Engaging Children in Question Asking for Problem Finding to Encourage Creative Thinking in Primary School Science Teaching

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by

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Abstract

Encouraging creative thinking is considered as the general function of education (NACCCE, 1999) and one of the aims under the national curriculum of England (DfEE/QCA, 1999). Though creative thinking is a broad term, in science it is seen as finding solutions to problems(D. P. Newton, 2010).Scientific enquiry is a creative process, commonly beginning with a question or problem, then generating a tentative answer or solution, and testing it. Generally teachers provide ready-made questions or problems for children to solve. If children themselves can find scientific problems or questions to solve in the classroom, then learning would be more engaging as it generates interest and motivation.

A review of existing literature on creativity in education focusing on its least recognised aspect, problem finding, revealed the potential for children's questions, particularly wonderment questions in encouraging deep thinking. Some studies recognised the scarcity of children's questions especially explanatory questions and questions that leads to investigations in the primary school science classroom. Therefore, the study sets out to explore strategies to stimulate children to raise questions with the potential to become problems to solve in science.
The study employed mixed methods using a descriptive questionnaire survey, classroom observations, short interviews, content analysis and controlled interventions with children to collect data. The sample included teachers, student teachers and Key Stage Two primary school children. It used phenomenography to analyse the data and derive useful conclusions thereby following an interpretivist approach.

A theory explaining the complex process of question asking which involves the construction and articulation of descriptive and causal mental models of situations emerged from the study. Several factors are suggested which influence and order the process, especially the situation or stimulus, the teaching and learning environment, and the attributes of the child. It takes time to produce questions which could lead to scientific enquiry and it needs teaching skill to provide effective opportunities for children to ask questions, and help them put them into a suitable form.

Table of Contents

List of Figures

List of Tables

Declaration

I declare that this thesis is my own work. No material contained in this thesis has previously been submitted for a degree in this or any other institution.

Statement of Copyright

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Dedication

To Praveen, my brother, my best friend, my teacher at times and my pillar, without him I would not have reached here.

To Deepth, my son, the reason why I took this rough but meaningful journey.

1 Chapter 1 Introduction

'Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world.'

(Albert Einstein, 1929 quoted in Smith D., 2014, p16)

This brief introductory chapter aims to highlight the rationale for the current study by addressing these questions: Where does the interest for this study come from? Why study it? Why does it matter? What is its potential significance? It also states the research objectives and research questions along with a diagram showing the main components of the study. The chapter then ends with a figure showing an overview of the chapters in the thesis.

1.1 Rationale of the Study

1.1.1 Where does the interest for this study come from?

The research grew out of the researcher's interest in fostering children's, particularly primary school aged children's creative thinking in science. The researcher's experience with creativity research emerged from her Masters' (M. Ed) dissertation where she designed a questionnaire (similar to Torrance Test of Creative Thinking) to assess secondary school aged children's scientific creativity. The questionnaire designing process was enjoyable as I used my creativity to make it more attractive for children. Prior to that, I had an art-based view of creativity, and my colleagues shared a similar view, as creativity did not seem to appear in any of the science textbooks. My love for oil painting and photography motivated me to explore the possibilities of using creativity in science teaching and learning. The researcher's prior experience as a science teacher at a budding school with smaller classes became an advantage in shaping the strategies in this study. As a science teacher, I tried to make lessons more engaging utilising methods like classroom demonstrations of live specimens, simple experiments and taking children out for field trips. Topics that are not feasible for hands-on activities like deforestation, pollution and life cycles when learned through dramatisation and research, followed by discussions, stimulated children to ask questions and clarify their doubts. As a homework activity, children were encouraged to watch television channels like National Geographic, Animal Planet and wild life documentaries while learning topics like habitats and adaptations and global warming. Children slowly showed more interest in watching nature and wildlife documentaries and they returned to the classroom with great enthusiasm to share their newly acquired knowledge that led to interesting discussions during science lessons. As children gained more understanding, they became more confident to voice their views and ask questions when prompted. All these experiences paved the way for the researcher's interest in fostering scientific creativity predominantly focusing on its least studied aspect, problem finding.

1.1.2 **Why study it?**

Encouraging creative thinking is considered as the general function of education (NACCCE, 1999)and one of the aims under the national curriculum of England (DfEE/QCA, 1999). There seems to be a lot of misconceptions about scientific creativity among teachers and student teachers. Though, teachers support the idea of encouraging creativity, there is a tendency to view creativity as associated with arts (Bereczki & Kárpáti, 2018; Bolden, Harries, & Newton, 2010; Diakidoy & Kanari, 1999; Kokotsaki, 2012; D. P. Newton & Newton, 2009b; L. D. Newton & Newton, 2010a; Wang & Kokotsaki, 2018). Scientific creative thinking is more likely to be seen as finding solutions to problems (D. P. Newton, 2010). It is important to understand teachers' and student teachers' conceptions regarding creative thinking, problem-solving and problem finding as they determine their classroom practice. It is equally important to observe if they use any strategies in the classroom to promote these. In addition, it is fruitful to know to what extend textual resources encourage creative thinking, problem-solving and problem finding, and thus recognise if they offer any support to teachers in doing so. A problem in science originates as a puzzling event or an observation that requires an explanation. In science, creative thinking is encouraged in the hypothesis space, when a child constructs plausible explanations. When a child, with teacher's support designs a method or a practical way to test these potential explanations, it promotes creative thinking in the experimental space (D. P. Newton, 2010; L. D. Newton & Newton, 2010a). Generally teachers and text materials provide questions or problems for children to solve. If children themselves can notice or find a scientific problem to solve in the classroom, then learning would be more challenging. Therefore, the study set out to explore strategies to stimulate children to think and raise questions or problems to solve in the science classroom.

