

During the research process Rob's teaching strategies were identified. Table 5.1 summarises the key themes that emerged. The red annotations show Rob's views and teaching strategies at the beginning of the research process. The green script relates to Stage 3 and how the action research impacted upon teaching approaches.

Table 5.1: Summary of Rob's practices over the duration of the research cycle

Theme	Main point
a) Rob's views of science	Science should be about discovery and children finding out about science by answering their own questions.
b) Structure of Rob's lesson	Lessons began and ended with a number of closed or low cognitive demand open-questions so that Rob was able to ensure that children understood the science concepts being covered. Rob understood the value of observation as a precursor to questioning skills. Instead of using artefacts, he used pictures to ensure that children were being taught how to observe carefully. The structure of the lesson remained the same – Rob began and ended the lesson with information questions. Rob planned time for children to generate questions using the Thinking Dice. However, the questions generated by children tended to be at the lower cognitive demand and were generally information questions.
c) Challenges relating to teaching approaches	There were limited opportunities for children to ask and answer their own questions because Rob was helping children to prepare for end of year testing. He reported that he was unsure of how to promote talk activities so he tended to orchestrate the classroom talk with IRE questioning patterns. Although there were no observed changes to Rob's teaching approach, he said that he now has an understanding of the different question types and was beginning to consider these when planning science lessons. He reported that he is aware of how observations support children in raising their own questions and suggested ways of valuing these by using a question wall.

5.3.1 Stage 1: Strategies adopted by Rob at the beginning of the research cycle

a) Rob's views of science

During Stage 1 Rob was asked to respond to a number of questions relating to his attitude towards teaching science. Table 5.2 shows how Rob responded.

Table 5.2: Rob's perceptions of his questioning skills and pedagogy

Aspect	Agree strongly	Agree	Unsure	Disagree	Disagree strongly
I can engage children in hands on science activities.					
I am effective at establishing a classroom climate whereby students feel confident to pose questions.					
I can pose open and closed questions to support the science activity.					
I am confident in responding to children's scientific questions.					
I am able to use a range of techniques to establish children's prior knowledge.					
I can use my subject knowledge to ask the right questions in order to move children's learning forward.					
I encourage children to pose questions that they can investigate.					
I am confident at planning for opportunities for classroom talk.					
I have a good understanding of science concepts required to teach primary school children.					

The self-reported responses in Table 5.2 identified that Rob 'agreed' that he was good at supporting children with 'hands-on' learning opportunities. When this was discussed during Interview 1 (Stage 1), Rob said that children should 'have the chance to set up their own experiments to answer their questions'. He continued to argue that children should undertake lots of investigations and be encouraged to:

> …discover things first hand...to do lots of investigations because they pose the best opportunity for children to be physically active rather than being passive learners whereby they just forget the lesson. I want them to understand the facts but also ask questions…so instead of me telling them the answers, they find out for themselves (Rob, Interview 1).

It would appear from the quote that Rob values discovery learning as a way of working by ensuring that learners are being physically active and 'doing science' but he did not mention the value of supporting children to think critically about science concepts by engaging in talk and argumentation or discussion. This may have been because he reported that he was unsure of how to plan for opportunities for classroom talk (Table 5.2).

b) Rob's reflections on the structure of his lessons

In Lesson 1, Rob was teaching children about how animals are adapted to live in different habitats. During Lesson 1 children were required to use computers to research how different animals are adapted to live in different habitats such as grasslands, deserts and rainforests. The lesson began with a series of closed-questions that required children to demonstrate their understanding of concepts and asked questions such as: what do we call them? what do we call an area where animals are found? When open-ended questions were posed during the introduction of the lesson, these were at the lower cognitive demand (what have we looked at so far this term? why did we go outside?) and required children appeared confident to answer because there was no one correct answer. The pattern of closed-questioning was repeated in the plenary as shown in Table 5.3

Table 5.3: Questioning pattern during the plenary of Rob's Lesson (1)

Transcript number	**Name**	**Transcript**
103	Teacher	Choose an animal and give me an adaptation. How has it changed?
104	Amy	Camel. It can close the nostrils to stop sand going up.
105	Eddie	I wrote about a leopard. It is nocturnal to help it.
106	Teacher	What does nocturnal mean? What part of the day are they awake?
107	Eddie	Night time.
108	Teacher	Excellent. Other adaptations?
109	Emma	A polar bear had hairy feet to walk on ice.

From the transcript in Table 5.3, it could be surmised that the format of the lessons was quite tightly controlled by Rob. Rob controlled the discussion and closed-down the discussion when he felt that children had provided the 'correct answer'. The above transcript provides evidence of an authoritative teacher-question sequence because children were provided with limited opportunities to demonstrate their depth of knowledge; the sequence began with a teacher initiated question that required a specific response from the children. On line 105 when Eddie said that being nocturnal would help a leopard instead of asking 'why' Rob focused on the technical language (what does nocturnal mean). It was proposed to Rob during Interview 1 that it would be useful for him to ask 'why' to encourage deeper thinking.

In Lesson 1 Rob aimed to foster children's observational skills by showing them a picture of a tree snake and a harlequin frog. He encouraged the children to look closely at the pictures. During Interview 1, Rob reported that he would often think out loud and would try to model the skill of observation to the children so that they would develop this skill, as exemplified in Table 5.4

Table 5.4: Developing the skill of observation

Transcript line	**Name**	**Transcript**
69	Teacher	This is a tree snake. What I like about this picture is that it shows how the animal is adapted. Not many snakes have scales that look like leaves. It looks like it has individual leaves stuck all over it.
70	Stephen	Some scales are black, like water.
71	Teacher	Yes, it blends with the bark of the tree. That is just one way in which the snake is adapted.

Being able to make close observations has been linked to the literature as being the starting point to being able to formulate a question and is a skill that needs to be taught and modelled (Harlen and Qualter, 2014). During Interview 1 Rob said it was important that children were able to observe carefully so that they are stimulated to ask questions. Rob continued to say that the picture of a tree snake helped children to observe features. When analysing the questions, it was suggested that when Stephen observed the colour of the scales on Line 70, he could have asked 'why are the scales were black?' At Line 70 it was also proposed that he could have asked children to note any questions that they have about their observations of the tree snake so that they could practice linking their observational skills to their questioning skills.

Although not necessarily representative of the class, providing a picture or an artefact appeared to be valuable for Year 6 focus group children who reported that they were able to ask questions because they had had the opportunity to 'play' with a Cartesian diver and observe how it worked. However, the focus group children maintained that it was sometimes difficult to think of questions that they could answer in science lessons but reflected that if they were to be presented with an interesting artefact or problem to solve then this would help them to formulate a question. The children said that they had been able to ask questions about the Cartesian diver because they had been provided with time to talk and explore as exemplified in the following quotes:

> ...it would have been hard to ask question about it [the Cartesian Diver] had we not had the chance to explore and observe what happened (Ellie)

> Yes, we may have just said 'Why is the sauce at the top, not the bottom'. The questions are different when you have the chance to explore firstly (Alex)

The views of the children were shared with Rob during Interview 1 and he said he did not use artefacts to stimulate question posing (only a picture on the interactive whiteboard) to engage children. This would indicate that children did not have the opportunity to observe and manipulate objects in the classroom which is when questions are often generated. Symington (1980) reported that letting children engage in unstructured observation increases the number of questions that they are able to ask. However, during Interview 1 it was clear that although Rob was aware of the link between observations and the subsequent framing of questions there was a challenge in terms of time available for children to answer questions:

> Children don't know how to ask questions because of the way we teach…children don't have time to set up their own experiments to answer their questions.

Indeed, during Lesson 1, children asked very few questions that were linked to the development of science concepts as indicated below in Table 5.5.

Table 5.5: Questions asked by children in Lesson 1

Question Types	Example
Classroom organisation questions	Can I have another learning pad? Do we have to be in English places?
Procedural questions	How many facts do I have to have? Do we have to do five facts?
Information questions	Is the skin black? Translucent?
Explanatory questions	Are there any guinea pigs in the desert? Why is it called a pink river dolphin? Why do some snakes spit at their prey?

Table 5.5 identifies that the majority of questions were linked to classroom organisation issues (checking the understanding of the task or who they could work with). However, there were some explanatory questions that were posed by three children. The explanatory questions were asked during group work time rather than in the whole class teaching input. To support all learners in his class to ask questions, it was suggested to Rob that he could plan for a period of time whereby children had the opportunity to apply their observational skills in order to practise posing questions.

c) Challenge of classroom talk

In Lesson 1 Rob asked closed-response questions that required children to provide factual information about concepts (see Table 5.3). Rob's approach to teaching was possibly due to him being unsure of how best to support the process of talk or knowing how to use a range of techniques to establish children's prior knowledge (as indicated in Table 5.2). However, it needs to be recognised that the format of the lesson may have been delivered via a more didactic approach because Rob was aiming to revise for end of year testing so it was important for him to monitor the children's understanding in order for them to reach the common scientific understanding of key concepts.

Rob's teaching approach and questioning skills observed during Lesson 1 seem to be in contrast to his ideals of how children should learn science because during Interview 1 he reported that children should be curious about the world around them and to actively construct their understanding of concepts through hands-on learning. However, Rob also recognised that there were limited opportunities for children to problem solve or apply their learning using a range of different types of investigation in Year 6 (Interview 1).

As Rob self-reported to having good subject knowledge (Interview 1) it was suggested that he could take risks with his teaching and begin his lessons with a problem that children needed to solve as this might stimulate questioning on the part of the children and enable Rob to change the format of his lessons. To support Rob with this aim, input on different question types was provided so that he was aware that different questions have different functions. The coding grid (Appendix 3) was used to talk through question types with Rob.

5.3.2 Stage 2 - Reflections on practices at the mid-way point of the action research process

In March (Interview 2, Stage 2) Rob had the opportunity to discuss how well the Thinking Cubes were being used to support children's questioning skills. He said that the Thinking Cubes had been useful because they linked to Bloom's taxonomy so he was able to 'judge the cognitive level of the children' (Rob, Interview 2). For example, during a lesson, a child had asked a 'why' question that was linked to their observation of colours in nature (Why are frogs coloured when they live in a dark environment?). Rob mentioned that this was a question that he was able to help the child answer through investigative work during a lesson on woolly worms (see Appendix 24). He mentioned that this was powerful because the child realised that their question was being answered during a lesson. He continued to assert that there was 'depth of learning that may not have been possible had we been using the learning pads to research camouflage'. It would appear that Rob was beginning to develop his awareness of the value of getting children to use their observation and questioning skills to engage in science investigations.

5.3.3 Stage 3 - Evaluation of how collaborative action research impacted upon Rob's practice

Lesson 2 and Interview 3 provided evidence for changes in teaching. Lesson 2 was delivered during an afternoon in June. This lesson was at the beginning of the unit of work on evolution and children had been asked to generate questions that they would like to know about inheritance and evolution using the Thinking Dice. Question generation formed the main part of the lesson. The lesson concluded with a video clip about selective breeding in dogs in order to model 'how we can control inheritance and evolution' (Rob, Transcript number 98).

a) Rob's views of science

During interview 3 Rob was asked to complete the same closed–response questions that he responded to during Stage 1 of the research process in order to evaluate any changes in attitude. The findings are shown below in table 5.6

Table 5.6: Rob's perceptions of his questioning skills and pedagogy

Aspect	Agree strongly	Agree	Unsure	Disagree	Disagree strongly
I can engage children in hands on science activities.					
I am effective at establishing a classroom climate whereby students feel confident to pose questions.					
I can pose open and closed questions to support the science activity.					
I am confident in responding to children's scientific questions.					
I am able to use a range of techniques to establish children's prior knowledge.					
I can use my subject knowledge to ask the right questions in order to move children's learning forward.					
I encourage children to pose questions that they can investigate.					
I am confident at planning for opportunities for classroom talk.					
I have a good understanding of science concepts required to teach primary school children.					

Pre action research

Post action research

After the collaborative action research, Rob reported that he was more confident on nine out of the ten aspects relating to questioning skills and teaching approaches.

b) Structure of Rob's lessons

Rob reported that he now routinely planned time in the lesson for children to ask their own questions using the Thinking Cubes. This is arguably a good approach as Chin (2002) argues that if time is set aside to develop this skill, then children can be supported in asking questions at a higher cognitive level. During Lesson 2, children worked in groups and used the cubes to generate questions in relation to evolution and inheritance. The children generated a number of questions using a variety of question stems as shown below in Table 5.7. Rob and I considered the questions in relation to the cognitive demand of each question because the Thinking Dice were organised according to Bloom's taxonomy (Appendix 25). This was used instead of the Coding scheme because Rob wanted to know if children were using information (remembering questions) or were able to use application and analysis questions.

Table 5.7: Questions generated by children according to cognitive demand

Question generated by children	Cognitive demand of the question
What is meant by evolution? Why is inheritance important? Is there a way to stop inheritance? How do diseases get passed on?	Remembering (Low cognitive demand) Enables recall of information
How long does it take for something to evolve? What is the main idea of evolution? What factors show that you have inherited a bad gene?	Understanding (low cognitive demand) Promotes explanation of ideas
Where else would you see evidence of evolution? What is the relationship between inheritance and evolution? What would you say to a person who said there is no such thing as evolution?	Applying (Transition from lower to higher cognitive demand) Pupils are required to use information in another situation
What are the problems caused by evolution?	Analysing (higher cognitive demand) Pupils explore relationships and making inferences

In Table 5.7 only one question was generated at the higher cognitive level. The majority of the questions were at the lower cognitive demand (remembering and understanding). It could be argued that maybe children did not know enough about inheritance and evolution to ask higher order questions and it is easier to generate information questions.

During Interview 3 (Stage 3) it was suggested to Rob that the format of Lesson 2 had remained the same in that he began and ended the lesson with a range of closed-response questions. The main change in the format of the lesson was a period of time for children to use the Thinking Dice to generate questions. The lesson consisted of quite tightly structured tasks even though Rob had planned time for children to undertake research based on questions they had posed (Table 5.7). However, he felt that the task (in Lesson 2) did not engage children at the higher cognitive demand as they were not being required to problem solve which according to Chin (2002) often elicits a richer range of questions and talk.

Rob reflected that it would be useful if children's questions were displayed in the classroom (e.g. post-it notes) so that the children could add the answers to the questions over the duration of the topic. Rob felt that by making the questions public, this would raise the profile of questions. He also said that he would use the investigation posters to show children that questions can be answered in different ways rather than just using research. Rob shared this vision with the rest of the teaching staff during a professional development meeting.

c) Challenges for Rob

Arguably, teaching children in Year 6 might require a different approach due to the knowledge centred priorities of the school. Research by Brownlee, Schraw and Berthelsen (2011) has shown that a teacher's personal opinions relating to effective teaching can bear little relationship to teaching approaches employed (e.g. those who value constructivism may utilise transmission approaches). According to Windschitl (2002) educational contexts often reflect objectivist outcomes in which teaching and learning are conceived of as transmission and reception of knowledge. Teachers in Year 6 are often under pressure to support their classes in reaching certain levels at the end of Key Stage 2. Lee and Tsai (2011) argue that teacher-focused teaching approaches may stem from the educational climate of high stakes exams and that teacher-focused approaches may be quite effective for enhancing student achievement on tests. This appeared to be the case for Rob when he reported:

> Being in Year 6 definitely makes a difference to my teaching. It is so pressurised that I often see science lessons as a bit of a release for children, a bit of down time. However, we have to do pre- and post-tests for each unit of work so that we have evidence and that can be a pressure because we need to show that children have learnt the subject knowledge (Rob, Interview 2)

The idea that teachers need to demonstrate that children have learnt content may arguably impact upon teaching approaches as teachers may not have sufficient time to employ student-centred approaches where children can apply their learning and demonstrate mastery of the curriculum by talking and working scientifically. For a change in teaching approaches to occur there needs to be an investment of time but the availability of time in Year 6 is often pressurised due to SATs preparation. Regardless of this pressure, Rob was keen to continue with the action research cycle independently. It would appear that Rob had understood the value of the approaches presented to him over the duration of the action research process and had now taken ownership for change to happen in his classroom. Rob asserted that he now saw the value of making time for children to pose their own questions and mentioned that in September he would introduce the Thinking Cubes to his new class and would link questions and observations together in his planning so that children could begin to ask higher order questions. He said that he would use a question wall so that the questions could be valued (interview 3).

5.4 Research Question 2: Is there a change in the type of question posed as a result of the collaborative action research?

This section will begin by summarising the key themes relating to Rob's questioning skills (Table 5.8) before discussing the types of questions posed during Stage 1 of the research. This will follow a comparison of questions asked in Lesson 1 and 2 in order to establish if the action research impacted upon Rob's questioning. Table 5.8 summarises Rob's questioning skills during Stage 1 and Stage 3 of the research.

Table 5.8: Summary of Rob's questioning skills

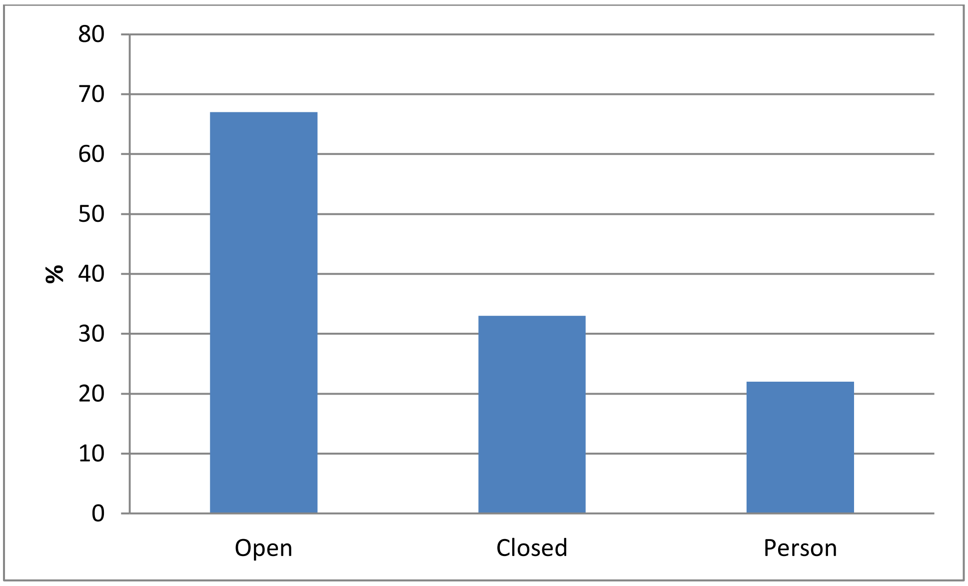
Stage 1	**Stage 3**
• Rob asked mainly open-ended questions during Lesson 1 but these were often of low cognitive demand and required the recall of facts. • The patterning sequence followed the IRE format with Rob orchestrating the lesson. • There was evidence of Rob elaborating upon children's ideas in order to extend their understanding of concepts.	• There was no observed change in Rob's questioning range; his questioning still required children to recall facts (even when the questions were open-ended). • He did not pose productive, comparison or problem solving questions in either Lesson 1 or 2. • He reported that the type of lesson could impact upon the types of questions asked and argued that fair testing lessons where variables are manipulated are better suited to asking productive or problem solving questions (see Appendix 23 for a summary of transcript analysis)

5.4.1 Stage 1: Rob's questioning skills at the beginning of the research

Evidence for Rob's questioning patterns was provided by transcripts of Lesson 1 and Interview data from Interview 1 (Stage 1). During Interview 1, Rob had decided to focus his research on developing children's questioning skills but was made aware that it was important that he modelled a range of questions so that children become accustomed to hearing different patterns of questions.