1.1.3 **Why does it matter?**

It would give children a fuller educational experience of the scientific process, and opportunities of this kind, i.e. being like a scientist are known to provide interest, motivation and engagement as it opens a way to satisfy their curiosity (Jarman, 1991; LaBanca & Ritchie, 2011; Ryan & Deci, 2002). Though this requires the child to possess domain specific conceptual knowledge, it promotes mental engagement and possibly leads to positive emotions if properly facilitated by a teacher (B. Chen, Hu, & Plucker, 2016; D. P. Newton, 2013). In addition, making the subject their own in this way could enhance learning and the durability of that learning. Learning becomes more meaningful when it stimulates children to wonder, ask questions, and find answers.

1.1.4 What is its potential significance?

Competence in creative thinking is becoming more important and this brings it to the fore, hopefully enhancing both the understanding of the children and the provision of opportunities by their teachers. It aims to restore to science what has long been sidelined, namely problem finding that it is, like other areas of the curriculum, a creative endeavour. If teachers can bring children's question asking or problem finding in line with curricular goals, science learning would become a more enjoyable and fulfilling experience (Stokhof, De Vries, Martens, & Bastiaens, 2017). Nevertheless, it is not suggested that every science lesson becomes one of problem finding, but problem finding should have its place in the science curriculum.

1.1.5 Research objectives and questions

In simple terms, the study will explore three concerns in turn:

A. the nature of creativity and what that means in the context of science, focusing on what is suspected to be the least recognised aspect of it, namely, problem finding;
B. the classroom context, focusing on what teachers think and do regarding problem finding in science lessons;
C. the construction and testing of strategies or approaches intended to help the teacher foster problem finding in the classroom. The diagram below (Figure 1.1) summarises these parts of the study, albeit in simple terms.

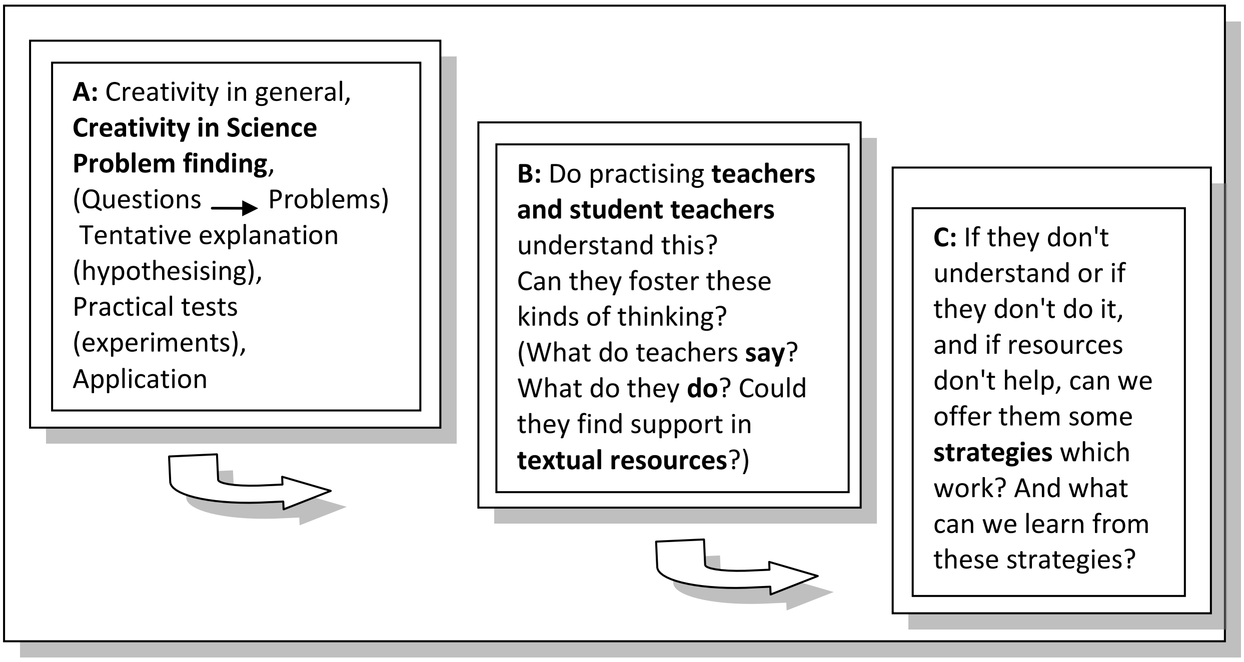


Figure1.1: Focus of the study- Three elements of the exploration of problem finding in the primary science classroom

The study intends to answer the following research questions to achieve the above objectives.

Q1. What are primary teachers' conceptions of creative thinking, problem-solving and problem finding in science? (see Chapter 6)

Q2. What are student teachers' conceptions of creative thinking, problem-solving and problem finding in science? (see Chapter 7)

Q3. What strategies do primary teachers use, to promote creative thinking, problem-solving and problem finding in science?

Q4. Are textual materials available for teachers in schools or online to support creative thinking, problem-solving and problem finding in science?

Q5. Do textual resources support creative thinking, problem-solving and problem finding in science?

Q6. What strategies can be used to engage children in question asking to raise scientific questions that can serve as problems to solve in the classroom?

1.2 Outline of the thesis

The focus of this thesis is creativity in primary school science, particularly problem finding, the least recognised aspect of it. The thesis comprises of eleven chapters. The study starts with a broad exploration of the existing body of literature in the area of creativity in order to narrow down the focus of the research and develop research questions. The introductory chapter presents the rationale of the study, the potential significance, the purpose of the study, the research questions and ends with an outline of the thesis chapters. Chapter 2 provides a brief review of what research is telling us about creativity in general. In Chapter 3, the researcher reviews the literature on creativity in educational contexts and subjects, looking particularly at the primary school context and science. Chapter 4 also reviews the existing literature however, it focuses on creativity, its least recognised aspect problem finding and children's questioning for problem finding and solving in science. Each chapter is concluded by extracting from the literature the key messages that inform my research questions.

Chapter 5 is concerned with the research methodology. It explains the research paradigm and decisions regarding data collection approaches and data analysis approach. The study employed mixed methods to collect data. Chapter 6 and chapter 7 present the findings from the data analysis of teachers' and student questionnaire survey. This answers the first two research questions; thus presenting the findings regarding teachers' and student teachers' conceptions of creative thinking, problem-solving and problem finding in science (or it answers Q1 or What do teachers say? and Q2 or What do student teachers say?). Chapter 8 presents the findings from: observations of teachers teaching science; short purposeful discussions with teachers; and content analysis of textual resources. Lesson observations gives insights into teachers' strategies to promote creative thinking, problem-solving and problem finding in science which answers the third research question (Q3 or it answers what do teachers do?). Discussions with the teachers reveal how useful textual resources were in promoting creative thinking, problem-solving and problem finding in the classroom. This answers the fourth research question (Q4). Content analysis of textual resources reveals the extent to which they support or promote creative thinking, problem-solving and problem finding in science and hence support the teacher in doing so. This answers the fifth research question (Q5). The researcher designed and trialled some strategies to encourage children's questioning for problem finding and chapter 9 explains the findings obtained from the analysis of this data. This answers the sixth research question (Q6). It reveals the strategies that stimulated children generate questions, the types of questions raised, patterns of questioning and what these patterns are likely to suggest. Chapter 10 outlines and integrates the overall key findings from the study (obtained from chapters 6 to

9) by relating them to existing literature. Chapter 11 concludes the study by clarifying the significant findings with my reflections and possible future research.

Figure 1.2 below sets out the way that the study is presented in the thesis. Following these, the thesis closes in the usual way with a list of References and Appendices

Chapter 1: Introduction Setting the scene	**Chapters 2, 3 & 4: Review of the literature** Exploring creativity, first more broadly then in this context **Element A**	**Chapter 5: Method Chapters 6, 7 & 8: Results** Teacher questionnaire, lesson observations, interviews and textual resources with summaries and interim comments **Element B**	**Chapter 9: Results** of Strategy tests. With summary and interim comments **Element C**	**Chapters 10: Overall discussion** Bringing together of the various strands of the study	**Chapter 11: Conclusion** Answering the research questions, considering implications, and looking to the future

Figure 1.2 Overview of the chapters in the thesis

2 Chapter 2: Creativity - A General Introduction

2.1 Introduction

In this chapter a review of published scholarly literature relating to some broad perspectives of creativity are provided. The chapter begins by exploring definitions of creativity followed by global perspectives on fostering creativity through education and differences in Eastern and Western creativity. The chapter concludes by looking at emotions and creativity, which also mentions the role of adversity or negative life experiences in stimulating creativity and post-traumatic growth.

Though, creativity has been widely accepted as a key driving force towards personal, social and economic development, it is not easy to define creativity. Several definitions of creativity have evolved over time. Originally, creativity was perceived as divergent thinking, the process by which one generates multiple ideas or solutions (Guildford, 1950). He explained the four stages of the creative process– preparation, incubation, illumination and verification. Creativity has been defined in terms of a process or a product, a person or an environment. Torrance, a pioneer who worked on the assessment of creativity, defined creativity*:"...in terms of the process of sensing problems or gaps in information, forming ideas or hypotheses, testing hypotheses, and communicating the results"* (Torrance, 1977). He added that one can also explore the personality characteristics, motivating factors and conditions promoting this process and the resulting product. A production of original ideas, a different point of view, or a new way of looking at problems and seeing new relationships among ideas, a successful step into the unknown, being open to experiences were some of the behaviours he associated with creativity. According to Torrance (1977) from a child's perspective, creativity may be manifested as a discovery of a new connection between ideas, which is at least new to the child, a poem, story or gadget. For an idea to be considered as creative, it should be novel or original as well as appropriate or fit. Sir Ken Robinson (2010), chair of the UK government's National Advisory Committee on Creative and Cultural Education (NACCCE, 1999) defines creativity as "*the process of having original ideas that have value"* (Robinson, 2010). He added, divergent thinking is not the same as creative thinking but is a vital capacity for creativity (Robinson, 2010). In short, a creative idea is the one that meets the two requirements, novelty or originality and appropriateness or usefulness (Amabile, 1996; Grigorenko, 2019; Hu & Adey, 2002; NACCCE, 1999; D. P. Newton, 2010, 2013; L. D. Newton & Newton, 2014; Mark A Runco & Jaeger, 2012). During the creative process, a person intentionally creates a product that is original and has some kind of value (Hu & Adey, 2002; NACCCE, 1999). Kaufman and Sternberg (2006) also defined creativity in similar terms, *"Creativity involves thinking that is aimed at producing ideas or products that are relatively novel and that are, in some respect, compelling"* (Kaufman &

Sternberg, 2006, p2). This reference to value of a product generated by an artist or a scientist, points to an indirect social element of creativity (Amabile, 1996). This means the product is judged on the basis of social desirability, considering the context and the people benefited. This is what Craft (2006) refers to as wise use of creativity. Terms like curiosity, imagination, discovery, innovation and invention are seen as closely associated with creativity (Torrance, 1963). The National Advisory Committee on Creative and Cultural Education (NACCE) in the UK described creative thinking as an imaginative activity that leads to the generation of outcomes that are both original and of value, a generally accepted view (NACCCE, 1999). How was creativity perceived in the past? Was creativity limited to a few or can we all be creative?