Twenty two percent of Rob's questions were coded as person-centred and Rob mentioned that he tended to ask person-centred questions so that children would feel confident to answer. He asserted that asking a question such as 'what did *you* find out about a camel last week?' or 'what animals do *you* think live in a rainforest?' were asked to assess understanding and the use of the pronoun 'you' made the questioning more inclusive as more children would be inclined to attempt an answer (Interview 1). The majority of Rob's questions during Lesson 1 were open-ended (67%) and were asked during the input and the plenary of the lesson (see Figure 5.2).

Figure 5.2: Open, closed and person centred questions asked by Rob during lesson 1



Although the majority of questions asked by Rob were open, thirty six percent of the open-ended questions asked were information seeking questions and followed the IRE pattern, whereby Rob asked a question and the children responded. The purpose of the triadic dialogue according to Rob was to check the children's understanding of concepts covered in previous lessons and to extend their understanding. The majority of open-ended questions (50%) asked in Lesson 1 were explanatory questions which required children to provide more expansive answers. However, the explanatory questions can still be seen as being authoritative as children were required to provide particular answers. Table 5.9 shows examples of open ended questions asked by Rob.

Table 5.9: Types of open ended questions posed by Rob during Lesson 1

Question Type	**Frequency (%) and examples of questions**
Productive	--
Comparison	--
Problem solving	--
Information seeking	36% What have we looked at this term? What other things does a camel have? How is a polar bear/camel adapted? What did you find out about a camel last week?
Defining	14% What made you say that?
Explanatory	50% Why does a camel have a hump? Why might you have fat? Why is it important for a polar bear to be white? Why has it adapted to this colour? Why is that feature special? Why does it need hairy feet? Why are the feet large?

Rob began Lesson 1 with an open-question; asking the children to tell him about something they had learnt this term (coded as an information question in Table 5.9). Children were keen to respond to the question but this may have been because the question was a low cognitive demand question it was easy to answer. Rob then began to funnel the questioning down to the previous lesson and asked the children to tell him what the adaptations of a camel and polar bear were. During Interview 1 Rob reported to being confident when responding to children's answers or questions (see Table 5.2). Evidence of Rob using his subject knowledge to challenge and extend children's conceptual understanding was evident in Lesson 1 as shown in Table 5.10

Table 5.10: Rob developing children's responses during Lesson 1

Child's response to question	Rob's elaboration of ideas
Rob: Why do they have a snappy nose? Rachel: So sand doesn't come up.	Excellent, so in the desert, in a sand storm, they have a flappy part on their nose so sand doesn't go up it.
Rob: What is important about the colouring (of a tree frog)? Tom: If predators look at it, they may see venom and stay away.	The frog is actually quite poisonous itself so if another animal is to eat it, that would cause the animal to be quite ill. It is actually called a harlequin tree frog and it lives in the rainforest. A very important thing about the colouring is that it wards off predators. These frogs are as big as a finger: they are tiny, tiny, tiny frogs.
Teacher: What might a python do to kill prey? Alex: It might have a long tongue.	They might have. They tend to wrap around the prey, crush it and eat it. Some snakes have venomous properties and they have poison in their fangs. Pythons and boas constrict their prey to stop it breathing. That's the way they feed.
Alex: Do some snakes spit at their prey?	Yes, some do. Who has seen Jurassic Park? There is one reptile that spits to confuse prey. Some species of snake do this because of many years of adaptation.

Table 5.10 shows that Rob was able to rephrase the child's responses and then provide additional information. During the evaluation part of the sequence, Rob often provided the children with additional information and could bridge the gap between student knowledge and the accepted view of scientific concepts. He maintained that he was able to do this because he had good subject knowledge (Rob has Advanced level in Biology) in relation to the topic (Interview 1). In each of the examples, Rob acknowledged the children's contributions and added additional information rather than asking further questions to build on children's earlier ideas. Simply posing a follow up question of 'why' may encourage children to speak more expansively about the science concepts. Asking 'why' may also serve the purpose of moving children on from simply recalling facts and towards higher ordered thinking. Although much of Robs' questioning tended to follow the IRE approach there was a chain of responses when children were asked an explanatory question - see Table 5.11.

Table 5.11: Children's responses to an explanatory question in Lesson 1

Transcript number	Name	Transcript
110	Teacher	Why does a polar bear need big, hairy feet to walk on ice?
111	Emma	It will get cold and has extra fat to keep warm.
113	Hannah	So it does not get stuck in the snow and so it can balance.
114	Tom	It won't sink.
115	Eddie	Also, I thought that if it has hairy feet it won't slip around so much.
116	Teacher	This group looked at a rock python. What did you find out?

Although there was a chain of responses, children were responding to Rob instead of talking to each other. This may have been because children were not familiar with this way of talking. Children were not yet 'inter-thinking' (Mercer, 2000) or collectively making sense of the experience by responding to each other's ideas. As previously mentioned, Rob's approach to teaching during his revision lessons was more teacher-centred rather than child-centred. In the above dialogue, Eddie provided a response that was a new idea, however, this was not developed and the questioning moved on to another animal. It could be asserted that the next steps for the children would be for them to begin to challenge each other because the children were waiting for the teacher to evaluate the ideas. This however, may be difficult because this is not the usual format of the lessons that they have been exposed to and they may feel unsure as to how to respond if they disagree with another child (McNeill and Pimental, 2009). The children were clearly not accustomed to responding to each other; the questioning was teacher-centred with a high number of IRE moves.

5.4.2 Stage 2 - Reflections on questioning skills at the mid-point stage

During Interview 2 (Stage 2) the conversation focused on how well the Thinking Cubes had been employed in developing children's questioning (these reflections will be shared in Section 5.6.2). However, there was also a discussion about how Rob's questioning skills had developed. During Interview 2, it was apparent that Rob was aware of the different types of questions that could be asked but said that he had 'not really changed his questioning approach and still used the plenary and introduction of the lesson to assess children's learning'. He continued to report that he was 'reluctant to alter the format of his lessons because he needed to ensure that children had the required level of knowledge at the end of each unit of work'. I then mentioned that in order to move children's questioning skills forward, it is beneficial if children are exposed to a wide range of questions and we looked at the range of questions that could be employed using the coding grid (Appendix 3).

5.4.3 Stage 3: Change in questioning skills

The format of Lesson 2 was similar to Lesson 1 in that children were researching. This ensured that it was easier to compare how questions were used.

After observing Lesson 2, the questions were coded using the Coding Scheme (Appendix 3) to compare the number of open and closed-questions posed in Lesson 2. Figure 5.3 shows the percentage of open and closed questions.

Figure 5.3: A comparison of the open and closed questions posed by Rob in Lesson1 and 2

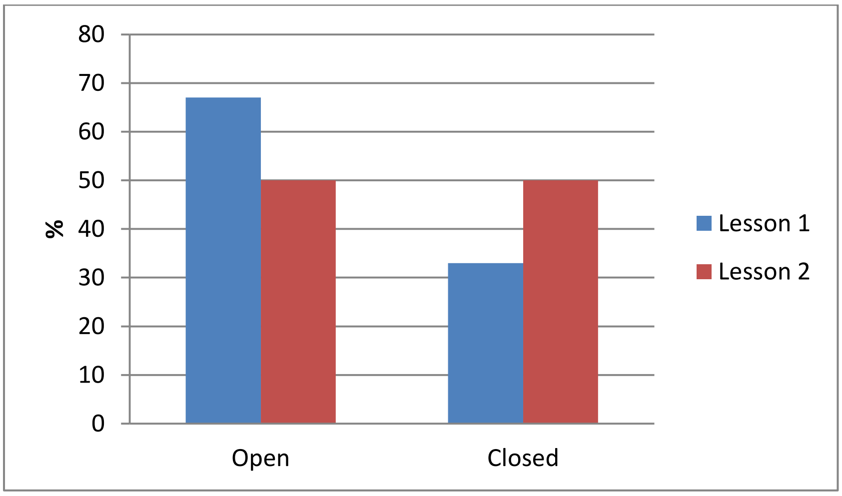


Figure 5.3 shows that during Lesson 2, Rob asked a higher percentage of closed-questions when compared to the first lesson (50% compared to 33% in Lesson 1). Rob maintained that posing closed-questions during the input and during the plenary (see Table 5.12) was justified because children did not engage in science lessons on a daily basis so it was important to re-connect children with the concepts covered in previous lessons at the beginning of each session.

Table 5.12: Pattern of questioning that Rob adopted during the plenary of lesson 2

Number from transcript	Name	Transcript
99	Teacher	Right, so that is selective breeding – when you select the characteristics you want. What examples did the video give for dogs?
100	Evie	A labra-doodle.
101	Teacher	A labra-doodle and a poodle because the Labrador is a guide dog and the poodle does not cause allergies. Other examples?
102	Tom	Chickens
103	Eddie	Cows
104	Teacher	What characteristics would you want from chickens?
105	Harry	Lay big eggs.
106	Teacher	What about cows
107	Amy	To produce lots of milk?
108	Teacher	Plants?
109	Stephen	Fruit
110	Teacher	Yes, things like strawberries – to have bigger or sweeter fruits.

The dialogue in Table 5.12 shows the IRE format, whereby Rob asked a question (Line 99), a child responded (Line 100) and this was followed by feedback or explanation and rewording by Rob (Line 101). In the transcript Rob was the adopting an authoritative stance in that he was the more knowledgeable teacher and was using the interactions to seek the correct answer. He had the final utterance in each triadic pattern. When open-ended questions were asked, during Lesson 2 they tended to be at the lower cognitive demand as shown in the following dialogue:

> Teacher: What things do you think you have inherited?
>
> Child 1: Eye colour.
>
> Child 2: Shape.
>
> Child 3: Hair colour.
>
> Child 4: Hair types.

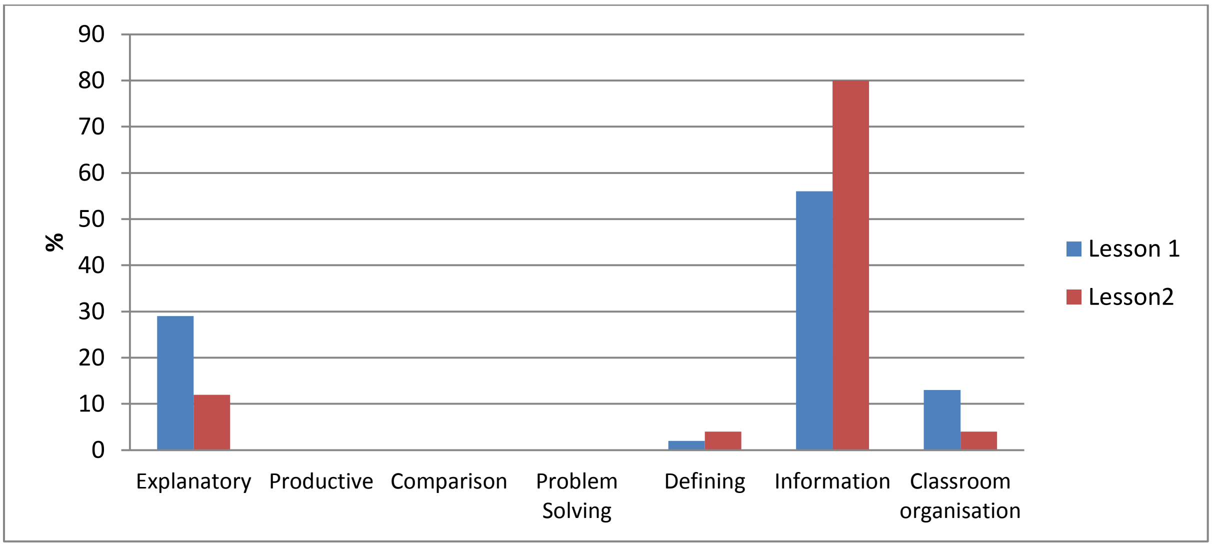
The range of responses shown above did not require children to reason or explain their understanding because they were used as information questions to assess knowledge. When compared to Lesson 1, Rob asked more defining questions during Lesson 2. However, he asked fewer explanatory questions in Lesson 2 when compared to Lesson 1 (29% of the open-ended questions were explanatory in Lesson 2 compared to 12% in Lesson 1).

Table 5.13: Open-ended questions posed by Rob during Lesson 2

Question Type	Examples of questions
Productive	--
Comparison	--
Problem solving	--
Information seeking	What do you think you have inherited from your parents? What things do you think can be inherited? What things do you think can be passed down? What things are inherited? So, what have you learnt about evolution and inheritance? So, what things did we come up with that we believe we may inherit?
Defining	Can you explain more fully? What else do we mean? What in particular about your eyes?
Explanatory	Can anyone explain to me who they think the parents are and why?

When coding the questions that he had asked during Lesson 2, Rob identified that he had not used the full range of questions as shown in Figure 5.4.

Figure 5.4: A comparison of questions asked during Lessons 1 and 2



Rob was quick to notice that he had not asked any productive, comparison and problem solving questions but asserted that the lesson was not really aimed at generating investigative work; rather, it was devised to ensure that children understood the key scientific terms such as evolution and inheritance. He identified that the type of lesson that he was delivering might have had an impact upon the questions that were asked. He knew that the lesson had been linked to research rather than fair testing; which may have resulted in more productive questions being asked.

5.5 Research Question 3: How does the use of a Thinking Cube support children in asking and answering their own questions?

5.5.1 Stage 1: Children's questioning skills at the beginning of the action research

To provide a baseline measurement of how well children were positioned to frame questions, focus groups were undertaken. Evidence was also collected from the transcripts of Lesson 1.

During the focus group task the children did not need any support in exploring the artefact and appeared confident to work in pairs to establish how the Cartesian Diver worked. The children observed whether or not the pressure applied to the sides of the bottle had an impact upon how the sauces behaved. While observing the Cartesian Diver, the children generated a range of questions that were analysed using a coding grid (Appendix 1) and are presented below:

Table 5.14: Questions posed by Rob's pupils during the focus group activity

Example of questions posed	Types of questions and definitions
How long does it take to come back up? (Referring to the sachets).	*Information questions* A question which was generated in response to an observation and could be answered by taking measurements of time.
Shall we count? Shall we squeeze in the same place? (Referring to the Cartesian Diver bottle). Who wants to count?	*Procedural or management questions* Here children were negotiating roles during the exploration.
Why doesn't the mayonnaise go down… the tomato and brown sauce do?	*Comparison questions* *Explanatory and exploration questions* There was an element of comparison here as the children noticed that the sauces behaved in different ways.
Does air make a difference in any way? Does the temperature of the water make a difference? Maybe we could change the shape of the bottle? …maybe the bubbles in the lemonade may make a difference to how they (the sauces) go up and down?	*Wonderment questions* These questions would require children to manipulate variable and to observe the impact.

The wonderment questions seem to indicate that the focus group children were accustomed to manipulating and changing variables during science experiments. Arguably, children's questioning skills improve not just by having different question types modelled to them but by explicitly promoting other scientific practices and skills. It appeared that the skill of observation supported children in generating questions. Indeed, a child in the focus group reported that 'it would be hard to ask questions about the [Cartesian] divers had you not had the chance to explore and to look.'

When discussing the transcripts of the focus group activity, Rob reported that he was impressed by the children's ability to pose questions but said that this was not 'the norm' in his class and that there were a number of children who lacked the confidence to ask questions. He continued to report that during lessons he tended to ask questions and the questions often required explanations or recall of facts rather than the exploration of concepts using enquiry based learning.

5.5.2 Stage 2 - Reflections on children's ability to question

Rob had not kept reflective notes but used his planning sheets and annotations to remind himself about the lessons that he had taught since the beginning of the action research process in February. Rob had noticed that the lower and middle ability children found it harder to pose questions when compared to the 'more able' children and that the questions that they generated tended to be at the lower cognitive level (see the yellow cube in Appendix 24). For example, one of the lower ability children asked 'can you list what was found in the school grounds?' and this could have been answered by recalling information. Although we talked about the value of children linking their questions to different types of enquiry Rob still felt that children needed support with this process. Rob decided that for the next stage of his research, he would continue to use the Thinking Dice because they had been successful in helping children to raise questions (even if these were at the lower different cognitive level). To support the less able children with their questioning skills, he felt that they needed more time to become familiar with the Thinking Cubes.

5.5.3 Stage 3 - Evaluation of how well the Thinking Dice supported children's questioning skills

Rob said that the Thinking Dice had supported children in asking questions and when he talked to his class about questioning skills a child reported that they were better at asking questions because they had used the Thinking Dice:

> It was quite hard at first but it has got easier as we practice asking questions. The beginning of the question [question stems on the cube] help you to ask a question (Year 6 child)

However, there was no real impact on children's questioning skills apart from the fact that Rob provided more opportunities for engaging in this practice. Rob elected to focus on giving students ownership through the way in which he chose to emphasise questioning in his class. However, it could be asserted that had he focused on improving his own questioning skills then children would have had the skill modelled to them so that they had a better understanding of the range of questions that can be generated.

5.6: Rob's reflections and development over the duration of the research

Reflections of Rob's questioning skills are referenced throughout this chapter but Table 5.15 highlights how the use of Thinking Dice influenced questioning skills during his science lessons over the duration of the research. Table 5.15 shows that Rob was providing children with time to practise using the Thinking Dice in order to question pose, however, Rob was aware that he did not alter his questioning skills over the duration of the research and attributed this to the challenges of teaching a Year 6 class when preparing for SATs.

Table 5.15: Rob's reflections on his practice over the duation of the research process

Stage 1	**Stage 2**	**Stage 3**
Rob made links between the skills of observation and question posing when he reported that it was important that children are able to observe carefully so that they are stimulated to ask questions. To support this idea he reflected that videos and pictures help (Interview 1). He was aware that he asked the questions and children answered them because 'of the way we teach in Year 6 when preparing for tests' (Interview 1).	Rob commented that he has 'a better understanding of question types' but did not alter his teaching. He still used the introduction and plenary to ask information questions and reflected that this was because he was 'a bit reluctant to change because he needed 'to be sure that they understand the subject knowledge' (Interview 2). Children had the opportunity to use the Thinking Dice and Rob noted that the 'Thinking Dice are useful to judge the cognitive level of the questions' (Interview 2).	Rob did not use a range of different questions during his second lesson and again reiterated that he needed to check children's understanding (Interview 3). Children had been using the Thinking Dice during Lesson 2 but the questions were of low cognitive demand. Rob reflected that the type of lesson that children were engaged in may have contributed to this. Rob reported that Lesson 2 was not the right sort of lesson to generate high cognitive demand questions lessons. Lessons that are linked to research often generated more information questions' (Interview 3).