Research shows that in the past, creativity has been seen to belong to a gifted few (Weisberg, 1986). Only people with special talents or abilities in particular areas were considered creative. For example, poets and, artists who engaged in fields like music, dance, art and drama, were considered creative people. There are other researchers who have argued that it is not the possession of a few, everyone has the ability to be creative to some degree as they solve everyday problems of life (Boden, 2004; Craft, 2011; D. P. Newton, 2012a). We are all creative when we solve everyday problems of life. Recent studies have generated a simple categorisation of creativity into two, 'little c' and 'big C' creativity. Psychologists call 'little c' creativity or everyday creativity to the one that is associated with the development of new solutions to everyday problems of limited significance. The creativity that is associated with exceptional people is referred as 'big C' creativity or creativity concerned with the development of transformative performances or products (Grainger & Barnes, 2006; J. C. Kaufman & Beghetto, 2009; D. P. Newton, 2010; Schmidt, 2010). This is clearly explained by Sawyer (2012) in terms of the two major approaches used to study creativity: an individualistic approach and a socio-cultural approach. The individualists study the thinking processes associated with a single person when he is engaged in creativity, while the socio-culturalists focus on a group of creative people. Development of a product that is novel to a society ('big C' creativity) will only satisfy the socio-cultural standard of creativity. The same product will be new to each individual in that society and therefore it will meet the individualistic criteria (‘little c’ creativity). Though ‘big C’ creativity may have social recognition which is not present in ‘little c’ creativity, but both originates from an individual and his or her idea (Mark A Runco, 2014). Newton (D. P. Newton, 2012a) referred 'little c' creativity as 'new to the person' and 'big C' creativity as 'new to the world'. When we understand something, we create meaningful wholes by making new mental connections (Grainger & Barnes, 2006) between different ideas and the result is often new to us. So, it is considered as a personal creative process (D. P. Newton, 2012a). In short, everyone has the capacity to be creative. This recognition of creativity has gained a global appeal, with many countries transforming to creative knowledge economies, where, producing ideas are valued more than producing things (Sawyer, 2012). At a personal level, creativity offers people the capacity to think and solve problems in a novel way and lead a more fulfilling life. This has led to an increased recognition for creativity particularly in the education sector around the globe. This also explains why schools should encourage children's creative thinking abilities. Leggett (2017) argues a teacher's role is crucial in supporting the development of children's creative thinking and therefore, recommends educators to come together by sharing their knowledge and skills to deliver a curriculum that nurtures creativity.

2.2 Global Perspectives on Fostering Creativity through Education

A growing recognition for creativity has been observed in recent years. Countries around the globe recognise creativity as a driving force behind social, economic and technological growth and have turned their focus on encouraging students' creativity as part of their education. Though, argument exist on the whether creativity can be assessed and increased, there seems to have an agreement in the field of education that all individuals are capable of creative thinking (NACCCE, 1999) and creativity can be fostered through training (Amabile, 1996; Baer & Kaufman, 2006; J. C. Kaufman & Beghetto, 2009; Mark A Runco & Chand, 1995). According to Lin (2011) teaching strategies, learning environment and the teacher ethos and attitude towards encouraging creative thinking are the three main aspects to be considered when planning to foster creativity through education. A creative pedagogy, which involves creative teaching, teaching for creativity (Jeffrey* & Craft, 2004) and creative learning (Grainger & Barnes, 2006) (more details in Chapter 3) is put forward to nurture the development of creativity in education. It has been recommended that teaching for creativity is learner focussed while creative teaching is more teacher centred (Jeffrey* & Craft, 2004). Teaching for creativity implies the explicit use of pedagogies and practices that foster creativity in children (James et al., 2019). A supportive, risk free classroom environment where children are allowed to learn through questioning, inquiring, experimenting, exploring, testing, modifying and, engaging in imaginative play, fosters creative learning. A learning environment which is filled with curious problems to explore, stimulates children's creative thinking or *'adventurings in creativity'* and learning (Lin, 2011; Torrance, 1963). Torrance (1963) contrasted learning creatively from learning by authority from teachers and text books and recommends fostering creative learning through questioning, inquiring, experimenting and manipulating. The current research suggests a balance of both methods. In order to ask good quality questions that can serve as problems to explore or investigate in the classroom, children should have an understanding about the topic, which is obtained with the help of a teacher and textbook. Teachers, through their focused classroom talk and the adoption of some simple strategies can stimulate children to think creatively and raise questions or problems to be solved in the classroom. Children may also require teachers' support in shaping their questions into problems that could be answered through methods like conducting research, observation (nature or natural phenomena), demonstration and investigation thereby promoting children's mental engagement.

Therefore, our educational institutions should aim at generating a stimulating, risk free, problem friendly eco-system to shape a generation of curious, imaginative students who are open to experiences and have a different view point or a new way of seeing problems. The world needs a creative and innovative human workforce that could cope with the pressures of globalisation. Eger (2011) pointed out that the emergence of a new economy based on creativity and innovation forces the reinvention of business strategies, communities, corporations and schools for survival. He addressed the need for re-designing the high school and college curricula in the United States to prepare students for the new global economy. The agile and flexible educational systems powered by their creative learning ecosystems (CLE) have enabled small countries such as Switzerland, Singapore and Finland to be the leading economies in the world (Crosling, Nair, & Vaithilingam, 2015). The three most important drivers of Swiss competitiveness are its excellent institutions, the dynamism of its markets, and its capacity for innovation (Schwab & Sala-i-Martín, 2016). The increased global recognition for creativity has initiated many invest in the development of creative learning environments (Crosling et al., 2015).