5.6: Key findings

Table 5.16: Impact of collaborative action research on Rob

Indicators of clear impact or consolidation of skills	Indicators of developing skills	Challenges/skills not addressed or no visible impact
• Rob is now planning time in his science lessons to provide learners with the opportunity to practise their questioning skills.	• Rob has an awareness of the different question types and how these link to different types of investigations. • From September, he plans to teach his class the link.	• The format of the lesson was the same. • He did not use a problem solving approach at the beginning of his lessons to encourage questioning. • There were a high number of information and closed questions asked during the introduction and plenary. • Children were not yet answering their own questions during science lessons on a regular basis.

The format of Rob's lesson remained the same over the duration of the research process. Rob began Lessons 1 and 2 with information questions that required children to recall their prior learning. The plenaries were also used to assess children's understanding using closed-questions. The collaborative action research approach had limited impact upon Rob's teaching and questioning skills and this may have been because Rob had chosen to focus his teaching on using an activity (Thinking Dice) rather than improving his own practice of using questions to promote children's understanding. It could be surmised that had Rob asked a range of questions (as discussed during interviews 1 and 2) then children would have been exposed to different questioning patterns (and not so many sequences of IRE) which may have changed the classroom dynamics

Rob reflected that the lessons that he delivered during the research did not engage children in problem solving, which according to Chin (2002) often elicits a richer range of questioning patterns. By presenting a problem solving approach, the pattern of questioning may have altered and the classroom environment may have been less ‘teacher-focused’ and more ‘learner-focused’ with children engaging in talk and co-constructing their conceptual knowledge. This may have supported children in asking questions to each other during key points in the lesson, such as the plenary, where they could compare findings. However, during a discussion with Rob, he reported that being in Year 6 made a difference to his teaching. Indeed research by Windschitl (2002) highlighted that teachers will change their teaching approach to meet the objectivist outcomes of schools; as was the case for Rob, who was preparing children for end of key stage testing. Rob was aware that he needed to ensure that children had developed their conceptual understanding and this resulted in the high proportion of closed-response, information questions with no productive, comparison or problem solving questions being asked by Rob during the research (See Figure 5.4).

Although children had the opportunity to practise raising questions using the Thinking Dice they were not engaged in problem solving via an enquiry and consequently posed only one question at a higher cognitive level (What are the problems caused by evolution?). Children were only required to research aspects of habitats and key terms associated with inheritance and evolution, therefore, productive questions did not emerge throughout the lessons and children did not have the opportunity to consider how questions could be answered using different types of enquiry. Conversely, Harlen and Elstgeest (1990) argue that providing children with opportunities to raise any type of question is a good teaching approach if they are to be supported to question pose. Although children asked mainly information and low-cognitive demand questions during lessons, Chin (2002) argues that when teachers initially use question–production strategies, the result is often the generation of knowledge based questions. It could, therefore, be argued that with continued use of the Thinking Dice, children may begin to ask higher cognitive demand questions.

5.7: Summary of the collaborative research process for Rob

When discussing Lesson 1, Rob reported that he was unsure of how to pose questions to support science learning or how he might encourage children's questioning skills (Table 5.2). Therefore, time was spent discussing different question types and how these might impact upon children's learning. Rob had received training during a PDM meeting about the use of Thinking Dice prior to beginning the research and as this was a tool that he was familiar with he wished to use these in his science lessons.

At Stage 2 Rob reported that he routinely planned time in his lessons for children to practise the skill of question posing using the Thinking Dice. He said that he was able to judge the cognitive level of the children (Section 5.4.3). He was asked if his questioning was changing but he maintained that he had really been focusing upon the children rather than his questioning skills. I suggested during Interview 2 that it would be useful to model the different types of questions to the children so that they became accustomed to hearing different types of questions and the purpose of them.

When analysing Lesson 2 it appeared that the structure of Rob's lessons remained the same. In Lessons 1 and 2, the introduction and plenary were used to assess children's learning using IRE questioning sequences. The only change was that children were given time to pose questions during lessons. The change in Rob's teaching was limited because although the chosen strategy focused on giving students ownership through the way in which he chose to emphasise questioning in his class, this is in contrast to focusing on developing his practice of using questions to promote children's conceptual understanding of science. The Thinking Dice did not challenge him to plan for questions in a strategic manner during the lesson.

Chapter 6

Discussion and conclusions

6.1: Introduction

This chapter will begin by reflecting upon how a collaborative action research approach contributes to a change in teaching and questioning skills and based upon the findings of this research, considers implications for teachers wishing to evaluate and change their current teaching practices. I begin by presenting a framework (Figure 6.1) that can be used to support teachers when reflecting on their practice during collaborative action research. After presenting Figure 6.1, the chapter focuses on the impact of the collaborative research process on questioning skills for Rob and Jack. Here, I will present the personal framework for each teacher (Figures 6.2 and 6.3) and will evaluate the extent to which each teacher changed over the research period. The chapter will conclude by considering the contributions of this research to the knowledge base, limitations of the research approach, reflections on my role as a researcher, implications for my practice and opportunities for further research.

6.2: Key findings

Although I was aware that, by the end of the data collection process the participating teachers had only just begun on their journey towards changing their questioning and teaching practices, I had learned much from discussions and transcript analysis; which has implications for me as a primary science teacher educator. What became clear was that the dynamics of each classroom differs and this influences teaching practices. In addition to this, the personal experiences of teachers can either hinder or support the process of change. However, it needs to be recognised that the research was small scale and as such I am aware that whilst findings may not be generalisable, they might be applicable (Cohen *et al*., 2003) to the experiences of other primary school teachers. Indeed, this case study could be perceived as a process of developing an explanatory and theory testing tool in order to begin to forge theories about the effectiveness of CAR on teaching (Thomas, 2011). The suggestions I make in this chapter are tentative but may be a starting point for scaffolding reflections upon practice and therefore, supporting teachers in school to learn more about the art of teaching and learning.

6.3: The development of a model to support collaborative action research

Figure 2.2 illustrates, in diagrammatic form, the inter-linked variables that impact upon teaching approaches employed when teaching primary science. Figure 2.2 was devised as a means of highlighting the complexity of teaching. To develop Figure 2.2 from a diagram into a useful model for teacher change, modifications were required. This section will explain how the diagram (Figure 2.2) has been developed into a model (Figure 6.1) for professionals to engage with in order to support changes to teaching practices.

Clarke and Hollingsworth's (2002) Interconnected Model, which identifies that there are multiple entry points for CAR (see Figure 2.1), influenced the development of Figure 6.1. Figure 6.1, like Clarke and Hollingsworth's model, accepts that growth in one domain will influence development in the others. In Figure 6.1 the reciprocal effect of subject knowledge, curriculum knowledge and subject specific pedagogy (shown by the black arrows connecting the rectangular boxes), is acknowledged in that improvement in one of these areas will impact upon the other two knowledge domains. Although Shulman (1986) asserts that subject knowledge should be developed initially in order to improve teaching I argue that this should not necessarily be the case and that developing a teacher's repertoire of teaching approaches is valuable as it increases teacher confidence and the subsequent willingness to teach science. This is corroborated by Loughran (2002) who argues that professional learning is not developed through developing more knowledge but is enhanced by one becoming more perceptive to the possibilities of different teaching strategies. Indeed, Naylor (2015) argues that teacher change is progressive and if a teacher tries a new teaching approach and the learners respond well to it on more than one occasion then the approach becomes embedded into practice.

However, there is the dilemma of how to move practice forward and which domain should be the focus. Instead of there being multiple entry points for teacher development, I propose that understanding motivations and personal competencies of individual teachers is an important process if CAR is to be personalised and effective in bringing about teacher change. Identifying a starting point at the beginning of CAR provides a teacher with a baseline measure against which they can assess the impact of the research. Therefore, in Figure 6.1 there is a clear entry point which aims to identify a teacher's motivation to change as well as their personal competencies; Parts 1 and 2 of the framework. It is important that at the onset of action research, the aims and outcomes of the research are considered in order to measure the effectiveness of interventions (Part 4).

Figure 2.2 included a triangle relating to teacher practice but this has been changed to illustrate the process of collaborative action research and the importance of reflection and enactment. By having a clear idea of why a teacher wishes to change their practice and having an understanding of their personal competencies, it is possible to jointly plan actions for change and to measure outcomes.

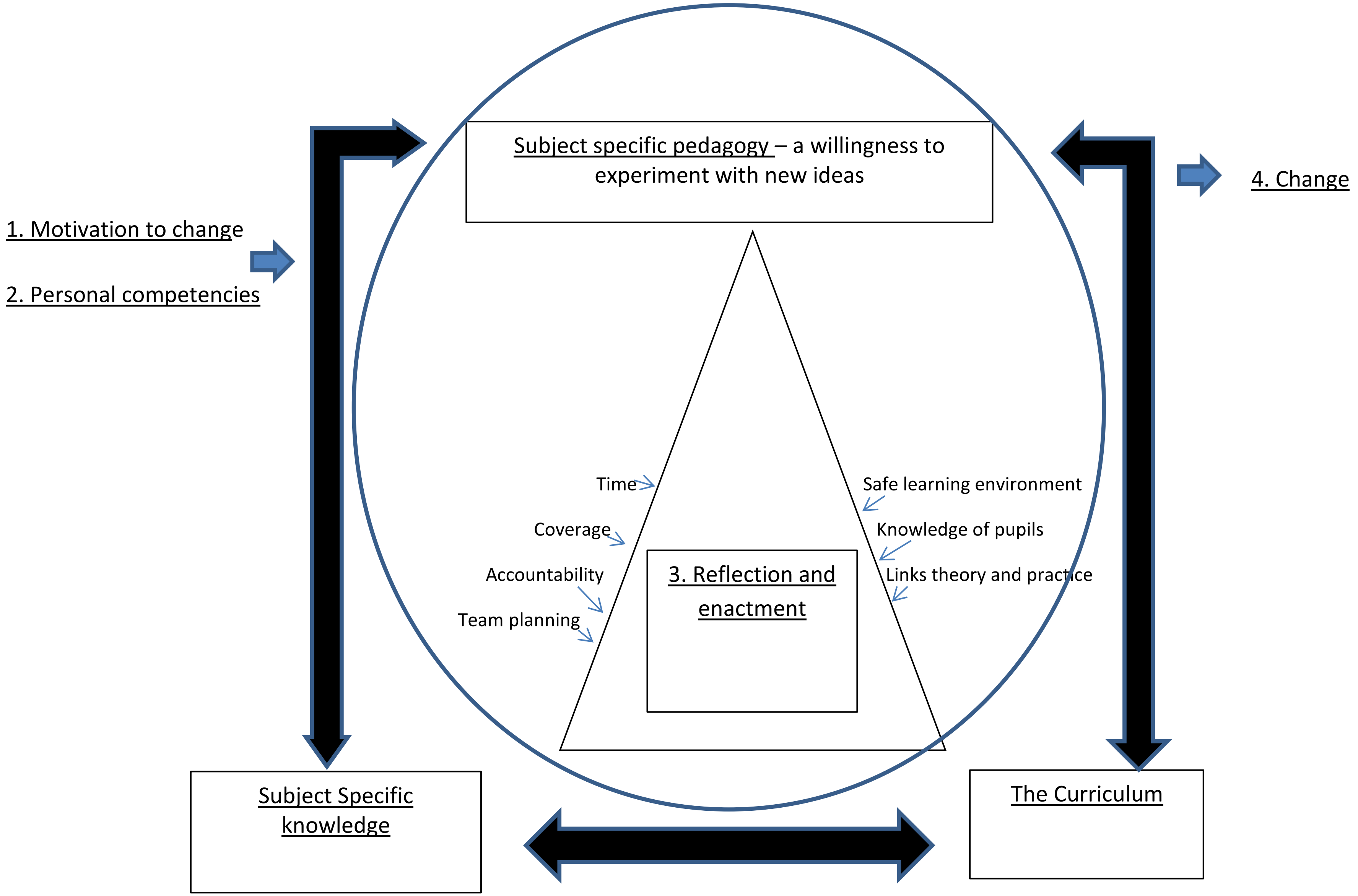
If CAR is to be personalised for teachers, as advocated by the Department for Education (2011), it needs to be recognised that teaching and learning are contextually situated. Being confident to use different strategies requires the right learning conditions to be in place. Therefore, an important modification to Figure 2.2 is the influence of the school context. The influence of the school was previously indicted by a blue arrow, however, as a result of this research, it became apparent that the school context is one of the most influential variables that enables or hinders teacher change. Indeed, Rob reported that the pressures of accountability and SATs impacted upon the way in which he was teaching. That is why in Figure 6.1 the blue circle (which represents the school context) encompasses the framework as the school community influences all activities that teachers engage in.

6.4: How the collaborative action research model (Figure 6.1) can be employed in practice

Figure 6.1 is a framework that is designed to be used with individual teachers when planning for learning experiences using collaborative action research. It is anticipated that the model will be personal to each teacher as this will determine the action of the collaborative action research. It is also anticipated that the framework is followed through sequentially by initially identifying a teacher's motivation to change as well as their professional competencies (as indicated in Parts 1 and 2 of the model). Ideally, a teacher's motivation to change should link to improvements in outcomes for children and will serve as a measure of the success of the collaboration.

A closed-response questionnaire to establish the enablers or barriers to change may help teachers to reflect upon their practice. Following this, a discussion with the teacher about three key domains; pedagogy, the curriculum and subject knowledge (indicated in the rectangular boxes in Figure 6.1.) will identify the professional characteristics of each teacher. In the triangle, the iterative cycle of action research is highlighted so that there is continual reflection followed by appropriate actions. It is anticipated that the model is annotated so that it becomes a working document to track progress and reflections.

Figure 6.1: Collaborative action research model



As indicated in Figure 6.1, changing teaching practice is a complex process and encompasses a range of variables that are unique to each teacher. Teachers' beliefs about themselves as professionals form a central part of their identity and can inhibit or support them in engaging in learning and reflective processes (Muirs *et al.,* 2010). Reflecting and making teaching the object of study can be a challenge if self-esteem or confidence levels are low (Postholme, 2012), therefore, it is important to recognise the complexity of professional learning and how ideas are translated into the classroom so that professional conversations can occur (Luft and Hewson, 2014).

In this research, the school context influenced the research outcomes for Rob It could be surmised that a whole school approach is needed in order to ensure that organisational factors are challenged and there is value ascribed to deep learning and the value of high quality questioning skills to challenge children's thinking. To achieve this, the leadership team need to ensure there is time for staff to interact (Jaipal and Figg, 2011) because being able to observe another teacher use a new approach effectively is motivating to others. In this research, Rob and Jack began to discuss how the use of a puppet supported learning but to better facilitate a change for Rob it would have been useful had he been able to observe Jack's lessons and to reflect upon the learning that took place.

So far this chapter has proposed a framework to support teacher change and identifies that the framework is unique to each teacher because it is based upon their motivations, attitudes and competencies. The next section will focus upon each of the participating teacher's profile to consider how the collaborative action research approach impacted upon practice. I begin by summarising the changes that took place.

6.5 Research Question 1: How do primary school teacher's questioning practices change as a result of collaborative action research?

The integration of a teaching approach into practice was implemented with varying success for each teacher as shown in Table 6.1.

Table 6.1: Summary of the impact of collaborative action research on teaching strategies

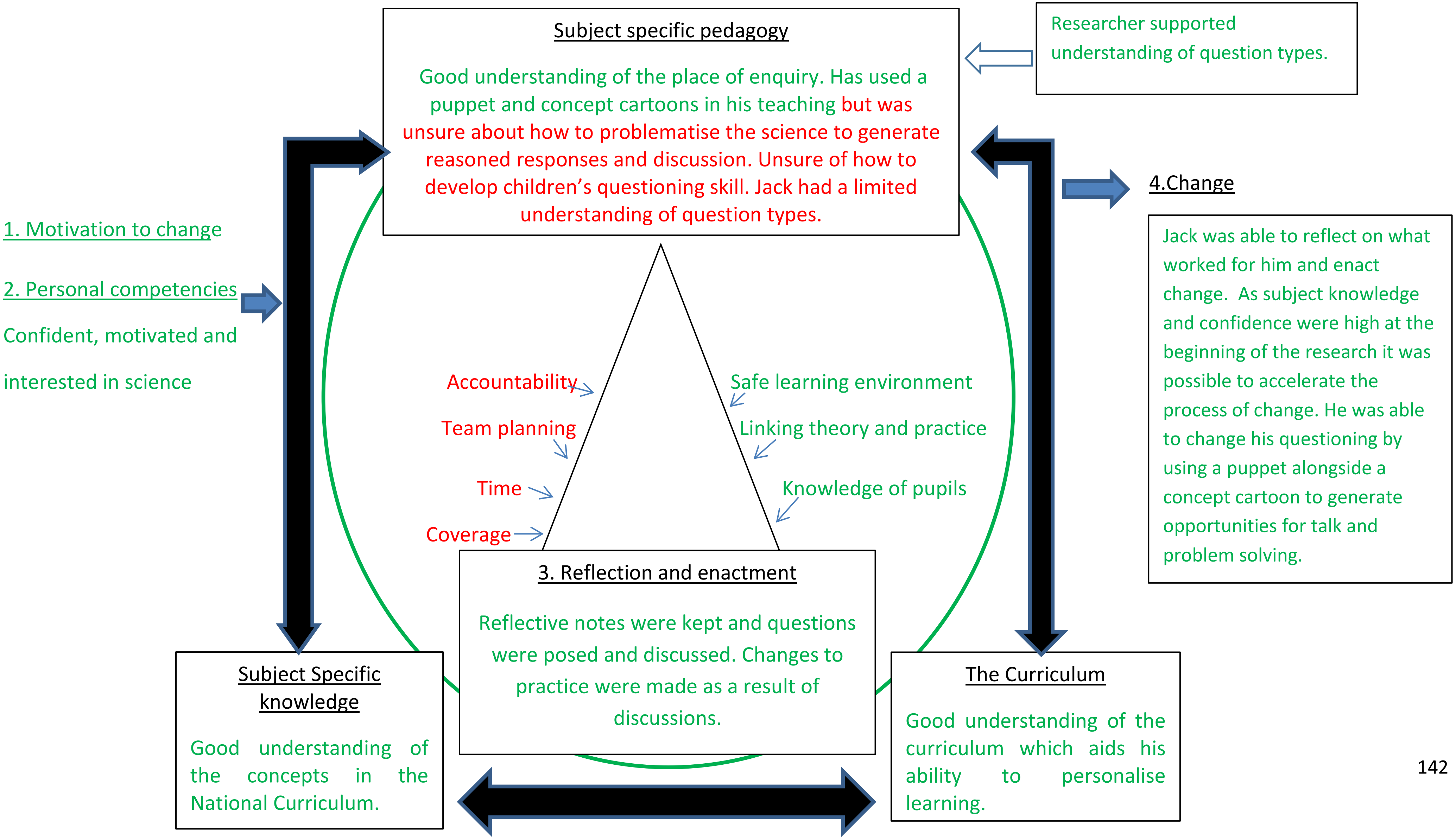
Teacher	**Evidence of change**	**Skills not addressed or no visible impact**
Jack	More planned opportunities for classroom talk using concept cartoons and a puppet. Longer 'wait time' Children were keen to talk to the puppet and help with his confusions. Children able to raise questions when conducting a fair test. Embryonic evidence that Jack was moving towards IRRE moves and cumulative talk.	The structure of the observed lessons remained the same The plenary and introduction were used to ask information questions using the IRE questioning sequence.
Rob	Time planned for children to practise the skill of asking questions using the Thinking Dice. Beginning to support children in answering their questions during lessons.	The structure of the observed lessons remained the same Plenary and introduction were used to ask information questions using the IRE questioning sequence. Rob 'controlled' children's investigations throughout the action research process.