China's creativity is in a crisis phase (Niu & Kaufman, 2013). The Chinese Ministry of Culture launched a new plan, *'Implementation Opinions'* to carry opinions announced by the State Council to promote cultural creativity and related sectors (Maags, 2014). Qatar organized the 2014 World Innovation Summit for Education (WISE), under the theme *'Imagine - Create - Learn: Creativity at the Heart of Education*' to explore ways to tap learner's potential for innovation and creativity. Experts, innovators and politicians from different parts of the world gathered and discussed three key areas: nurturing creativity at all ages, particularly younger students; designing an environment of engaging pedagogies where creative learning and innovative teaching can blossom; and, assessing talents and skills in both formal and informal systems (AbAdzi, MArtelli, & Primativo, 2014). It is important to encourage children's creative potential at all ages particularly younger ones in primary schools. In the UK, the *Durham Commission on Creativity and Education* (DCCE) has been set up to study ways in which the education sector can nurture the capacity for creativity in children. The commission stressed that creativity is based on deep understanding and therefore, there shouldn't be any conflicts between knowledge and creativity. Addressing the traditional mis-conception that creativity is associated with arts, the commission pointed that creativity can be encouraged in all subjects including arts, humanities, mathematics, and the sciences through good teaching based on in-depth knowledge (James et al., 2019). Having good conceptual understanding along with teacher prompts can stimulate children to stretch their thinking beyond what is expected and lead to questioning and problem-solving. Above all, as creativity depends on collaboration, it improves personal well-being as well as empowerment of communities (James et al., 2019). Thus, it is very evident that creativity has become a band wagon in the twenty-first century inspired by policy makers, scientists, industry, business sector and education systems around the world (Van Harpen & Sriraman, 2013). Lin (2011) expressed concerns over creative pedagogy especially when it is adopted in context that is less supportive to the development of creativity. It has been suggested to study perceptions on the application of creative pedagogy from participants in different positions in the educational system, which includes academic researchers, policy makers, school head teachers and teachers. Studying teachers' perceptions would be useful to nurture their own creativity as well as children's creativity. The study recommends learning and comparing notions of creative pedagogy in Western and Eastern classrooms and cultures; this might help to reach a balance between the two sets of values and practices (Lin, 2011). The researcher feels it would be fruitful in understanding and comparing what Western and Eastern teachers see as incidents of creativity under different subject domains in schools. In the UK, though teachers show great interest in teaching for creativity and there are several good examples of best practice among them, it is not widespread (DCCE, 2019). A lack of policy documents voicing teaching for creativity, lack of clear statement of opportunities and examples of creative thought in different subject disciplines under the curriculum, lack of confidence among head teachers and teachers due to absence of professional development programmes on encouraging teaching for creativity, are some of the challenges faced by UK schools. It would be interesting to know the challenges faced by other countries and cultures both in the West and the East in developing creative potential of their students. Learning how different cultures perceive and promote creativity would be of significance.

2.3 East - West Differences in Creativity

Most of the creativity research carried out in the past came from the West, particularly from the United States. The two most studied populations in the field of creativity research are American and Chinese students (Niu & Kaufman, 2013). As creativity has become a global focus, the way each culture values and perceives creativity is particularly important in promoting it. Culture plays an important role in judging creativity (L. D. Newton & Newton, 2014; Niu & Kaufman, 2013). Newton & Newton (2014) pointed that educators have a tendency to view creativity through Western eyes. They suggest, studying creativity only from one angle is not enough in this highly interconnected 21st century world. As teachers are expected to prepare students to become creative problem solvers in life, they should make them aware of other perspectives of creativity (L. D. Newton & Newton, 2014). In the East, usefulness or appropriateness is perceived as creativity while novelty or originality is the valued in the West (Morris & Leung, 2010). Cultural differences affect creative performances (Yi, Hu, Scheithauer, & Niu, 2013). Every culture has its own norms. Western culture has individualistic norms (Van Harpen & Sriraman, 2013), where there is more freedom for individuals and creativity is fulfilled by producing original or novel solutions. Eastern culture has a collectivist norm (Van Harpen & Sriraman, 2013), where the environment or the society is more important (less freedom for individuals) and creativity is achieved by devising solutions that are useful and acceptable (Morris & Leung, 2010; Pang & Plucker, 2012). The East favours usefulness, while the West encourages novelty, and this may be due to the difference in the social norms (Morris & Leung, 2010). For example, finding a low-cost solution in an intelligent way or having a 'Jugaad' approach (a Hindi word) is a tradition in India, other BRIC countries and other emerging economies where cost efficiency matters when creating a product. Here, creativity is more about adapting quickly to the situations or coming up with a satisfactory solution that does the job (Bobel, 2012). As a person born and brought up in the East and settled in the West, I think this East-West gap may influence how one solves real life problems. In the East, one may have more pressure to generate solutions that are acceptable not only to the individual but also to society and this may limit avenues for novelty. With the advancement of technology and access to digital information, exchange of ideas and values are taking place more rapidly than before (L. D. Newton & Newton, 2014) particularly in East. Exchange of Western values and creativity directed at novelty and personal freedom are slowly creeping into the minds of the younger generation in the East through digital media. Eastern students, particularly females, who gain higher education from the West, return with improved self-esteem and a changed perspective to life and learning. Though this helps them to achieve personal and financial independence, self - reliance, empowerment and in some cases social mobility, it may also generate some tensions in their home society. Newton & Newton (2014) also mentioned about the occurrence of similar tensions resulting from economic growth and empowerment through creative skills. They pointed, such tensions for example- freedom versus control, or rote learning versus solving problems, comes in touch with the education systems and shape programmes of study (L. D. Newton & Newton, 2014).

Globalisation has minimized the distance between countries and more people meet up with cultures that are different from their own (Saad, Damian, Benet-Martínez, Moons, & Robins, 2013). The greater visibility obtained globally for Indian cultural products from

Bollywood cinema to Bhangra music are evidences of this. Increasingly, Indian films are being watched by international audiences in more than 70 countries around the world (Thussu, 2013). South Indian fusion music generated by combining the south Indian Carnatic music (classical music) and Western music is another product of intercultural exchange. Contexts that encourage real blending of cultures in their products (e.g., fusion food), policies (e.g., multicultural education) and institutions (culturally diverse environments of work) may enhance the creativity of its members (Saad, et al. 2012). Research shows, such experience enhances creativity, particularly among biculturals who blend their two cultural identities. It was noted that only biculturals who were successful in resolving the discrepancies between their cultural identities might make the most of the bicultural context in this increasingly multicultural world. Therefore, exposure to diverse cultural contexts may not result in increased creativity. Greater bicultural identity 'blendedness' predicted domain-general creativity in bicultural, but not in monocultural contexts (Saad et al., 2013). Individuals exposed to multiple cultures may have new ways of looking at problems and solving them. However, high cultural knowledge beyond a creation level can be detrimental to creativity due to cognitive overload (Chua & Ng, 2013). When people learn about a new culture, they will challenge their assumptions about culture obtained from their home culture, integrate and combine new ideas into existing cognitive structures, make new connections and thus develop new insights (Maddux, Adam, & Galinsky, 2010). Exposure to a different culture has helped me to learn and integrate positive values from two cultures. Sometimes, it gives the advantage of viewing and approaching problems from two different angles, which in turn may lead to new ways of approaching them. A study conducted by Maddux, et al., (2010) reported enhancement in creativity when participants were asked to recall a functional multicultural learning experience and when they had a previous experience of living abroad (Maddux et al., 2010). Having exposure to diverse cultures may naturally widen our understanding about the world and in turn develops confidence to mix with people from diverse cultures, generating positive feelings. Opportunities for cultural and professional exchange between educational institutions in the West and the East through student and teacher exchange programmes open up ways for creative exchange of ideas. Knowledge of different cultures may generate an interest in learning more about them. As interest is likely to generate positive emotions (D. P. Newton, 2012b), more research should be conducted on the role of children's emotions on their creative behaviour and learning so that teachers can utilise them wisely.

2.4 Creativity and Emotions

Recent research by Newton (2013) has shown that the impact of the emotional state on creativity has been ignored (D. P. Newton, 2013). This is important because, in a context of rapid globalisation, the study of emotional reactions towards foreign and global cultures is relevant. People with an integrative attitude towards foreign cultures may experience negative emotions that enhance creativity. Less positive or negative emotional states are associated with integrative responses towards foreign culture (Cheng, Leung, & Wu, 2011). Conflicting ideas from different cultures can elicit negative moods that can open the door for creative problem-solving. In the study conducted by Cheng, et al., it was found that simultaneous exposure to local and foreign cultures produced more creative enhancement than when exposed to two foreign cultures (Cheng et al., 2011). Moods and emotions affect one's ability to think productively. Anxiety can make children disengaged from the learning task (Y. Liu, Fu, & Fu, 2009). Teachers should handle children's moods in a way so that it will increase the likelihood of the development of understanding while nurturing their interest in a particular subject (D. P. Newton, 2012b). Classroom teacher demonstrations, allowing children to try out some simple hands on activities with easily available materials, taking children outdoors and encouraging observation of nature, using easily available teaching aids or artefacts with some amount of novelty to capture children's attention etc can make learning interesting. It would be fruitful if teachers could utilise children's curiosity and prior knowledge to generate positive feelings leading to better productive thought.

People who are highly engaged in day-to-day creativity have been found to have a greater sense of well-being and personal development (S. B. Kaufman & Paul, 2014). Most individuals unfortunately face adverse events at some point in their lives and they may use their experiences for growth and fulfilment of their creative potential (Forgeard, 2013). Creative individuals utilise their negative experiences as opportunities and sources of motivation for their growth. Thus, adversity might have played an important role in fostering creativity and that increased creativity could be a manifestation of post-traumatic growth (Forgeard, 2013). Several examples of similar creative people can be seen around the world which includes famous people from diverse fields to several empowered men and women from all walks of life who overcome adverse life challenges in creative ways leading to personal growth. A study by Elisondo, Donolo, & Rinaudo (2013) proposes the importance of creating unexpected contexts as a strategy to promote creativity in students. They include creating new learning contexts focused on creativity, which creates challenging opportunities for students as well as teachers. Learning activities, contexts, materials, teachers, and teacher intervention are some of the components that can be designed in an unexpected way to promote creativity (Elisondo et al., 2013). More research should be conducted to develop challenging opportunities that force students to question, think outside the box and take action towards innovative solutions. As creativity is important for economic growth and well-being, it is important that our educational institutions nurture and develop students' creative thinking skills to enable them to come up with creative solutions to life's problems. To solve problems, one should be observant enough to sense problems. Hence, problem finding is an essential skill to be fostered in students to help them lead a fulfilled life.

2.5 **In Conclusion**

From this chapter on creativity generally, the key messages included:

- Importance of creativity globally for economies (Sawyer, 2012);
- Impact of cultural perspectives on what counts as creativity (Maddux et al., 2010);
- The notion of little 'c' creativity for all (Newton, 2010);
- The impact of emotions on creative thinking (D. P. Newton, 2013); (Y. Liu et al., 2009; D. P. Newton, 2012b)
- The need for school and college curricula to prepare students for this need to be able to think creatively and problem solve (Eger, 2010);
- Conflicting ideas from different cultures can elicit negative moods that can open the door for creative problem-solving (Cheng et al., 2011);
- The role of adversity in fostering creativity and post-traumatic growth (Forgeard, 2013);
- The importance of providing new or unexpected contexts for experiences to foster creativity (Elisondo, Donolo, & Rinaudo, 2013)

Next chapter deals with creativity in education, different phases, subjects and then leading to creativity in primary school science.

3 Chapter 3: Creative Thinking in Educational Phases and Subjects

Having looked at creativity generally in Chapter 1, this chapter focuses on creativity in educational contexts, i.e. in different phases of education and in different subjects of the curriculum. It will move towards creative thinking in primary school science as this is the focus of this study. The different sections in this chapter, which give an overview of creativity in education includes, creativity in different phases namely higher education, particularly teacher education, secondary education, early years and primary education, and different subjects. The chapter concludes by looking at creativity in science, particularly in primary schools.