Each teacher implemented a change in their teaching to differing extents. The change in teaching approach was greatest for Jack but more limited for Rob. The degree of engagement and subsequent change demonstrates the complexities inherent in teacher development. This may have been as a result of the chosen approach or the emotional connection to the action research process.

Figure 6.2 summarises inhibitors and enablers that impacted upon Jack's engagement in the research.

The green text shows the variables that enabled teachers to engage in the research and subsequently change practice; the red text shows the inhibitors.

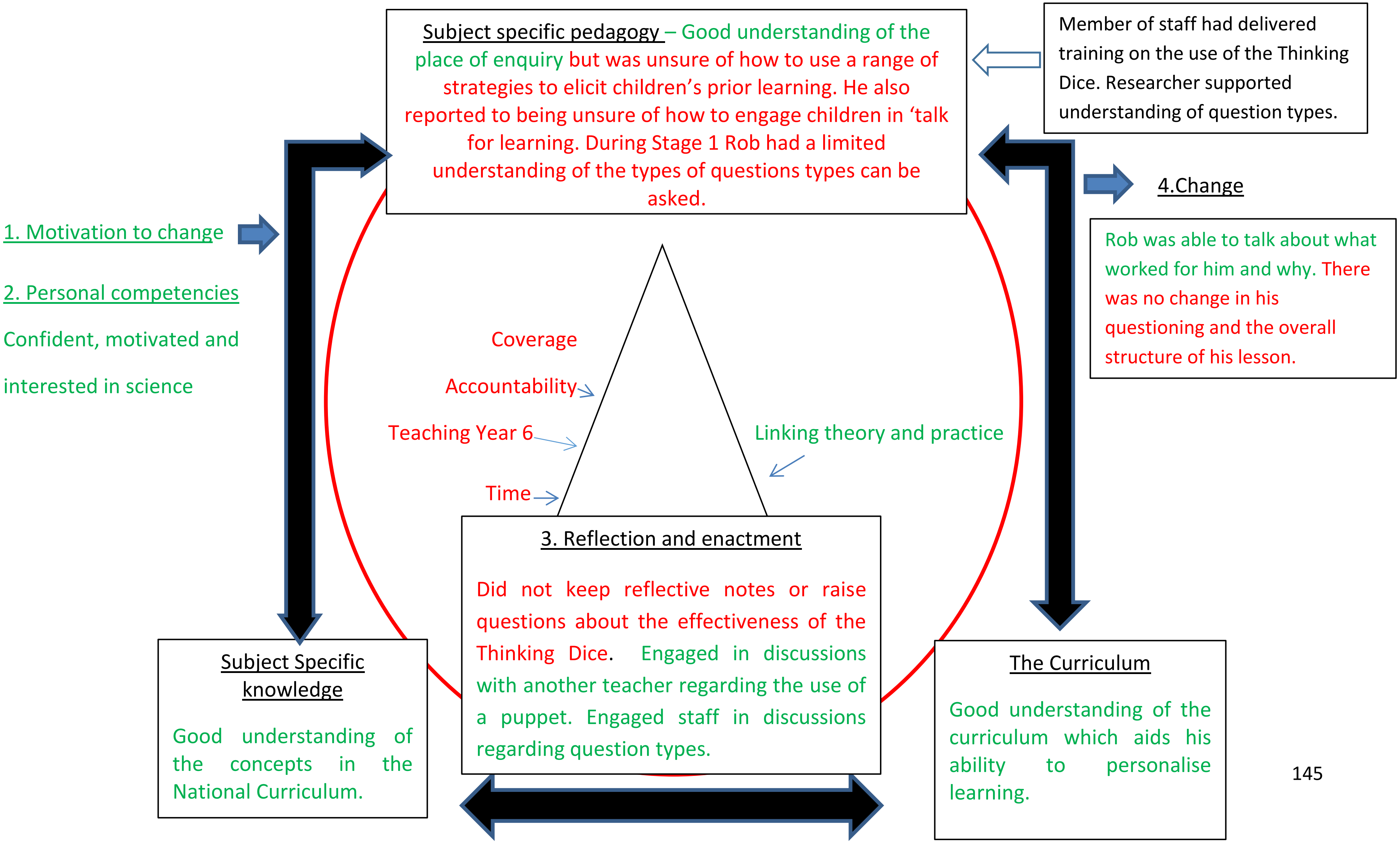
Figure 6.2: Collaborative action research model for Jack



The data collated during Stage 1 of the research indicated that Jack had many 'enablers' which supported his engagement during the action research (as shown in Figure 6.2). Jack was already capable of teaching science effectively due to his high confidence levels, subject knowledge and understanding of the curriculum (Table 4.2). This high level of self-efficacy provided Jack with the confidence to actively engage in the collaborative action research process. Ford (1992) identified that a combination of a person's motivation, skills and environment influence a teacher's competencies relating to teaching. There were a few inhibitors that were linked to contextual issues of the school (see the red annotations in Figure 6.2). Although Jack mentioned the inhibitors he did not feel that they impacted upon his ability to set goals that he wished to achieve in order to improve his teaching (Interview 1). The school context was not a barrier for Jack and this may be explained by the fact that he was leaving the school at the end of the year in order to work in Vietnam. Therefore, the pressures associated with performance management may have been limited for Jack and provided him with the licence to take risks with his teaching.

Throughout the process Jack reported that he was confident when teaching science and had good subject knowledge and these factors according to Jones and Leagon (2014) are significant predictors of a teacher's ability to adopt new strategies. Postholme (2012) reviewed studies relating to professional development and argued that for change to occur, teachers need sustained professional development of at least 20 hours of development stretching over a two year period. This is aligned the work of Loughran (2002) who advocate a time frame of over a year. However, Jack instigated change in a much shorter time frame and this was as a result of him having many 'enablers' at the beginning of the research. Indeed, Ramsey-Gassert, Shroyer and Staver (1996) add that teachers with higher levels of subject knowledge tend to be motivated to adopt more student centred practices and this was the case for Jack's teaching because he planned more opportunities for talk. However, the change could have been due to the input provided about how to use a puppet alongside a concept cartoon to modify his teaching approach (Appendix 13). For example, at the end of the research Jack considered Ricky's misconceptions and thought about how the puppet (in conjunction with a concept cartoon) could present a problem to encourage children to talk about science ideas. In successful lessons (Appendices 18 and 19) children talked about concepts and posed their own questions which they were able to investigate. Had Jack just been provided with a puppet, there may not have been a change in the problematizing of concepts and the strategic planning of questions as exemplified in his plans (see appendices 18 and 19). He needed the concept cartoon to help him to plan the naïve idea for the puppet.

Figure 6.3: Collaborative action research model for Rob



During Stage 1 Rob reported that he had 'good' subject knowledge, understood the curriculum and the place of enquiry as a teaching approach to support children's learning. These enablers (see Figure 6.3) ensured that he was confident to respond to children's questions and to engage children in science learning (see Table 5.2). However, there were a number of inhibitors that impacted upon his practice such as accountability and time to teach science. The orientation of the school towards assessing subject knowledge and to generate evidence of progression, through pre and post unit test scores influenced Rob's teaching (see section 5.4.3). In Lesson 1 Rob was preparing children for SATs testing and was observed to adopt a monitoring role during science lessons (Tabak and Baumgartner, 2004). He tended to set the tasks and provide the feedback; as was evidenced from the high number of IRE sequences and closed-questions. It appeared that issues of accountability resulted in the subsequent teaching employed having little resemblance to a Rob's personal values. Indeed it has been identified from research that teachers who value constructivist teaching approaches may adopt more traditional didactic teaching approaches and the transmission of knowledge due to contextual variables (Windschitl, 2002; Brownlee, Schraw and Berthelsen*,* 2011).

Although there were opportunities for discussion during Stages 2 and 3 of the research, it may have been beneficial had Rob been provided with additional professional development time to develop his reflections on the effectiveness of the Thinking Dice (he had not written any reflective notes). Support could have been provided via e-mail as research by Harlen and Doubler (2004) established that online environments can help to support the process of reflection. Alternatively, I could have supported Rob's reflections 'on action' (Schon, 1987) by using the videoed lessons to encourage Rob to reflect upon the 'question choices' made during the lesson and to judge the quality of the task for children's learning. During Stage 2 and 3, Rob and I did not go back to the videoed lesson but relied upon the transcripts to evaluate the usefulness of the Thinking Dice. However, Appleton (2008) suggests that teachers need to unpack and focus on the learning that is occurring and the videoed lessons may have supported Rob in this process. It could, therefore, be hypothesised that the level of reflection was linked to the extent of observed change.

6.6 Research Question 2: Is there a change in questions posed as a result of collaborative action research?

Table 6.2: Summary of the impact of collaborative action research on questioning

Teacher	**Evidence of change**	**Skills not addressed or no visible impact**
Jack	Asked a wider range of questions that required children to explain and justify their answers.	No comparative questions were posed during the plenary.
Rob	Developed an understanding of question types (self-reported) Aware that questions could be linked to different investigations.	Questioning remained the same over the duration of the research period.

During Lesson 2 Jack was observed to ask a wider range of questions as well as more open-ended questions which incorporated the question stems 'how' and 'why' (Section 4.4.3). Asking 'why' and 'how' questions requires children to demonstrate their reasoning skills and according to research by Martin and Hand (2009) after 18 months of professional development, only 1% of teachers were observed to adapt their teaching to use these question types. Jack's accelerated change in questioning was due to his use of a puppet. Jack reported that when he used Ricky to ask naïve questions such as 'how do you know which rock is granite – they are all grey aren't they?' children provided more expansive answers. Jack reported that he often asked naïve questions using the puppet (he did not do this when he was in his teacher-role). In analysis of the lesson, Jack was also heard to say (via Ricky) 'I am confused can you explain that to me again?'

Conversely, Rob asked mainly open-ended questions in Lesson 1 that required children to explain their answers. However, the questions were low-cognitive demand questions because a certain answer was required (Section 5.5.1). Rob was orchestrating the learning and the children viewed him as the person who asked and checked responses to questions. However, during Stage 2 it appeared that Rob attempted to alter the classroom dynamics by planning time for children to pose questions. He was also valuing the questions posed by children by incorporating them into lessons (see section 5.4.2).

Rob appeared keen to ensure that children understood how questions could be answered through different types of enquiry. Rob had comprehended that questions can be answered in different ways and was keen to share this understanding with his colleagues during a professional development meeting.

During Stage 3, Rob reported that he understood that there are different question types and that these may be linked to different types of enquiry but during Lesson 2 he asked more information questions and no productive, comparison or problem solving questions. He was still using his questioning to check children's comprehension of concepts. Although he recognised that the type of enquiry impacts upon questions asked (easier to ask comparison and problem solving questions for fair testing enquiries) it could be argued that there was 'habituation of practice' so that it was difficult for him to change his practice (Haworth, 1999 p. 101). Rob was comfortable with the format of his lessons and whilst he demonstrated an ideological commitment to change, in practice continuity was easier.

Teachers often face tensions as professionals when delivering the statutory curriculum and fulfilling mandated requirements to assess pupils. Continuing with practice that they are familiar with, therefore, enables them to enact their role with confidence. This finding is aligned with research by Martin and Hand (2009) who established that experienced teachers are often reluctant to give up their pedagogical strategies; especially if these have been proven successful over time. To alter practice, Marin and Hand (2009) argue that there needs to more research on how to support teachers. I propose that this may be provided, not only external professionals, but by other colleagues because it is important to develop learning communities within school. Indeed, Hargreaves and Fullan (2012) also identify the importance of teachers meeting and working in small groups to plan and assess the effectiveness of ideas and termed this 'interactive professionalism'. At the end of the research Rob and Jack began to discuss the value of using a puppet to develop teaching practices and Rob appeared keen to try using a puppet. The dialogue between teachers seemed to indicate that time to share and exchange practice is a good stimulus to professional development. However, for this to be effective teachers need to see themselves as part of a learning community, feel that they have adequate knowledge and skills to support others within a supporting school setting. Lewis (2014) identified that change inducing professional development should be iterative, so head-teachers need to plan regular Professional Development Meetings so that teachers have time to reflect and discuss their teaching using new approaches.

6.7 Research Question 3: How does the use of a puppet/Thinking Cube or concept cartoon support children in asking and answering their own questions?

Findings from this research indicate that children did not change their questioning skills during observed lessons. However, self-reported reflections by Jack show that children were able ask questions if engaged in certain types of enquiry. For example, children were better positioned to question if they were undertaking fair testing or an enquiry requiring children to problem solve.

6.7.1: The impact of using a puppet and concept cartoon

During the focus group task, children in Jack's class were able to ask 'why' questions but found it difficult to ask wonderment or productive questions. It was suggested to Jack that it would be useful to provide children with an artefact to explore when the puppet introduces a problem as this might support them in question posing. This approach proved useful because during Lesson 2 children asked exploratory and philosophical questions (section 4.6.2) based upon their observation of rocks. Jack also self-reported that the questioning skills were more pronounced during a fair testing lesson relating to plants and children asked a range of productive questions (Section 4.6.2).

These findings suggest that when children are presented with a problem or an artefact, that makes them curious, they are stimulated to ask questions and that certain types of enquiry are better suited to stimulating question posing from children.

6.7.2: The impact of Thinking Dice

During the focus group task, children in Rob's class used their observation skills to ask a range of questions. However, Rob felt that this was not the norm in his class. During Interview 2 Rob reported that children often only asked lower cognitive demand questions. It was suggested that he could model the impact of different question types to children. However, Rob decided that he would continue using the Thinking Dice because he felt that children just needed more time to 'get used to using them'.

In Lesson 2, children were afforded time to pose questions using the Thinking Dice and a child in his class had reflected that the resource had been good because they could practice asking questions. Indeed, being able to practice question posing is the starting point to develop this process skill (Harlen and Elstgeest, 1990). However, there was no observed change in children's questioning skills using the Thinking cubes. The limited change in children's ability to question pose may have been as a result of the way in which Rob orchestrated the learning in his science lessons. The lessons generally began and ended with a series of teacher generated, closed-questions during the input and plenary. It could be argued that children did not ask questions because they were acting in accordance to the norms of their classroom; they had learned not to ask questions. In effect the children had been socialised into the norms of school talk in that the teacher asks the questions and children respond. In addition to this the perceptions of a teacher's role and pupils' perceptions of their role will impact upon the nature of questioning sequences (Fisher and Larkin, 2008). However, another reason for the limited number of question posed could have been because the children were unwilling to share their questions. Research by Dillon (1988) established that younger children will often ask questions whereas older children are less inclined to question during class discussions. This could be as a result of a number of variables such as not wishing to have attention focused on them.

6.8: Contribution and significance of the study

This research aimed to provide an understanding of questioning practices in primary science lessons but in doing so I was able to build a theory from the case studies and generate a theoretical framework (Figure 7.1) that may be used in school to support reflective practices. The second contribution is the use of a concept cartoon in conjunction with a puppet. There is currently much research (Naylor, 2015; Naylor *et al.* 2008; Hackling *et al.* 2010) relating to how puppets can develop children's confidence but evidence from Jack's teaching indicates that puppets can also develop teacher confidence by allowing them to adopt new roles and consequently ask a wider range of questions.

Jack was able to change his questioning skills over a short time frame due to the use of a puppet alongside a concept cartoon. Using the concept cartoon and the puppet enabled Jack to introduce problems in his science lessons that required children to be curious, to talk and to engage in enquiry. In this research when Jack used a puppet and a concept cartoon he was shown to alter the dialogic nature of the classroom.

6.9: Limitations of the Study

Although all teachers were supported in developing their understanding of different question types and approaches it is difficult to ascertain whether or not the changes made to teaching practices were permanent. I was unable to make judgements about teachers' change beyond the research period. As previously noted, there were limited changes to children's questioning skills and this may have been as a result of the short time frame for the study. Teachers were only just beginning to model different question types. On reflection, analysing children's questioning may have been beyond the remit of this research and warrants a longer time frame to assess accurately.

Secondly, the sample was a convenience sample because teachers were not randomly selected for the study. This limits inferences that could be made to other teachers. I was unable to make broad generalisations, however, as previously mentioned the findings can be transferable to other primary school teachers (Cohen *et al.,* 2005).

Finally, the fact that lessons were being observed might have influenced the chosen teaching approaches employed. Although interviews were used to discuss teaching, it cannot be assumed that the new approaches had become embedded into practice. In addition to this, the observed lessons were subjected to a range of variables and the mood of the teacher (and children) could have impacted upon the lessons and findings. Therefore, it is accepted that the data is subjected to these variables.

6.10: Implications of research on my practice and the research community

A key implication of this research for teacher trainers is ensuring that there is an understanding the contextual and personal beliefs and attitudes of teachers. At the university where I work, the science team undertake an audit of subject knowledge and although it is useful to identify areas for development (as well as ensuring that they meet the requirements in the Teacher Standards) this approach of focusing on subject knowledge competencies alone is problematic. Increasing teachers' subject knowledge is, according to Schibeci and Hickey (2000) a panacea and the focus should instead be supporting teachers to become learners of science. Seeing beyond the technical aspects of learning to teach and valuing the use of questioning approaches can develop the confidence to teach aspects of the curriculum that they may have previously avoided teaching. Indeed, research by Shallcross, Spink, Stephenson and Warwick. (2002) identified that it is counterproductive to highlight weaknesses in subject knowledge as this increases anxiety and may result in avoidance or controlled teaching approaches. Therefore, although my teaching sessions will develop the three strands of knowledge; curriculum, subject and pedagogy, I will ensure that teachers are taught approaches that will develop their confidence to deliver science. This will follow by considering how to improve opportunities for talk and the impact of different questions on children's learning and engagement.

This research has shown that using concept cartoons and puppets can change teacher practice, therefore, these approaches could be utilised in sessions to model how teachers can effectively problematise science. In changing teaching approaches from being teacher-centred, this should ensure that classroom practice is more child-centred thus ensuring curiosity and engagement in the subject. If we want to have creative, critical thinkers in our society, then we need to teach the skills of observation, question posing and solving and this begins with the teaching approaches we elect to use and by considering the opportunities we afford to children to practice these skills.

6.11: Implications for future research

Looking ahead to future endeavour, it is clear that the personal profile of teachers and the school context is a key variable to implementing changes to practice successfully. It became clear through this research that confidence levels and lower levels of subject knowledge can result in a reluctance to engage in CAR. Therefore, focusing upon a teaching approach that may reduce anxiety to teach science seems to be valuable. A teaching approach that I am keen to explore is the use of a puppet alongside concept cartoons so that the structure of lessons can support teachers in becoming co-

constructors of science rather than adopting authoritative approaches. I would, therefore, like to explore, in depth, how the use of these two teaching approaches, in tandem, can contribute to teacher confidence and consequently, children's engagement in lessons.

6.12: Reflections on my role as a researcher

A researcher's personal beliefs, values and background all influence the design and conduct of research. My professional background, as a primary school teacher (and later in my role as a teacher educator) has shaped the design and subsequent analysis of the data. In order to reflect upon my role as a researcher I feel it is necessary to document my learning journey in education in order to explore and justify how my experiences have shaped this research.

During my time as a primary school teacher I was keen to develop and improve my practice and would often engage in action research with my class based upon the professional development sessions that I had attended. Although I often had success with my interventions, in terms of gains in attainment for the children, I was not yet evaluating the extent to which the success was due to the new teaching approach or other confounding variables such as my enthusiasm for the approach or the novelty factor of the approach. It was when I began my Masters degree that I began to understand the need to identify the causes of change and the challenge of generating sufficiently objective data to support the justification for using the approach. At this point in my professional career I employed an objectivist epistemology whereby I attempted to search for relationships between an intervention and a successful intervention. This was driven by my science background. However, on completion of my Masters I was cognisant that classroom interactions rely upon social interactions in a social world and therefore, an interpretivist approach was of value when developing an understanding of the choices that teachers make when teaching. Indeed, Clough and Nutbrown (2012) argue that people do not gain knowledge by simply observing the world but by interacting with people.

In my current role as a teacher educator I have been in the privileged position of being able to observe lessons. During lesson observations of student teachers I was able to develop my skill of producing notes relating to the salient points of a lesson in order to help students reflect on their teaching. Notes were utilised to help me to question and discuss the lesson in order to enrich student's ability to make connections between teaching and learning. The skill of observing lessons and discussing teaching and learning and the effectiveness of approaches was applied to this research.

Providing teachers with the opportunity to reflect upon their teaching was important because I wanted to know why they elected to ask certain questions at key points in a lesson. Therefore, the transcribed lessons were used to help teachers to recollect incidents in the lesson. At the beginning of the research process I had envisaged that dialogue and reflections and support within a social constructivist framework would influence teachers and encourage them to use a wider range of questions. However, at this point in my research journey I did not fully anticipate the inhibitors that prevented teachers from changing their practice. After analysis, I noted that I tended to adopt a coaching approach whereby I offered guidance, helped teachers to evaluate their lessons and provided by own personal anecdotes rather than probing the responses and asking for further explanations to questions and examples from lessons to illustrate ideas. However, as the research was a collaborative approach the teachers viewed me as being on the leaning journey with them they were confident to articulate their views.

6.13: Key findings of the research

Changing questioning practice is a complex process and is dependent upon a range of inter-related variables. These variables may support or inhibit a teacher's proclivity to change their teaching. According to Postholme (2012) it is important to recognise the complexity of professional learning though conversations to see how ideas are translated into practice (Luft and Hewson, 2014). Therefore, using Figure 6.1 can support the professional conversations about teaching and learning and can be used to monitor and track reflections and changes to practice over a period of time. In this research, both teachers reported that they had well-developed subject knowledge and this provided them with high levels of confidence when delivering science concepts to children. According to Jones and Leadon (2014) this is important if teachers are to adopt new teaching strategies. Although both teachers were keen to employ and reflect on the effectiveness of their chosen teaching approach, this research established that accountability and lack of curriculum time (school context issues) were cited as being inhibitors when altering practice. This finding is aligned by other research undertaken by Brownlee, Schraw and Berthelsen (2011).

Preparation for end of year testing resulted in a high proportion of IRE exchanges in Rob's lessons because he was reluctant to adopt different questioning patterns in case the children did not perform well on tests. It could also be asserted that teachers are often reluctant to change their teaching if it has been deemed effective (Martin and Hand, 2009). However, the dynamics of each classroom differs and this influences teaching practice. Jack, who was teaching a Year 3 and did not have the same accountability pressures as Rob, was better positioned to alter his teaching approach.

Jack instigated a change in his questioning in a relatively short period of time when compared to previous research whereby changes to questioning skills took over a year to become embedded into practice (Loughran, 2002). This change could be attributed to the chosen teaching approach that Jack elected to use. The use of a puppet and concept cartoon gave him the confidence to introduce problems when teaching science which altered the dialogic nature of his classroom.

If schools are to foster a community of learning that will encourage enquiry-based learning in science, rather than a reliance on worksheets and didactic teaching, then a whole school approach is warranted. I argue that teachers, therefore, need to have the reassurance that they can take risks with their teaching and should be provided with time to reflect upon their teaching with another person. Teachers should have the opportunity to interact and the leadership team need to ensure that this happens if there is to be a change in practice (Jaipal and Figg, 2011).

6.14: Summary of the research

This chapter reflected upon how collaborative action research contributed to a change in teaching and questioning skills. I argue that changing practice is a complex process and encompass a range of variables that are unique to each teacher and these may enable or inhibit change. In addition to this, the school community and organisation of the curriculum also impact upon teaching. To support teacher development it is important to identify the motivation for change as well as the personal competencies of the teacher if CAR is to be personalised to scaffold and support learning. Therefore, a collaborative action research model (Figure 6.1) was presented as a framework to discuss individual enablers and inhibitors. The CAR model is designed to help teachers (and researchers/coaches) to action plan to improve practice. The plan of action matters. In this research the choice of approach impacted upon teacher confidence and questioning skills. Jack elected to use a puppet alongside a concept cartoon which supported him in problematising science and changed his questioning approach to incorporate more 'how' and 'why' questions as well as altering he dialogic nature of his classroom. Conversely, the Thinking Dice did not alter Rob's questioning skills.

Definitions of terms used in the methods

Coding – the way in which questions are organised to describe the number of each question type posed over the duration of a lesson. Each question was initially coded as closed (C) or open (O) and where appropriate Person centred (PC). In addition to these codes questions were also assigned a code linked to science teaching e.g. explanatory (E) etc. The codes were added to the transcribed lesson. See Table 3.4 for codes.

Coding scheme – a way of categorising questions as exemplified in Table 3.4

Pre-determined categories – questions were assigned to certain codes. This was supported by previous studies relating to questioning See Table 3.4 to show how the literature supported the formation of categories.

Thematic analysis – This explains how the observed lessons were analysed. The first step in the analysis was to look for patterns in the coded questions. This followed a discussion to consider why certain questions were employed.

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Appendix 1 – Coding Grid for the focus group task

Question types and example of questions	Function of question
Basic information questions What does the dictionary say about salt? Why does the sachet float?	To generate questions in response to cues or to seek information.
Wonderment What would happen if…?	Application of an idea – requires children to be active and to test an idea.
Philosophical questions I wonder why that happens?	Does not require another person to answer; just a think out loud question.
Procedural or Management questions Who would like to count? What do we do next?	Requires clarification of a procedure or task. Children negotiating roles during experimental work. Classroom management questions are associated with – Where is your pencil? Have you written the title?
Comparison questions Which goes fastest? In what ways are they the same/different?	Use of observational skills to compare variables.

Appendix 2 – Questions asked to focus group children (these varied slightly according to the groups of children)

After a period of exploration children were asked the following:

In pairs, think about a really good question that you would like to know the answer to. Think about what you have observed (using the Cartesian Divers). What might you like to investigate?

How would you find the answer to your question?

Can you tell me about a ‘wow’ science lesson?

Do you enjoy science lessons?

Do you have the chance to ask your own questions in science? If, for example, you are doing a lesson on magnets, how might questioning work?

Do you think that it is hard to ask your own questions?

What helps you to ask a question?

Would you like to develop your questioning skills?

Is there anything you would like to tell me about science lesson?

Appendix 3 – Coding sheet for videoed lessons (teacher questions)

Question type	Description	Example
Closed (C)	Often requires a one word answer and is used to check for understanding or recall of facts	How many bones in the body? So you mean...? What is...?
Open (O)	Requires a more open response in the form of a sentence or explanation. There is more than one possible answer.	What do you think might happen if...? Can you tell the class about...? So what does that have to do with...?
Explanatory (E)	Requires a more detailed response on the part of the person being questioned. Often asked once a child has provided an answer.	Can you give an example of...? Can you explain how that happens? What do you mean by...? Why ?
Classroom organisation (CO)	Links to classroom management issues.	Can I see hands up of those people who have an answer? Have you written the date? Do you know what to do?
Productive (Pr)	Questions support children in being active in order to find the answer to questions. Involves questions that lead to some sort of investigative work.	How would you test...? What do you notice…? How many/how long? What if …? Can you find a way to…? If… then…?
Comparison (Comp)	Questions require children to be use careful observation skills in order to answer a question.	In what ways are they the same/different?
Person Centred and opinion questions (PC)	Questions that includes the pronoun 'you'. The question provides limited jeopardy on the part of the learner.	So what do you think the problem is? Why do you think it ...? What is your opinion?
Problem Solving (PS)	Supports children in applying their conceptual understanding to another situation.	Can you find a way to...? How would you use...? How would you apply what you have learned to develop...?
Defining questions (D)	Asks for clarification.	What do you mean…? Do you mean that…? So…? In other words…? Tell me more about…?
Information Seeking (I)	Recalling facts – open ended but of low cognitive demand	Do you remember what we did last week? How would you summarise? How would you describe?

Appendix 4 – Coding sheet for videoed lessons (children's questions)

Question types and example of questions	**Function of question**
Basic information questions What does the dictionary say about salt? What does the sachet contain?	To generate questions in response to cues or to seek information.
Wonderment What would happen if…?	Application of an idea – requires children to be active and to test an idea.
Philosophical questions I wonder why that happens?	Does not require another person to answer; just a think out loud question.
Procedural or Management questions Who would like to count? What do we do next?	Requires clarification of a procedure or task. Children negotiating roles during experimental work.
Comparison questions Which goes fastest? In what ways are they the same/different?	Use of observational skills to compare variables.
Explanatory and exploration questions Why does the sachet float?	Children needing an explanation based upon their observation of events that they have observed or items they have been exploring.

Appendix 5 - Questions used in the semi-structured interview with teachers during Stages 1 and 3

Aspect	1 Agree strongly	2 Agree	3 Unsure	4 Disagree	5 Disagree strongly
I can engage children in hands on science activities.					
I am effective at establishing a classroom climate whereby students feel confident to pose questions.					
I can pose open and closed questions to support the science activity.					
I am confident in responding to children's scientific questions.					
I am able to use a range of techniques to establish children's prior knowledge.					
I can use my subject knowledge to ask the right questions in order to move children's learning forward.					
I encourage children to pose questions that they can investigate.					
I am confident at planning for opportunities for classroom talk.					
I have a good understanding of science concepts required to teach primary school children.					

Adapted from Hackling *et al*, 2011, p.21.

Appendix 6 – Questions asked to teachers during the semi-structured interview (Stage 1)

Do you have any A'levels in science? Do you feel that having a science background makes a difference to teaching science?

Consider the phrase 'primary science' – what does it mean to you?

What is the role of the teacher in a science lesson?

Tell me about your philosophy for teaching science concepts to children (how do you feel it should be taught?).

What subject specific pedagogies are you aware of that may engage children in their learning during science lessons? (prompt - concept cartoons, puppets, modelling, research, hands on learning, transmission-reception).

Which of these have you used?

What is the place of questions in science?

How do you use questioning in science?

Are you aware of the different types of questions that can be used in science teaching?

How often do children have the opportunity to answer their own questions in science?

Are there any merits in children being able to answer their own questions?

What (if any) are the challenges of children posing and answering their own questions?

Do you plan for different types of questions in science?

Do you plan science lessons in teams?

As part of being a reflective teacher, how would you like to further improve your teaching of science?

Appendix 7 - Coding sheet linked to the literature

Question type	Description	Links to literature
Closed (C)	Often requires a one word answer and is used to check for understanding or recall of facts	Carr (1998) Yip (2004) Koufetta-Menicou and Scaife (2000)
Open (O)	Requires a more open response in the form of a sentence or explanation. There is more than one possible answer.	Carr (1998)
Explanatory (E)	Requires a more detailed response on the part of the person being questioned. Often asked once a child has provided an answer.	Chin (2007) Koufetta-Menicou and Scaife (2000)
Classroom organisation (CO)	Links to classroom management issues.	Not linked to the literature but identified from observational work
Productive (Pr)	Questions support children in being active in order to find the answer to questions. Involves questions that lead to some sort of investigative work.	Elstgeest (1985) Koufetta-Menicou and Scaife (2000)
Comparison (Comp)	Questions require children to be use careful observation skills in order to answer a question.	Elstgeest (1985) Yip (2004)
Person Centred and opinion questions (PC)	Questions that includes the pronoun 'you'. The question provides limited jeopardy on the part of the learner.	Harlen and Qulater (2014)
Problem Solving (PS)	Supports children in applying their conceptual understanding to another situation.	Elstgeest (1985) Chin (2007)
Defining questions (D)	Asks for clarification.	Chin (2007) Carr (1998) Koufetta-Menicou and Scaife (2000)
Information Seeking (I)	Recalling facts – open ended but of low cognitive demand	Yip (2004) Chin (2007) Koufetta-Menicou and Scaife (2000)

Appendix 8 – Ethical approval

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SSEGM ETHICS SUB-COMMITTEE APPLICATION FORM

Please note:

- ***You must not begin your study until ethical approval has been obtained.***
- ***You must complete a risk assessment form prior to commencing your study.***
- ***It is your responsibility to follow the University of Southampton's Ethics Policy and any relevant academic or professional guidelines in the conduct of your study. This includes providing appropriate information sheets and consent forms, and ensuring confidentiality in the storage and use of data.***
- ***It is also your responsibility to provide <u>full and accurate information</u> in completing this form.***

1. **Name(s):** Deborah Wilkinson

2. **Current Position** Postgraduate (EdD) student at the University of Southampton

3. **Contact Details:**

   Division/School Education School, University of Southampton

   Email d.wilkinson@chi.ac.uk

   Phone (01243) 812152

4. **Is your study being conducted as part of an education qualification?**

   Yes X **No** ☐

5. **If Yes, please give the name of your supervisor**

   Dr Marcus Grace and Dr Andri Christodoulou

6. **Title of your project:**

   The use of questioning in primary science: a participative action research study designed to develop reflective practices

7. **i) What are the start and completion/hand-in dates of your study?**

   September 2013 – April 2015

   ii) When are you planning to start and finish the fieldwork part of your study?

   January 2014 – July 2014

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8. Describe the rationale, study aims and the relevant research questions of your study

The importance of children actively constructing knowledge through practical experiences and discussion is recognised in the literature as being an effective way for children to learn science (Harlen, 2000; Sharp et al, 2000). The theoretical framework for practical work (or enquiry based learning strategies) in science is embedded in the constructivist theory of learning whereby children are actively engaged in constructing their own understanding of the world as a result of their experiences. Constructivism ensures that children are challenged to use problem solving and investigative work which should require children to pose and answer their own questions. However, teachers with a superficial understanding of scientific concepts either, according to Harlen (2000) avoid teaching challenging concepts or adopt didactic teaching methods with an emphasis on the transmission of factual information. The link between good subject knowledge, confidence and knowing how to teach science (pedagogy) is well documented with research indicating that teachers who possess a good understanding of science concepts are more confident when teaching. When teachers are not confident they often avoid asking open ended or productive questions which lead onto investigative work and will limit the opportunity for children to ask and answer their own questions (Skamp, 2006). The research is being undertaken at a time of substantial curriculum change, whereby teachers will be expected to deliver considerable subject knowledge content to children. As a result of the new science curriculum, teachers may feel pressurised to adopt pedagogies which do not allow children to construct their knowledge by posing and answering their own questions or via investigative work.

The overarching aim of the study is to work alongside three teachers in a junior school in West Sussex in order to support reflective practices in terms of the questioning skills they employ in the primary science classroom. The key aim will be to develop questioning skills but the actual research aims for each of the three teachers may differ slightly because the research will be driven from their perceived needs (e.g. less confident teachers may need support with subject knowledge or use of puppets to help both them and the children to ask questions; others may wish to develop a classroom environment whereby children are supported in asking and answering their own questions). This approach is aligned with the principles of adopting a collaborative approach to research design and echoes the work of Carr and Kemmis (1986) who maintain that collaborative research should support teachers in 'self reflective enquiry in order to improve their understanding of their practices' (p.162). During this process the participants will be involved in every stage of the research process (Munn-Giddings, 2012). Therefore, my role during the research will not be to act as an 'outside research expert' who 'does' research on other people's practices. Instead, the research will be led by 'insiders' in the school (teachers) who define the situation and try to develop their own practice. Although the actual support provided may differ for each of the three teachers, the following research questions will be guiding the research:-

1. Does collaborative action research have an impact on teacher confidence and efficacy in promoting a classroom climate conducive to questioning in primary science lessons?

2. Does collaborative action research contributes towards the development of reflective practices and the subsequent pedagogy employed?

3. Is there a change in the types of questions posed as a result of collaborative action research?

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9. Describe the design of your study

1. Focus groups with children from the classes of the three participating teachers will be undertaken. During the focus groups, children will be asked to discuss key questions such as their experiences of science at school, what they like and dislike about science and if there is anything they would like to do differently when undertaking science. The children will also be asked to participate in an activity task whereby they will be presented with an artefact (a Cartesian diver) and will be required to pose three questions that they would like to know the answers to. The focus group findings will serve as a starting point when interviewing the three participating teachers in order to share the children's perspectives regarding science as well as serving as a starting point when discussing the use and type of questions posed by children. The children will again participate in a focus group at the end of the action research in order to assess and gain their perspectives regarding questioning in the primary science classroom.

2. A semi-structured interview will be conducted in order to ascertain the views of participating teachers in terms of their confidence, understanding of pedagogy and the place of questions in science lessons (see appendix 1 for the questions that will be posed during the interview).

3. The teachers will be required to complete a short questionnaire both pre and post intervention in order to help identify attitudes towards teaching science (see appendix 2). As a result of the interview and questionnaire, teachers (with support from the researcher) will identify the focus for the action research (e.g. developing questions asked during the input of the lesson or how the use of puppets and/or concept cartoons support in helping children to pose and answer their own questions).

4. The cyclical process of action research will begin when each of the participating teachers has chosen a focus. There will be an initial observation followed by two further observations of a science lesson over a six month period (the observations will be spaced at two monthly intervals). The observation will be analysed alongside the teacher and if necessary, the teacher will identify any training needs or support they feel they may need.