3.1 Creativity in different phases and subjects of schooling

Everyone has the potential to be creative as they solve everyday life problems through the generation of novel ideas (Boden, 2004; Craft, 2011; D. P. Newton, 2012b). This is referred to as little 'c' creativity or new to the person approach to creativity (L. D. Newton & Newton, 2014). Though it is accepted that children can be taught to use their creative thinking skills, teaching for creativity is still not widespread (Grigorenko, 2019; James et al., 2019). Hattie (Hattie, 2009) in a synthesis of more than 800 meta-analyses linked to achievement, identified the importance of creative thinking skills. Many countries are interested in gaining economic prosperity by encouraging the creative potential of their students through education. In order to guide schools and local authorities in promoting creativity HMIe (HMIe, 2006) gathered evidence and produced a report that underlined some key ideas on creativity:

- Creativity is not a separate area of the curriculum.
- Creativity can be encouraged in all subjects and areas of the curriculum.
- All pupils have creative abilities.

The report cited examples of activities done in different school settings to encourage creativity. In a pre-school context, creativity was at its best when children asked questions or made observations or reached a problem naturally during their play. Primary school teachers provided opportunities for creativity in expressive arts, creative writing in literacy, and designing and making products in technology. Secondary schools encouraged children to compose and perform music, design and make in home economics and technology, choreography and dance performances and doing practical work in science (HMIe, 2006). A detailed look at the creativity research carried out in different phases of education and subjects are given below starting from teacher education, secondary and finally primary schools.

3.1.1 **Higher Education (Teacher Education)**

Science, Mathematics, Music, English, and English as a Foreign Language (EFL)

Most of the literature collected in the context of higher education, were studies conducted among teacher trainees and in-service teachers. A study by Manning et al., (Manning, Glackin, & Dillon, 2009) reported that the three main features of creative science lessons suggested by PGCE science students are the need for variety of teaching approaches, relevance of the topic to real life and appropriate classroom environment. Manning et al., (Manning et al., 2009) pointed that creativity is thinking or acting imaginatively in a purposeful way (QCA, 2008) and not just giving lessons with relevance and variety. The study suggests the need for creating awareness among teachers on what counts as creativity in science and in different subjects (Manning et al., 2009). Though the above authors pointed out the misconception among teachers, a clear description of what counts as scientific creative thinking is not being provided. Student teachers should be taught explicitly what counts as creative thinking in science with specific examples, both at primary and secondary level. Also, information on appropriate classroom environment that nurtures creativity should be given. Teacher's beliefs about creativity can influence the learning activities they provide in their classrooms. Therefore, it is necessary to raise awareness among teachers on what counts as opportunities for creativity in different subjects and ways of promoting it (L. D. Newton & Newton, 2014). It is fruitful, if educational materials and challenging tasks are available for teachers to encourage children's creativity.

A recent study, which reviewed the literature on teachers' beliefs about creativity, reported that teachers in general hold a democratic view of creativity and support the idea of fostering creativity (Bereczki & Kárpáti, 2018). Some studies show, some teachers still hold a narrow view of creativity as an inborn gift of a few and not a trait found in all (Diakidoy & Kanari, 1999; Ndeke, Okere, & Keraro, 2016). According to Newton (L. D. Newton, 2013) pre-service and in-service teachers (UK) were found to hold a general art-based view of creativity. They believed art subjects like music, art and drama were seen providing plenty of opportunity, while subjects like mathematics, science and ICT were seen providing none. Story writing (English), painting (arts) and making music were cited as examples of creativity. School mentors of pre-service teachers were also found to have the same beliefs about creativity(L. D. Newton, 2013). Both pre-service and experienced teachers mentioned about lack of time to develop creativity due to curriculum constraints (L. D. Newton, 2013). Though, teachers support the idea of encouraging creativity in all subjects, most of them share an art-based view (Bereczki & Kárpáti, 2018; Bolden et al., 2010; Diakidoy & Kanari, 1999; Kokotsaki, 2012; D. P. Newton &

Newton, 2009b; L. D. Newton & Newton, 2010a; Wang & Kokotsaki, 2018). This contradicts the findings obtained by Alsahou & Alsammari (Alsahou & Alsammari, 2019) who explored 152 Kuwaiti pre-service science specialist teachers' beliefs about scientific creativity and claim that the majority (68%) ordered science as one of the most creative subjects, second to the arts (Alsahou & Alsammari, 2019). The participants in this study were pre-service teachers specialising in science while the other studies mentioned above included a general sample of teachers from different subject backgrounds. As a specialist science teacher from the East, I also had an art-based view of creativity prior to coming into scientific creativity research field. Wider research with a more representative sample should be conducted to explore whether there are any differences between the notions of pre-service and in-service teachers in the West and the East regarding creativity in general and in different subject domains. This is important when shaping a training programme for fostering children's creativity that could be applicable in the West and in the East.

The government in UK, through its handbook *Excellence and Enjoyment* (DfES, 2003) urges teachers to promote children's creativity and problem-solving skills across the primary curriculum through creative approaches. Unfortunately, the example this government agency gives for scientific creativity is an example of creativity in Technology. All subjects in the English National Curriculum have the potential for creativity and teachers are expected to foster creativity in specific subjects. For this, they must have solid subject knowledge and a clear understanding of what counts as creative learning in that subject (D. P. Newton & Newton, 2009b). Does creativity look the same in all subjects? Is it different in different subjects, sciences and the arts? Are teachers fostering creativity in their subject teaching? Do teachers have a clear understanding of what counts as creative thought in different subject domains? It is interesting to know how teachers and student teachers perceive creativity in different subject domains.