5. Throughout the research process, teachers may decide to keep a reflective journal and if they feel that this will be beneficial to them, then support will be provided by the researcher.

10. Who are the research participants?

Three primary school teachers from a junior school in West Sussex will be the main research participants. The researcher has worked alongside the teachers previously as a mentor for student teachers for the past two years and has delivered a number of Professional Development Meetings linked to science. This working relationship has enabled trusting relationships to be established.

Three focus groups of six children will be part of the study and will be drawn from the classes of each of the three teachers who are participating in the study. It is expected that the sample will be a random sample from each of the classes and will not total more than six children from each class.

11. If you are going to analyse secondary data, from where are you obtaining it?

N/A

12. If you are collecting primary data, how will you identify and approach the participants to recruit them to your study?

Please attach a copy of the information sheet if you are using one – or if you are not using one please explain why.

The proposal will be discussed with the head teacher and deputy head teacher (who is also the science subject leader) at the school. The proposal and information sheet will be presented to staff and volunteers (teachers) will be asked for. The teachers will have the opportunity to ask questions about the research before agreeing to participate.

Interviewing children is part of the 'normal' school routines and as such the gatekeeper (head teacher) will provide consent to this activity in the first instance. However, parental and child consent will also be sought in advance of the research process and six children from each of the three classes will be selected to participate in the focus group activity but only if both parties (parent and child) have consented. Therefore, the selection will be drawn only from the children who have consented to take part and whose parents have also provided their consent. Some children may feel upset if they have not been chosen for the research so the researcher will make time to talk to these children so that they have been provided with a voice.

13. Will participants be taking part in your study without their knowledge and consent at the time (e.g. covert observation of people)? If yes, please explain why this is necessary.

Children will be informed that they are being observed during science lessons. However, the researcher is aware that videoing children will have an impact upon their behaviour. In order to limit the Hawthorne effect of observing children, the video recorder will be in place in the classroom for a period of time before data is collected for the research. Pupils will be provided with an information sheet which will explain the research to the children. The researcher will also orally explain the research aims to the children and will provide time for children to ask questions about the research and observations that will be undertaken. Children who are anxious about being recorded will not provide their consent to being videoed and the researcher will ensure that these children are not in the video (the class teacher will help the researcher in this process by ensuring that the researcher knows where children not being videoed are seated).

14. If you answered 'no' to question 13, how will you obtain the consent of participants?

Please attach a copy of the consent form if you are using one – or if you are not using one please explain why.

The information sheet attachment will provide enough detail for teachers to make informed decisions about whether or not to participate in the collaborative action research. There will be the opportunity for teachers to ask questions before they agree to participate. The three teachers will be provided with a consent form to sign at the start of the project which will include all data collection processes; consent to be observed, interviewed and agreement to discuss and reflect upon their teaching practices after the observation or in their reflective journals, which will be collected at the end of the data collection process. Throughout the research process, participants will have the right to withdraw.

According to BERA guidelines (2011) children should be facilitated in providing informed consent, therefore, a child friendly consent from will be produced to make the focus group aware of their role in the research. The class will be informed that lessons (or part of lessons) will be video recorded and analysed in order to assess the use of questions in the primary science classroom.

15. Is there any reason to believe participants may not be able to give full informed consent? If yes, what steps do you propose to take to safeguard their interests?

In order to gain informed consent from children in the focus group, a child friendly consent form will be produced and the researcher (or class teacher) will also orally explain why they have been asked to participate in the focus group. Children and teachers will be reminded that they have the right to withdraw at any stage should they wish to. Some children may be anxious that their comments will be shared with the class teacher and that there may be repercussions relating to the conversation. In the information sheet relating to the focus group activity children will be informed that the researcher will share some of the findings but that children's names will not be provided to the teacher. It needs to be acknowledged that teachers who are volunteering for the research are keen to develop their practices and will possibly be more 'open' to frank and honest dialogue concerning their practices.

16. If participants are under the responsibility or care of others (such as parents/carers, teachers or medical staff) what plans do you have to obtain permission to approach the participants to take part in the study?

Although children will not be the main focus of the study, the researcher will be video recording the full science lesson so a child friendly consent form will be produced. By observing the full science lesson, a deeper understanding of teacher's practices relating to questioning (during whole class discussions or groupwork) will be captured. As children will be video recorded it will be necessary to gain parental consent – see parental consent form. If there are any parents who do not wish to have their child video recorded then the child will remain out of camera shot for the duration of the videoing but will otherwise participate fully in the lesson. At the school, it is common practice to video-record lessons for CPD purposes, therefore, the children will not be doing anything that is outside the everyday practices of the school and their learning.

It is important to stipulate that all children will be engaged in the science lesson – there will not be different interventions for different groups of children – all children will be encouraged to participate in the lesson as is normal practice. The lesson will run as normal but only children who have consented and whose parents have consented will be in the line of the video camera. The teacher will ensure that the researcher is aware of children who are allowed to be video recorded.

A child and parental consent form will also be sought for those children who will participate in the focus group activity.

17. Describe what participation in your study will involve for study participants. Please attach copies of any questionnaires and/or interview schedules and/or observation topic list to be used

<u>Teachers</u>

Teachers will complete a semi-structured interview and short questionnaire at the beginning and end of the research project. It is anticipated that the interview process will not take any longer than 30 minutes for each interview and will be digitally recorded so that the researcher can check responses.

Science lessons will be video recorded on three occasions and teachers will be asked to support the researcher in the analysis of the lesson. It is anticipated that the analysis will take up to an hour for each observation.

Some teachers may choose to keep a reflective journal.

<u>Children</u>

The focus group activity will not take longer than about 30 minutes.

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18. How will you make it clear to participants that they may withdraw consent to participate at any point during the research without penalty?

Teachers

In the information sheet, which will be presented to teachers during the pre and post interview process and the right to withdraw will be detailed. After each of the three observations, teachers will again be orally reminded of their right to withdraw from the study.

Children

At the beginning and end of the focus group activity children will be reminded of their right to withdraw from the research process.

19. Detail any possible distress, discomfort, inconvenience or other adverse effects the participants may experience, including after the study, and you will deal with this.

It could be argued that the process of being observed and having the science lesson analysed will cause a degree of anxiety to the teachers being observed. However, as teachers will be involved in the analysis process, this may lessen the anxiety. As previously mentioned, the researcher has spent time working alongside teachers in the school so trusting relationships have already been established. It will also be made clear that the findings of the observations will not be shared with other members of staff.

20. How will you maintain participant anonymity and confidentiality in collecting, analysing and writing up your data?

The school where the research is conducted will not be named in the write up, nor will the names of teachers. Each teacher will be provided with a pseudonym in order to protect their identity. No information obtained during interviews or during observations will be shared with other members of the teaching staff at the school, and participants will be asked not to discuss who said what during the interviews with others outside the group. The interview transcripts will be stored on a password protected memory stick and computer and will be destroyed on completion of the research. The videos will be analysed on the school property and will be stored safely at school. The video of lesson observations will be destroyed on completion of the study.

21. How will you store your data securely during and after the study?

The University of Southampton has a Research Data Management Policy, including for data retention. The Policy can be consulted at http://www.calendar.soton.ac.uk/sectionIV/research-data-management.html

All interview, questionnaire and observations will be kept in accordance with the Data Management Protection policy. Data, in terms of transcripts will be stored on a password protected computer and memory stick and will only be accessible to the researcher and research supervisors.

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22. Describe any plans you have for feeding back the findings of the study to participants.

An executive summary will be offered to interested participants detailing the key findings of the research.

23. What are the main ethical issues raised by your research and how do you intend to manage these?

Anonymity and confidentiality are the key issues for the research – details relating to how these issues will be managed are detailed above. Although some children will be video recorded, it is important to note that all children will partake in science lessons as normal – those children being videoed will not benefit more than those not being videoed (all children will be working on the same set tasks and the teacher will work with these children as they would in a normal lesson).

Some children may be worried about talking to a researcher during a focus group – children will therefore have the right to withdraw at any time and their consent (as well as parental consent) will be gained.

Some teachers may be worried that the lesson observations will be shared with the head teacher so in the information sheets it will be made clear that this will not be the case. It will also be made clear that, if parts of their lesson transcripts are shared in research reports, their names as well as the school's and children's identities will be protected.

Children whose parents have consented to them working on the focus group but were not selected will have the opportunity to talk to the researcher should they wish to do so.

24. Please outline any other information you feel may be relevant to this submission.

As the researcher will have access to children, it needs to be highlighted that the researcher has a Disclosure and Baring Service (DBS) check (formerly CRB) in place. When working with children in a school setting, the researcher will be sure to work in an area that is visible to members of the school team.

The researcher is aware that teachers have high workloads and that analysing the observations will be time consuming – this process will be made clear to volunteers at the beginning of the research. The researcher will be flexible in terms of when lessons are observed and analysed.

The researcher will endeavour to communicate the findings in an honest and truthful manner. The data (and participants) will be treated in a respectful way.

Appendix 9 – Risk assessment

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September 2013

Risk Assessment Form

- Please see Guidance Notes for completing the risk assessment form at the end of this document.

Researcher's name: Deborah Wilkinson

Part 1 – Dissertation/project activities
What do you intend to do? (Please provide a brief description of your project and details of your proposed methods.) The overarching aim of the study is to work alongside three teachers in a junior school in West Sussex in order to support reflective practices in terms of the questioning skills they employ in the primary science classroom. The following research questions will be guiding the research:- 1. Does collaborative action research have an impact on teacher confidence and efficacy in promoting a classroom climate conducive to questioning in primary science lessons? 2. Does collaborative action research contributes towards the development of reflective practices and the subsequent pedagogy employed? 3. Is there a change in the types of questions posed as a result of collaborative action research? Methods 1. Focus groups with children from the classes of the three participating teachers will be undertaken. During the focus groups, children will be asked to discuss key questions such as their experiences of science at school, what they like and dislike about science and if there is anything they would like to do differently when undertaking science. The children will also be asked to participate in an activity task whereby they will be presented with an artefact (a Cartesian diver) and will be required to pose three questions that they would like to know the answers to. The focus group findings will serve as a starting point when interviewing the three participating teachers in order to share the children's perspectives regarding science as well as serving as a starting point when discussing the use and type of questions posed by children. Children will also be interviewed at the end of the action research cycle in order to gain their perspective relating to the use of questioning skills. 2. A semi-structured interview will be conducted in order to ascertain the views of participating teachers in terms of their confidence, understanding of pedagogy and the place of questions in science lessons. 3. The teachers will be required to complete a short questionnaire both pre and post intervention in order to help identify attitudes towards teaching science. As a result of the interview and questionnaire, teachers (with support from the researcher) will identify the focus for the action research (e.g. developing questions asked during the input of the lesson or how the use of puppets and/or concept cartoons support in helping children to pose and answer their own questions). 4. The cyclical process of action research will begin when each of the participating teachers has chosen a focus. There will be an initial observation followed by two further observations of a science lesson over a six month period (the observations will be spaced at two monthly intervals). The observation will be analysed alongside the

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teacher and if necessary, the teacher will identify any training needs or support they feel they may need.

5. Throughout the research process, teachers may decide to keep a reflective journal and if they feel that this will be beneficial to them, then support will be provided by the researcher.

Will this involve collection of information from other people? (In the case of projects involving fieldwork, please provide a description of your proposed sample/case study site.)

The sample will comprise of three primary school teachers who work in a Junior school in West Sussex. The school has been selected because I have worked with teachers in the school for a number of years (as a mentor to student teachers).

Focus groups of children will be will be randomly selected by the three class teachers who are participating in the research. There will be a maximum of 18 children involved (6 from each class).

If relevant, what location/s is/are involved?
A local junior school in West Sussex. The school is close to my place of work and is a school that I have worked with on a number of occasions. I am familiar with the school policies of the school. I have work insurance to cover travel to the school (I visit the school on a regular basis).

Will you be working alone or with others?
I will be undertaking interviews and analysis of lessons with a teacher on a one to one basis. The interviews and observation analysis will, however, take place in a school building and other members of staff will be present in the building.

Part 2 – Potential safety issues / risk assessment.

Potential safety issues arising from proposed activity?

Focus groups with children could cause potential issues in terms of alleged abuse, however, I have a Disclosure and Baring Service (DBS) check (formerly CRB) and will undertake the focus group activity in an open access area that can be seen and is used by other members of staff.

As I work with the school on a regular basis they have a copy of my DBS check.

Person/s likely to be affected?

Me and the children.

Likelihood of risk?

Very low.

Part 3 – Precautions / risk reduction

Existing precautions:

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I will ensure that other members of staff are present when I undertake the focus group tasks and when I am interviewing/observing lessons.

Proposed risk reduction strategies if existing precautions are not adequate:

N/A

CONTINUED BELOW ...

Part 4 – International Travel

If you intend to travel overseas to carry out fieldwork then you must carry out a risk assessment for each trip you make and attach a copy of the International Travel form to this document

Download the Risk Assessment for International Travel Form

Guidelines on risk assessment for international travel at can be located at: www.southampton.ac.uk/socscinet/safety ("risk assessment" section).

Before undertaking international travel and overseas visits all students must:

- Ensure a risk assessment has been undertaken for all journeys including to conferences and visits to other Universities and organisations. This is University policy and is not optional.
- Consult the University Finance/Insurance website for information on travel and insurance. Ensure that you take a copy of the University travel insurance information with you and know what to do if you should need medical assistance.
- Obtain from Occupational Health Service advice on any medical requirements for travel to areas to be visited.
- Ensure next of kin are aware of itinerary, contact person and telephone number at the University.
- Where possible arrange to be met by your host on arrival.

If you are unsure if you are covered by the University insurance scheme for the trip you are undertaking and for the country/countries you intend visiting, then you should contact the University's Insurance Office at insure@soton.ac.uk and check the Foreign and Commonwealth Office website.

Risk Assessment Form for International Travel attached	**NO**	**(Delete as applicable)**

Appendix 10 – Consent forms

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Parental consent FORM

Study title: The use of questioning in primary science: a participative action research study designed to develop reflective practices

Researcher name: Deborah Wilkinson

Ethics reference: 7469

Please initial the box(es) if you agree with the statement(s):

I have read and understood the information sheet [15/10/2013, V3] and have had the opportunity to ask questions about the study.

I agree to allow my child to talk to a researcher about their science lessons.

I consent to my child talking to the researcher about their science lessons in the school setting during a group interview.

I consent to my child having the opportunity to pose some questions that they would like to know the answers to when given an artefact.

I agree for my child to be video recorded during science lessons at school.

I consent to my child appearing on a video recording of their science lessons.

I have been made aware that the video will be analysed in the school grounds and the recording will not be removed from school property. My child will remain anonymous and the findings will only be used for research purposes.

Data Protection

I understand that information collected about my child during their participation in this study will only be used for the purpose of this study. I understand that data collected during this study will be stored on a password protected.

Child's name: ....

Parent/Guardian name: ....

Father ☐ Mother ☐ Guardian ☐ Other...........

Please return this consent form to your child's classroom teacher.

Thank you.

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Teacher CONSENT FORM

Study title: The use of questioning in primary science: a participative action research study designed to develop reflective practices

Researcher name: Deborah Wilkinson

Ethics reference: 7469

Please initial the box(es) if you agree with the statement(s):

I have read and understood the information sheet [16/10/2013, V3] and have had the opportunity to ask questions about the study.	☐
I agree to take part in this research project and having my science lessons video recorded on three occasions.	☐
I consent to working with the researcher in order to analyse the findings of the observations.	☐
I consent to being interviewed about my questioning skills.	☐
I am happy for the researcher to talk to children in my class about the use of questions in science.	☐
I understand that my responses will be anonymised in reports of the research	☐
I understand my participation is voluntary and I may withdraw at any time without my legal rights being affected	☐

Data Protection

I understand that information collected about me during my participation in this study will be stored on a password protected computer and that this information will only be used for the purpose of this study.

Name of participant (print name)..

Signature of participant...   Date...........................

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Pupil consent form

Study title: The use of questioning in primary science: a participative action research study designed to develop reflective practices

Researcher name: Deborah Wilkinson

Ethics reference:

I am happy to talk about my science lessons

I am not happy to talk about my science lessons

I am happy to be videoed during science lessons

I am not happy to be videoed during science lessons

Colour in the face that you are happy to agree with.

Your name (print name)..

Your class...

Date..

Appendix 11 – Information Sheets

Parental Information Sheet

Study Title: The use of questioning in primary science: a participative action research study designed to develop reflective practices.

Researcher: Deborah Wilkinson **Ethics number**: 7469

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

What is the research about?

I am undertaking a doctoral degree at the University of Southampton and this research study is part of my dissertation. The research focuses on the use of questions in the primary science classroom. I am keen to develop my understanding of the use of questions in order to support me in my role as a university lecturer in initial teacher training. I am also a qualified primary school teacher and have a valid Disclosure and Barring Service (CRB) check.

Why has my child been chosen?

I keen to establish how questions are applied in science lessons. Your child will have the opportunity to voice their opinion about their ability to ask and answer science questions during a group interview or during lessons. If you (and your child) consent to participating in the focus group activity then their name will be drawn from a hat and the first six names from the hat will form the focus group. However, if your child is not part of the focus group then they will have the opportunity to talk to the researcher about the use of questions should they wish to do so.

What will happen to my child if they take part?

There will be a group activity at the beginning of the research. If your child is selected and is happy to participate in the focus group, they will be asked to discuss key questions such as their experiences of science at school, what they like and dislike about science and if there is anything they would like to do differently when undertaking science. The children will also be asked to participate in an activity task whereby they will be presented with an artefact and will be required to pose three questions that they would like to know the answers to in relation to this artefact. The focus group activity will not take longer than about 30 minutes and will take place during the normal school day.

I aim to video science lessons on three occasions to establish the type and frequency of questions used in science lessons. The videos will be analysed with the class teacher at the school. The video will <u>not</u> be shared with external agencies and will <u>not</u> be in the public domain.

Are there any benefits in my child taking part?

If your child is selected for the group activity they will have the opportunity to discuss their learning.

Are there any risks involved?

There are no risks associated with participation in this study. The data collected will only be used for academic purposes and children will remain anonymous. The video will remain on school property and will be destroyed on completion of the research. Some children may be anxious about talking to a researcher about their experiences in science. The outcomes of the focus group will be shared with the teacher but children's names will not be linked to any comments.

Will participation be confidential?

The school where the research is conducted will not be named in the write up, nor will the names of teachers or children. The videos will be analysed on the school property and will be

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stored safely at school. The videos will be destroyed on completion of the study. All data will be kept in accordance with the University of Southampton Data Management Protection policy.

What happens if I change my mind?
Participation in this study is entirely voluntary. You may withdraw your child from this study at anytime.

What happens if something goes wrong?
In the unlikely case of concern or complaint, please contact Dr Martina Prude, Head of Research Governance (02380 595058, mad4@soton.ac.uk).

Where can I get more information?

If you have any questions about the research project and your child's participation please contact me using the e-mail detail below. I will be happy to answer your questions, either by e-mail, phone or in person. If you would like to contact the research supervisors for the project then they can be contacted using the following e-mail addresses:-

Andri Christodoulou - A.Christodoulou@soton.ac.uk
Marcus Grace – m.m.grace@soton.ac.uk

Deborah Wilkinson (e-mail:- dw1c11@soton.ac.uk or telephone:- 01243 812152)

Teacher Information Sheet

Study Title: The use of questioning in primary science: a participative action research study designed to develop reflective practices.

Researcher: Deborah Wilkinson **Ethics number**: 7469

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

What is the research about?

I am undertaking a doctoral degree at the University of Southampton and this research study is part of my dissertation. The research focuses on the use of questions in the primary science classroom. As part of the research I am aiming to adopt a collaborative action research approach whereby teachers are able to reflect upon their practices in relation to the use and types of questions adopted during science lessons. The overriding research questions are as follows:-

1. Does collaborative action research have an impact on teacher confidence and efficacy in promoting a classroom climate conducive to questioning in primary science lessons?

2. Does collaborative action research contribute towards the development of reflective practices and the subsequent pedagogy employed?

3. Is there a change in the types of questions posed as a result of collaborative action research?

As the research is collaborative, you will have the opportunity to decide upon what part of your practice they would like to develop (e.g. the use of puppets or concept cartoons, supporting children in asking and answering their own questions etc.).

Why have I been chosen?

I am approaching teachers in your school because I feel that trusting relationships have been established. Trusting relationships are a key variable when undertaking collaborative action research and feel that working with you will be beneficial to both parties. Your voluntary participation in this study is greatly appreciated.

What will happen to me if I take part?

You will be asked to complete a semi-structured interview and short questionnaire at the beginning and end of the research project. It is anticipated that the interview process will not take any longer than 30 minutes for each interview and will be digitally recorded so that I can check responses.

As part of the action research cycle it is anticipated a science lesson will be video recorded on three occasions. The part of the lesson to be videoed will be determined by you and will be dependent upon the practices that you have chosen to reflect upon (it may be focused on how the children use questions during the main part of the lesson or on the introduction. In both instances an aim will be to analyse the types of questions employed and the impact of these). After the observation you will be asked to watch the video and engage in discussions with regards to how questions were used. It is anticipated that the analysis will take up to an hour for each observation.

Some teachers may choose to keep a reflective journal throughout the research process

There will be a focus group activity with children from your class at the beginning and end of the research process. During the focus groups, children will be asked to discuss key questions such as their experiences of science at school, what they like and dislike about science and if there is anything they would like to do differently when undertaking science. The children will

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also be asked to participate in an activity task whereby they will be presented with an artefact and will be required to pose three questions that they would like to know the answers to. The focus group findings will serve as a starting point when interviewing you in order to share the children's perspectives regarding science as well as serving as a starting point when discussing the use and type of questions posed by children. The focus group activity will not take longer than about 30 minutes.

Are there any benefits in my taking part?
It is hoped that you will have the opportunity to reflect upon your science teaching, to learn more about the value of questions, how they are used in lessons and the impact of using different question types on the learning process. The research comes at a time of much curriculum change – the new science curriculum is very subject knowledge driven and this has the potential to impact upon pedagogy.

Are there any risks involved?
There are no risks associated with participation in this study. The researcher is aware, however, that having a lesson videoed may cause some anxiety. The data collected will only be used for academic purposes and you will remain anonymous. The findings will not be shared with other members of teaching staff in the school.

Will my participation be confidential?
The school where the research is conducted will not be named in the write up, nor will the names of teachers. Each teacher will be provided with a pseudonym in order to protect their identity. No information obtained during interviews or during observations will be shared with other members of the teaching staff at the school. The interview transcripts will be stored on a password protected memory stick and computer and will be destroyed on completion of the research. The videos will be analysed on the school property and will be stored safely at school. The video of lesson observations will be destroyed on completion of the study. All interview, questionnaire and observations will be kept in accordance with the University of Southampton Data Management Protection policy.

What happens if I change my mind?
Participation in this study is entirely voluntary. You may withdraw from this study at anytime.

What happens if something goes wrong?
In the unlikely case of concern or complaint, please contact Dr Martina Prude, Head of Research Governance (02380 595058, mad4@soton.ac.uk).

Where can I get more information?
If you have any questions about the research project and your participation please contact me using the e-mail detail below. I will be happy to answer your questions, either by e-mail, phone or in person.

I can let you have a summary of the findings if you are interested.

Deborah Wilkinson (e-mail:- dw1c11@soton.ac.uk or telephone: 01243 812152)

Appendix 12 – Puppet training input

University of Chichester

Professional Science

Puppets in Science

Research about puppets in science can be found in:

- Teaching Earth Sciences (2006) 30, 2, 26
- Primary Science Review (2006) 92, 26-28.
- Paper presented at the Australasian Science Education Research Association Conference, Freemantle, Australia, July 2007.
- Paper presented at the European Science Education Research Association Conference, Malmo, Sweden, August 2007.
- Naylor S., Keogh B., Downing, B., Maloney, J. and Simon, S. (2007) The Puppets Project: using puppets to promote engagement and talk in science. In R. Pinto and D. Couso (Eds) Contributions from Science Education Research, p289-296. Springer.
- Paper presented at the Nordic Research Symposium on Science Education, Reykjavik, Iceland, June 2008.
- Naylor S., Keogh B., Downing, B., Maloney, J. and Simon, S. (2008) International Journal of Science Education.
- Naylor S., Keogh B., Maloney, J. and Simon, S. (2008).

All of this research can be found in one easy place: http://www.puppetsproject.com/research.php

The research

These findings come from:

International Journal of Science Education. Vol. 30, No. 9, 2nd July 2008, pp. 1229-1248.

- Value of talk in children's learning has been well documented – close links between Vygotsky's (1962, 1978) social constructivism and zone of proximal development.
- Exploratory talk makes children's knowledge and reasoning visible – but they must feel confident to voice their opinions.

So what does the research say?

- Exploratory talk has been shown to develop scientific arguments and conceptual understanding.
- Big problem – this kind of talk is absent in many classrooms. This could be due to a number of factors:
  - Pressure on [illegible] curriculum
  - Focus on written recordings
  - Teacher subject knowledge
- The teacher has a central role in promoting the 'learning conversation.
- Scientific understanding is developed through a combination of teacher-led interactions and peer interactions.

So what does the research say?

The right kind of talk is where teachers and children address learning tasks together and talk is reciprocal, supportive and purposeful.

- Stimuli needs to get children personally involved. Examples of effective stimuli:
  - Grouping and classifying
  - Concept Cartoon
  - Graphic Organisers
  - Predict – observe – explain
  - True – false statement

How do you maintain 'the right type of talk' e.g. dialogic?

- Puppets have an impact in 3 distinct ways:
  - On the nature of discourse in both teacher-child and child-child interactions.
  - On the engagement and interest of children.
  - On teachers' beliefs and practice.

So why puppets?

EYFS

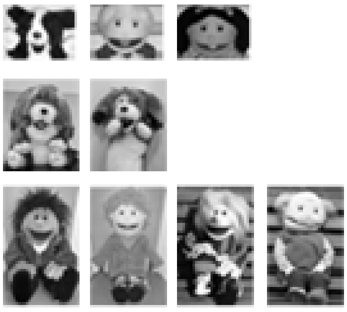
- Problem Pup

Key Stage 1

- Discovery Dog

Key Stage 2

- Spellbound Science



What puppets are available?

EYFS

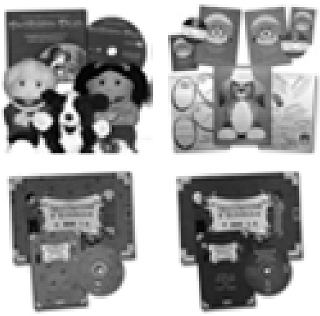
- Problem Pup

Key Stage 1

- Discovery Dog

Key Stage 2

- Spellbound Science



What resources are available?

So how do you use the puppets?

- Introduce your puppet to the class before you want to use it for science. Have a back story.
- Your puppet must be part of the class and have a place to sit when they are not being used.
- Once children get to Year 3 you need to start using human puppets.
- Remember you are not the sole user of your puppet. You may use your puppet to set up the problem and then it may work with a group of children.

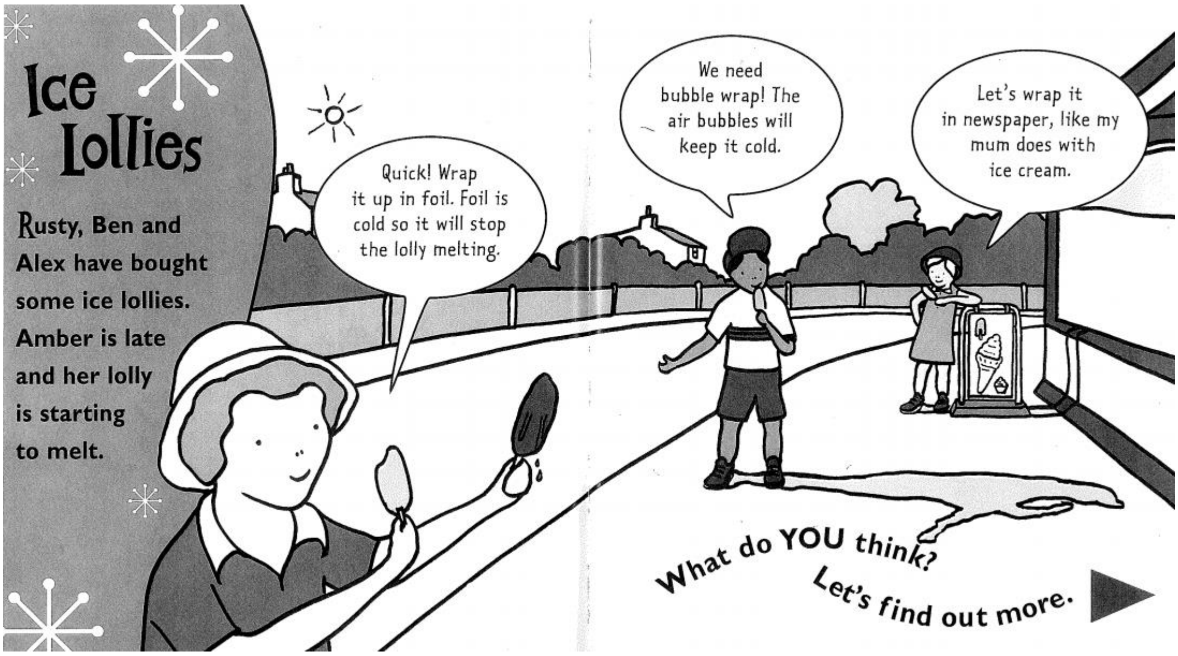
Top tips

- Consider how your puppet will introduce the problem, what is the story? Is it something the children can relate to?
- Remember your puppet is always the weakest scientist in the class and never the expert.
- Ensure your puppet makes eye contact with the children and you make eye contact with the puppet when it is speaking.
- You don't need to put on a different voice.

Top tips

Appendix 13 – Modelling how to use a concept cartoon alongside Ricky

The session began by considering material science and we looked at a concept cartoon relating the insulators (see below) from the book Bungee Jumpers and other science questions by Naylor and Naylor (2000).



It was suggested that Ricky could take one of the viewpoints which could be developed and presented to the class in the form of a problem or story.

The story was along the lines of Ricky loves ice lollies and often makes his own lunch in the morning. One day he decided he would like to have an ice lolly for break time so he took a lolly out of the freezer and put it into his lunchbox. His Nana said it would melt and that he should put some material around the lolly to stop it melting. Ricky thinks it will melt faster because he gets hot when he puts his coat on. What do you think? Do you think different materials will make a difference?

Appendix 14 – Transcript coding example of the Year 3 focus group

Children came out and were encouraged to play with the Cartesian divers. These were arranged on the table; one between two. Children came out and shook the bottles – they were then asked to squeeze the bottles.

It goes up and down

It goes up again

It goes down and when you let go, it goes up again

Magic

Look, this only goes down.

Yes, look at the blue one.

Right, what do you notice then, what is happening?

That when you push down, it (tomato ketchup) goes down.

So when you have the bottle upright (modelled to show what upright means) do both the sauces (mayonnaise and tomato) go down and back up?

Only the tomato sauce goes up and down but the blue one says at the top.

Right I have got a bigger bottle; it has got tomato sauce, mayonnaise and brown sauce sachets in it. What do you think will happen when we squeeze the bottle?

I think the tomato sauce will go down because it did in the little bottle.

I think the ketchup and brown sauce will go down because in McDonalds I tried it with my fruit drink and it basically… (Stopped)

You will have to help me squeeze the bottle because I am not very strong ready, steady, SQUEEZE!

What happened?

The black one wins.

A bit like a game of wacky races – shall we try that again just to make sure that we have observed carefully?

Do you think the brown sauce will win again?

Yes

Ready, steady, SQUEEZE!

What happened? What did you observe?

The brown sauce shot to the bottom.

Yes, it beat the tomato sauce!

Okay, I would like you to have a bit of talk time. I would like you to work in pairs and to think of a question that you would like to know the answer to about what we have just seen.

Children continued to play with the Cartesian divers

Appendix 15 – Transcript coding example of Jack's lesson in January

Line	Speaker	Words spoken	Code	Comments
1	Teacher	We'll be carrying on with our learning in science. Let's have a quick reminder of our learning in science this term	Not a question but open ended statement.	Recapping on prior learning – making links between sessions. Used to assess knowledge to date.
2	Sam	That North and North can't sick together and South and South can't stick together but North and South stick together.	Recalling prior learning	
3	Teacher	Are you going to use scientific vocabulary? You are absolutely right in what you said but tell me again.	Closed. Classroom Org.	
4	Sam	North and North can repel and South and South repel but North and South attract.		Few hands were up – children given a chance to talk in pairs – value of paired shared talk.
5	Teacher	What have you learned? (directed at another child)	Open Information	Low cognitive demand – little jeopardy on child. Seeks information
6	Jess	North and South attract because they have magnetic metal inside them, which literally means that when you push them they will attract and turn around.		
7	Teacher	Yes, if you put magnets on a smooth table, they will spin around.		
8	Teacher	What do we mean by magnetic materials?	Person Information	
9	Tia	They attract		
10	Teacher	What materials are magnetic?	Closed Information	
11	Tia	Metals		
12	Teacher	What metals?	Closed Information	
13	Ellie	Steel		Develop Subject knowledge
14	James	Iron		

15	Katie	Brass		
16	Teacher	Is brass magnetic?	Closed Information	Did not unpack why not.
17	Katie	No		
18	Teacher	Something else?	Open Information	
19	Matt	They don't stick to rocks		
20	Teacher	Is that always true?	Closed Defining	
21	Matt	No. Some metals don't stick to metals		
22	Teacher	Do you mean magnets?	Closed/person Defining	
23	Matt	Some rocks can attract to magnets		
24	Teacher	Yes, some rocks are magnetic. I've got an important problem that I need help with. My friend Roger works at a recycling plant and he has a problem. Roger is a crocodile and he is rubbish at science but we know you are really good and he has made a video to show you his problem. I want you to watch the video and see what Roger's problem is. Watched video What is Roger's problem?	Open Explanatory	Quite a few variables to manipulate. A little confusion – what puppet? Value of having tins in class for children to use senses to explore?
25	Bradley	When my dad took me to a recycling plant I saw a big crane with a magnet. Once I saw a can fly up		Nice contextual link t0 everyday life – child attempting to apply learning – higher ordered thinking.
26	Teacher	What do you mean it flew up?	Open/Person Explanatory	Language being used?
27	Bradley	It's magnetic		
28	Teacher	Did all the cans fly up?	Closed Information	
29	Bradley	Um, some of them have.		
30	Teacher	What about the other ones?	Closed Information	

Appendix 16 - Transcripts of interviews with Jack

Interview 1 - Jack

Do you have any A 'levels in science? Do you feel that having a science background makes a difference to teaching science?

I have A' level biology and I think that this helps me to provide children the chance to learn from investigations. If I was not so confident I think I might be more likely to use work sheets.

Primary science - what does it mean to you?

Discovery – I guess… children working together and finding stuff out.

Philosophy for science

I am concerned that they are not using enough [radical science approaches so are not really constructing their understanding enough. When I first started reaching I thought that science should be open… here is an idea now off you go but that doesn't seem to work with Year 1. I want to be generally steering children but I find myself dragging them to where I want them to be. I guess my philosophy is changing. I used to think it should be really open. Here is an idea, now off you go but that doesn't seem to work with Year 3 anyway. So I don't know really. I am trying to find a balance between really open ended and very scaffold investigations.

Teaching approaches are you aware of?

Concept cartoons, puppets. I like to give science a purpose and finding an answer to a problem.

Place of questions in science?

I think it is important to teach children to question and not to just accept the answers. So if they read a newspaper they will question things. For example, if they see an advert and I want them to think … that doesn't sound right. I want them to be more scientifically literate.

Areas of development for you?

I want children to ask questions but they need to be taught how to ask questions. I hadn't really thought about that until today. I may need to model and say how it will be answered through types of investigations. I guess I could use a working wall to show the question types.

Discussion relating to lesson 1 and the focus group task

Let's look at the focus group transcript. I'm not sure if the observation skills are great. You need to develop observational skill before you can develop their questioning skills.

Yes, it is something that needs to be taught rather than caught and that questions can be answered through investigations.

Children are only asking quite a limited number of questions in relation to the Cartesian diver

I am not surprised by the types of questions that children were asking.

Why?

Children are more familiar with answering questions rather than asking them.

It was great that in the lesson you provided children with time to explore the magnet and to use their observations

Yes, but children were off task and not doing what I expected them to do.

Yes, you worked really hard during the lesson. Look at how much talking and questioning you were doing. The children were only giving you short answers.

It took a long time for children to comprehend what they needed to do.

I don't know, but maybe you could have provided children with some sort of scaffolding. You mention that you have used concept cartoons… maybe you could have put some different questions or thought on the board and encouraged children to think about the answers using their explorations.

How do you feel that the plenary went?

The children did not really explain their results

You could have provided opportunities for children to compare their findings . this would have been useful as the children were working on different investigations to find the strongest magnet.

I noticed that you used a puppet

Yes, in the video… but with hindsight it would have been better had I had the puppet in the class so that I could model the problem to the children and repeat things if needed. It took a long time for children to understand what they needed to do. I'm not really sure what is going on in their groups – it would be interesting to focus on the talk… I am unsure of how to plan for classroom talk and questioning.

Would you like to develop the use of a puppet?

Yes, that would be an interesting idea. I guess it would support children in providing opportunities for children to compare their findings and so forth.

The puppet can give you the licence to ask quite naïve questions so this may change the type of dialogue in your lessons. If the puppet had been sorting and testing the cans in front of the children, they may have responded differently. Research seems to suggest that children will engage with a puppet.

Originally we all did science at the same time so that video kept that part of the lesson the same but that is a silly reason really. We would have been better off with the actual puppet as you mention.

Mentioned how to use puppets

Discussed different question types and coded the lesson using the coding scheme.

Mid-point discussion

How have you found using the puppet?

It has been well received. Children are keen to talk to the puppet and they respond sensitively when he looks confused or excited. As Ricky is the weakest scientist, children seen keen to help him. Because the puppet found science challenging, the children took care to ensure that they used scientific language correctly and that they reasoned and justified their thinking and this seemed to clarify their thinking. The puppet has helped me to dispel misconceptions because I can think aloud ideas using the puppet…I was able to use the puppet to seek clarification. Ricky is still confused, can you explain that to him again.

Has it changed your questioning?

I guess it has made me think about the different types of questions. I think the strength is that it allows me to challenge thinking. The puppet has not made a difference to children's questions yet.

Maybe you could place the puppet on a table when you have posed a challenge or work with the puppet during group work. The first approach maybe should be to help children to understand that there are different questions and that their matter. Alternatively you could use the plenary to model asking a range of questions.

Yes, I guess, it would be good to move away from the idea that the teacher asks the questions.

Time was spent looking at plans and considering where comparative questions could be asked.

Interview 3

We started by coding the transcribed lesson and questions developed as a result of the discussion including identification that a wider range of questions had been posed.

Why had you used the concept map?

I feel that it will help children to have a clear focus for their observations…to help them to compare the different rock…this would be needed later in the lesson when they looked at Colin's letter. I realised that it would help to focus them.

Looking at the transcript children seem to able to raise an investigation – there were fewer classroom management questions being asked. You were also asking some interesting comparison questions during the main part of the lesson

Yes. children are definitely thinking carefully about concepts and how to plan an investigation. The productive question which rock was best was good.

Why?

It helped children to think about what best would mean to them.

How do you feel the puppet the puppet helped in this lesson?

Using the puppet in tandem with the concept cartoons was very productive as it gave the lesson real focus. Ricky was really a tool to support children with their ability to reason and use scientific language.

Yes, they seemed to be using their skills of observations – one child referred to the grain sizes and the physical properties of rocks to support her answer.

I also feel that I am also beginning to slow down the pace and am giving children longer to answer.

Why does this help?

They have more thinking time. Their answers seem to be longer. (Looked at the script for examples of where children were providing more reasoned answers and using dialogic bids)

At this point, Jack referred to lesson plans he had previously produced relating to material and plant science to explain why the puppet was a useful teaching tool.

It was not the best lesson that I have taught using Ricky. These lessons were better. Ricky had some ideas for uses of materials... a chocolate teapot. The children explained why the characteristics of his materials were unsuitable and made more appropriate suggestions.

<u>Do you think that there are some investigations that are better at supporting children's questions?</u>

Yes, the pant lesson was really good and children asked questions and then had the time to investigate.

Shared feelings of children when using Ricky

<u>So do you felt that your questioning is beginning to change?</u>

Yes, I think about the questions that I will ask (referred to plans on materials and plants) and I am giving children longer to answer. I don't feel that I have consolidated children's questioning skills but I intend to keep using Ricky and the concept cartoons.

<u>Great – you could also keep modelling the comparison questions during the plenary and ensure that children have the chance to do different types of investigations.</u>

Appendix 17 – Summary of Transcript analysis of Jack's lessons

(All questions were initially coded as either open or closed)

(Some questions were also coded as person centred)

Question Type	Code	Lesson 1		Lesson 2	
		Number	%	Number	%
Closed	C	40	68	25	58
Open	O	19	32	18	42
Explanatory	E	10	17	22	52
Classroom organisation	CO	20	34	3	6
Productive	PR	13	22	3	6
Comparison	COMP	0	0	3	6
Person centred	PC	6	10	10	4
Problem Solving	PS	0	0	3	6
Defining	D	2	3	5	12
Information	I	14	24	5	12

Appendix 18 – Lesson plan on materials

TOPIC: Magnets and Springs

YEAR 3 SUBJECT: Science TERM: Spring Week 1

Learning Intentions	POS/AT	Activities	Key Ideas	Resources	Time	Learning Outcomes
Assess children's current understanding **To learn that materials can be sorted according to their characteristics** **RED ON THE PLANNING DENOTES WHERE JACK HAS PLANNED FOR TALK.**	Sc1: 1a Sc1 : 2a Sc 1: 2j Sc1: 2l Sc4: 2b Sc4: 2e	**Pre topic assessment:** Model making a concept cartoon on the board, first jotting down children's knowledge, then linking spate ideas and justifying those links. Children will work in pairs and will be encouraged to talk about their understanding. Teacher to work with Ricky and a group of children (Ricky will be used to ask questions to the children) Show children a selection of objects made of a variety of materials. Use Ricky to sort the objects according to the materials. Ricky will initially sort according to the object but the teacher will explain that he needs to consider the material carefully and to link abut scientific language. Ricky will sort according to colour and the teacher and children will help Ricky to use language associated with material science. Teacher and children will come to a clear definition of what a material is. Look at objects again and encourage children to explain to Ricky what the different objects are made from and the properties of the materials (heavy, light, strong, brittle, flexible, shiny, dull etc.) allow children to work in groups to sort the materials according to their own criteria – work in groups and use a large piece of sugar paper in order to encourage children to talk. Teacher and Ricky to work with a group (Ricky to help sort materials). Provide children with a problem – what is the best material for a teapot. Ricky will state that chocolate would be good. Children to be encouraged to explain why this would not be suitable. Ricky will present children with a range of naïve inventions for children to work through.	Materials are selected for different purposes based on their properties	A selection of random objects made from different materials	2 hours	To learn that materials can be sorted according to their characteristics Materials are selected for different purposes based on their properties.

Appendix 19- Lesson plan on plants

TOPIC: Helping plants grow well

YEAR 3 SUBJECT: Science TERM: Summer Week 1

Learning Intentions	POS/AT	Activities	Key Ideas	Resources	Time	Learning Outcomes
To understand the roles of different parts of the plants RED ON THE PLANNING DENOTES WHERE JACK HAS PLANNED FOR TALK.	Sc1: 2c Sc1 : 2d Sc 1: 2g Sc1: 2h Sc1: 2i Sc1: 2j Sc1: 2k Sc2 1d Sc2 2a	Ask the children to imaging it's a really hot day and they've been running around. How will they be feeling? Talk about how they need water to stay healthy and that plants are the same. How do people and plants get water? What about animals? Ricky to make some suggestions that the children will discuss. Use Ricky to introduce his thinking (use a concept cartoon to stimulate talk) Children to talk in pairs and to justify their thinking. Take the children to the quiet garden. Each group is to collect a weed – it is important that we get the roots up as well so model this carefully (Help Ricky to understand the parts of the plant). Explain to the children that we need to set up an investigation to see if we can show that liquid is taken in through the roots. Ricky to ask if he can use something other than water – he thinks that they might like coke! Encourage children to explore and pose other questions that they would like to find out (children will have been exposed to water. Children to set up their investigations.	Most life on this planet gets its food directly or indirectly from the sun	A beaker, water, cling film elastic band, concept cartoons, weeds, Ricky, a range of different liquids	2 hours	To understand that the different plant parts have different roles To understand that the roots take up water from the soil.

Appendix 20 – Transcript coding example of the Year 6 focus group activity

RED = Researcher

The Cartesian divers were arranged on the table (one between two and the children were encouraged to explore.

It's going back up

It's coming up

Leave it

How long does it take to come back up?

Shall we count?

1,2,3,4,5, 5 Seconds

Look at your bottle compared to our bottle.

Ours took three seconds to come back up.

I introduced the large bottle with three sauces. Let's look at this a bit harder. There are three sauces in this bottle.

Wow!

You will all need to help squeeze the bottle.

Shall we squeeze it in the same place?

Do you think that will make a difference?

Let's try.

Children squeezed in the same place.

Guys look how long it took to get down and come back up.

Don't put your hands all over it. We won't be able to see…

Who wants to count the brown sauce time?

I'll do the mayonnaise, it won't go down.

Does it matter how you squeeze the bottle?

Quite hard I think, otherwise the water won't…

1,2,3. The brown sauce was first.

Can you maybe make the sachets stay in the middle of the bottle?

Explored. They squeezed the small bottles and compared how quickly the sachets went up and down.

In pairs, think about a really good question that you would like to know the answer to. So think about what you have observed when you have explored the Cartesian divers. What might you like to investigate?

Why doesn't the mayonnaise do down and why do the ketchup and brown sauce go down?

Maybe change the liquid?

Change the shape of the bottle.

So change the type of liquid or the shape of the bottle? Okay.

Maybe use differ types of sachet.

Tell me more.

Mc Donalds food has lots of salt in it so maybe a Mc Donalds sachet will sink because it has a lot of salt in it.

So are you saying that we could have different brands of tomato sauce and observe to see if they all go up and down?

Yes. We could investigate that.

Appendix 21 – Transcript coding example of Rob's lesson

Line	Speaker	Words spoken	Code	Comments
1	Teacher	In science so far this term, what have we looked at?	Open Info	Low cognitive demand – limited jeopardy on part of learner
2	Amy	We went outside to look at materials and animals		
3	Teacher	So why did we go outside to look at materials?	Open/Info.	
4	Tom	We looked at insects and where they are found		
5	Teacher	What did we call them? Not insects, we called them something else. Something specific.	Closed Info	
6	Eddie	Mini-beats		
7	Teacher	Excellent, we were looking at somewhere where they live – what do we call an area where animals live? We don't just say it lives there, we call it something else.	Closed Info	
8	Eddie	A habitat		
9	Teacher	Last week we looked at specific animals in two very different areas of the worlds. What did we look at?	Closed Info	
10	Evie	Did we look at a camel and a polar bear?		
11	Teacher	Excellent, we looked at a camel and a polar bear. Two very different animals with very different adaptations. Can anyone describe the adaptations of a camel maybe? What did you find out about a camel last week? Can you describe it? How were they adapted to live in the environment?	Open/ person Info	Three questions posed in quick succession – paraphrasing of the question – same answer required
12	Stephen	If they are in a cold environment they eat snow for water		
13	Teacher	Good, excellent. They eat snow so they can recuperate some of their water.		Rephrasing so that all learners could hear the response.
14	Emma	They have a snappy nose		
15	Teacher	Why do they have a snappy nose?	Open/ Explanatory	
16	Emma	So sand doesn't go up it.		
17	Teacher	Excellent, so in the desert in a sand storm they have a flappy part on their nose so sand doesn't go up. Any other parts we can describe? What does a camel have that most animals don't?	Closed/info	
18	Harry	A hump		
19	Teacher	Why?	Open/explore	
20	Harry	To store water		
21	Teacher	Anything else?	Open/info	
22	Alex	Fat		
23	Teacher	Why would you have fat?	Closed/info	
24	Alex	To keep you warm		
25	Teacher	To keep you warm at night because in the desert it gets very cold at night.		
26	Alex	Does it turn into food?		Child question seeking information
27	Teacher	Yes, they could metabolise the fat into food –		

		they could use it as a store so there is water and food in the hump.		
28	Teacher	What other things?	Open/info	

Appendix 22 – Interview transcripts with Rob

Red – interviewer

Do you have any s levels in science/ Do you feel that having a science background makes a difference to teaching?

Yes, biology and chemistry A'levels. Yes, I feel better equipped to answer questions

What does primary science mean to you?

A basic level of understanding of different concepts.

Philosophy?

I want them to understand facts but I want them to ask their questions so instead of me telling them, they found out. I want them to discover things first hand…to do lots of investigations because they pose the best opportunity for children to be physically active rather than being passive learners whereby they just forget the lesson. I want them to understand the facts but also ask questions…so instead of me telling them the answers, they find out for themselves.

Pedagogy?

Lots of investigations because they pose the best opportunities for children to physically do things rather than being passive.

Hands-on. Research skills are important not just goggle. Guided questions are good… having question about pictures has been an approach that I have found useful.

How do you use questions in science?

Really important for them to ask. I want them to be curious about the world …to challenge ideas. A lot of the science work seems to be worksheet based so they don't have the chance to set up their own investigations to answer their questions.

Do children ask their own questions?

It is mainly me asking questions because of the way we teach…children don't know how to ask questions.

Do you plan science in teams?

Science is planned by a member of the team.

Area for development?

To develop children's questioning skills.

Interview 1

Modelling the skill of observation so that they develop the skill. It is important children are able to observe carefully so that they are stimulated to ask questions. The tree snake helped children to observe.

Maybe you could have asked 'why' or allowed children the chance to pair talk about questions they might like to know about the snake in relation to the appearance of it. Do you ever use artefacts?

No, not really, I just use the interactive whiteboard. Sometimes I use a video clip and that works well but time can be a factor. I often ask questions using pictures as stimulus…this is important because children don't know how to ask questions because of the way we teach…children don't have time to set up their own experiments to answer their questions.

It is just that the children in the focus group seemed to respond well to the Cartesian diver and were able to talk and ask questions. They seemed very capable of asking questions …these often linked to manipulating variables. They seem vary able to undertake fair testing.

Yes, much of the learning I linked to fair testing.

Are teachers aware that there are other types of investigation other than fair testing?

I wasn't until you did a staff meeting… when I was at school the science tended to be linked to fair testing. I guess that is the same for most of us and that might be how we think science should be taught.

Yes, different questions can be answered in different ways … the poster investigation posters can help to remind teachers of the different types of investigations.

How would you like to improve your practice?

We had thinking cubes introduced to us during a staff meeting. I'd like to use these to develop children's questioning skills.

This followed a discussion of investigation types.

Interview 2

How have thinking cubes supported children in raising their own questions?

They are useful for judging the cognitive level that children are working at because it links to Bloom's taxonomy. Before I used the thinking cubes I asked children to write a question on a piece of paper and throw it to someone else. To start with the questions were a bit silly but because we talked about the questions they became better.

How have your questioning skills changed?

I have a better awareness of question types but I have not really changed my questioning approaches. I still use the beginning and end of the lesson to check children's understanding. I am a bit reluctant to change because I need to be sure that children have the level of knowledge at the end of the unit of work. As I don't do science on a daily basis children forget so I need to remind them of the previous learning.

Could this be due to the way in which lessons are planned? Maybe if you had problems for children to work on then they may remember the previous lesson.

Time was spent discussing evolution.

Interview 3

Time was spent coding questions and discussion arose from this.

Key themes included Rob being aware that he was not using the full range of questions. He was aware that Lesson 2 was not the right sort of lesson to generate high cognitive demand type questions. He said that being in Year 6 definitely makes a difference to my teaching. It is so pressurised that I often see science lessons as a bit of a release for children, a bit of down time. However, we have to do pre an post tests for each unit of work so that we have evidence and that can be a pressure because we need to show that children have learnt the subject knowledge.

Appendix 23 – Summary of transcript analysis for Rob's lessons

Question Type	Code	Lesson 1		Lesson 2	
		Number	%	Number	%
Closed	C	15	33	13	50
Open	O	30	67	13	50
Explanatory	E	13	29	3	12
Classroom organisation	CO	6	13	1	4
Productive	PR	0	0	0	0
Comparison	COMP	0	0	0	0
Person centred	PC	9	22	7	26
Problem Solving	PS	0	0	0	0
Defining	D	1	2	1	4
Information	I	25	56	21	80

Appendix 24 – Woolly worms

From Weavers, G. (2012) *Look, think, Talk*. Millgate Publishers, Cheshire.

What it is

In this lively activity small pieces of coloured wool, representing caterpillars, are scattered over the school field and/or shrubs. Children investigate which colour of caterpillar is most easy or difficult to locate. If the school does not have easy access to a green field, a large piece of fabric laid out in the school hall is a suitable substitute, although wool colours and the amount of time allowed may need to be adjusted, as this is less of a challenge for the children.

This activity helps children to learn about the role of adaptation in both plants and animals. It can be used as a precursor or a follow-up to work on food chains.

Resources

You need:

- a collection of wool strands, each about 4 cm long in a variety of colours and shades (there should be the same number of strands of each colour)
- Tally Chart 1 so children can record how many colours of each type were found. It is on the CD.

Explore your school field beforehand and check for potential hazards, such as animal waste, broken glass and so on. Provide disposable gloves for the children or ensure children understand the need for effective hygiene and hand-washing after the activity. (Child size disposable gloves are available from equipment suppliers.)

Appendix 25– Thinking cubes

Taken from - http://www.thinkingdice.com/

Remembering Dice (Yellow)

This is Bloom's lowest level of thinking.
Enables recall of information.

Understanding Dice (Orange)

Bloom's second level of lower order thinking.
Promotes explanation of ideas or concepts.

Applying Dice (Red)

Transition level fron lower order thinking higher order thinkin
Engages pupils in usi information in anoth situation.

Analysing Dice (Green)

Higher order thinking.
Encourages the child to break information into parts to explore understanding and relationships.

Evaluating Dice (Blue)

Higher order thinking.
Guides the child to justify a decision or course of action.

Creating Dice (Purple)

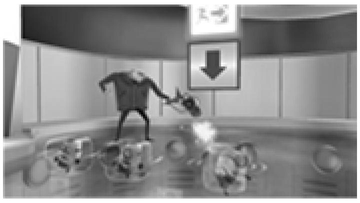
Higher order thinking.
Challenges the child to generate new ideas, products or ways of doing things.

Appendix 26 – Concept cartoon input

University of Chichester

Professional Science

Using concept cartoons

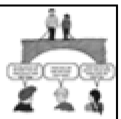


Put material around the ice prison ... it will warm it up and melt it.

The material will stop the ice from melting.

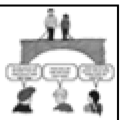
The material will not make any difference.

Keep the minion in the ice for as long as possible



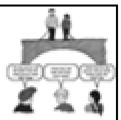
- Cartoon style drawings putting forward a viewpoint about science involved in everyday situations.
- Not normally humorous
- Provoke discussion and stimulate scientific thinking
- Don't provide a single 'right answer' – but provide a reasonable conclusion that often begins with 'it depends on'. This has developed over time.
- Started in 1992, as an INSET and has been developing ever since … for example shift from single statements to alternatives, no facial expressions etc.

What are Concept Cartoons?



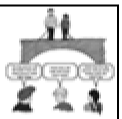
- Making learners' ideas explicit
- Challenging and developing learners' ideas
- Offering an alternative viewpoint
- Provide stimulus for discussion
- Help learners to ask their own questions
- Starting points for investigation
- Motivation
- Applying scientific ideas to everyday situations
- Promote scientific vocabulary
- Extension or consolidation activities

Some common reasons for using them



- Used across a wide age range EY→mature adult learners
- Promotes social interaction
- Protects learner's self esteem
- Learner experiences uncertainty and cognitive conflict
- Promotes thinking skills

Concept cartoons and learning



- Differentiation at many levels due to learners interpretation
- Language development
- Motivation – motivated learners are effective learners? Research shows motivation not diminished after 'novelty' worn off.
- Easy to manage – used at many levels and forms
- Creativity

Concept cartoons and teaching

Devised by

Stuart Naylor

Brenda Keogh

2000