Usually, what teachers practise in the classroom depends on their beliefs. Therefore, it is important to understand teachers' conceptions of creativity in different subjects. According to Kokotsaki (2012) pre-service teachers view music as a highly creative subject. Teachers consider active listening as a vital skill for the constant refinement of the musical product. The study suggested that children's creative approach towards music can enhance creativity in other subjects (Kokotsaki, 2012; Wang & Kokotsaki, 2018). Kokotsaki & Wang (2018) studied Chinese primary school EFL (English as a foreign language) teachers' conceptions of creativity and produced four categories that include: creative products, cognitive development, pedagogical approaches or teaching creatively, and control of behaviours., for example allowing children the freedom to make decisions. The majority favoured the concept of creating new products, which are also connected to thinking and imagination, the mental activity behind them. Though teachers recognised their role in encouraging creative thinking, their strategies were more focused on teaching creatively using music, art and not teaching for creativity (Wang & Kokotsaki, 2018). Bolden et al. (2010) reported that pre-service primary teachers had very narrow conceptions of creativity in Mathematics, mostly associated with 'teaching creatively' making use of different resources and technology rather than 'teaching for creativity'. Newton & Newton (D. P. Newton & Newton, 2009b) explored student teachers' conceptions of creative thinking and came up with five categories of conceptions:

i) construction of explanations of scientific events and sometimes proceeding to the testing of explanations;
ii) construction of descriptions of the scientific world;
iii) construction of fair tests to produce fact-like information or application of facts to solve practical problems or both;
iv) creativity as generating a shared positive feeling about some science topics and
v) creativity as making things following instructions.

The last two categories, creativity as a positive feeling and as making things were regarded as misconceptions as the former could confuse creativity with its possible effects, such as generating attention, interest or between teacher's creativity and children's creativity and the latter could simply mean creativity as a reproductive making activity without novelty. Majority of the teachers focused on the experiment space with more attention on generating fact-finding investigations but few involving the testing of tentative explanations. Very few teachers saw generation of explanations as an opportunity for scientific creative thought. It was concluded that most student teachers seemed to have narrow conceptions of scientific creativity focussing on practical investigations for finding facts and application of scientific knowledge to solve practical problems (D. P. Newton & Newton, 2009b). Recent findings by Alsahou & Alsammari (2019) also confirmed pre-service teachers having narrow conceptions of creative thought in science focussing on experiments and practical work. Similar narrow conceptions of scientific creative thought among primary teachers were reported by Newton & Newton (L. D. Newton & Newton, 2010a) favouring fact seeking investigations and application of facts to solve practical problems as opportunities for creative thought. Some teachers favoured reproductive making activities and those which simply generated interest and on-task talk as encouraging creativity in science (L. D. Newton & Newton, 2010a). A Kenyan study which looked at 205 Secondary school Biology teachers' perceptions of scientific creativity noted that majority of them saw creativity as associated with problem-solving using the application of scientific knowledge. They did not see identification of problems as related to creativity in science. Also, majority of the teachers (82%) viewed that creative thinking cannot be encouraged without subject knowledge as it helps to broaden imagination (Ndeke et al., 2016). Also, most of the participants (85%) could identify activities stimulating creative thinking like problem-solving, brainstorming, role-play and use of probing questions. The study recommends the need for in-service programmes for practicing Biology teachers to broaden their knowledge on encouraging creativity in science (Ndeke et al., 2016). This agrees with the findings obtained from an early study by Diakidoy & Kanari (1999) in which student teachers associated scientific creativity with problem-solving, hypothesis formation and conceptual change.

Generally, teachers' conceptions of creativity in different areas of the curriculum reflect an art-centred view. It appears as they hold a narrow view of creative thought. The need for providing more specific direction to teachers on encouraging creative thinking across the Key Stages (Turner, 2013)and subjects was suggested (L. D. Newton & Newton, 2010a). Several studies address the inadequate conceptions of creativity among teachers and recommend the need for providing training to both pre-service (Alsahou & Alsammari, 2019; Bolden et al., 2010; D. P. Newton & Newton, 2009b) and in-service teachers (Bereczki & Kárpáti, 2018; Ndeke et al., 2016; L. D. Newton & Newton, 2010a; Turner, 2013). A recent review of literature on teachers' beliefs about creativity by Bereczki & Karpati (2018) suggests several valuable insights. The study reported that though many teachers (in-service K-12 teachers) believe that they are capable of encouraging creativity and perceive themselves as doing it, the data from several studies show that there is incongruence between teachers' beliefs and their classroom practices. Teachers' misconceptions and narrow conceptions about creativity and the ways of fostering it in the classroom, manifested in their teaching practices make the implementation of teaching for creativity, highly unlikely (Bereczki & Kárpáti, 2018). The study suggested factors like provision of training and experience in teaching for creativity, personal creativity, educational background and professional competency can positively influence teachers' notions on creativity. Specific areas suggested by the study where teachers need more support include, identifying original and appropriate creative products, understanding subject-specific conceptions of creativity, identifying learner's creativity and generating more awareness on pedagogical practices promoting creativity across different subjects in the curriculum and at different education levels. The study stressed the need for providing strategies, activities, materials and examples of promoting creativity informed by field research (Bereczki & Kárpáti, 2018). Bereczki & Kárpáti (2018) suggested that *"teacher* *education should lay special emphasis on supporting teachers to conceptualize, recognise, explicitly teach for and assess creativity across specific subject areas and education levels"* (p.50).

Characteristics of creativity can vary with different subjects and a primary teacher, who teaches all subjects, should have thorough knowledge on what counts as creativity in each subject and ways to promote it. There is a lack of clear understanding of what constitutes creativity in different subjects (Burnard, Fautley, & Savage, 2010). Teachers' beliefs about creativity influence learning activities in their classrooms (D. P. Newton & Newton, 2009b; Odena, 2006).Therefore, training for creativity should address teachers' conceptions (Bereczki & Kárpáti, 2018; Bolden et al., 2010; L. D. Newton & Newton, 2010a) and should demonstrate different ways of fostering creative thinking. With regard to scientific creative thinking, it was suggested that training should illustrate a clear distinction between creativity and imitation and help teachers widen their view on encouraging creative thinking through the generation of explanations (L. D. Newton & Newton, 2010a). All these point towards the urgent need for providing training programmes on fostering creative thinking in different subjects to both student teachers and in-service teachers in both primary and secondary schools. For this, what counts as creative thinking in different subjects should be explicitly stated and strategies should be developed and shared.

Dobbins (2009) interviewed 10 primary teachers about practising teaching for creativity within the current educational climate. Most teachers felt the pressure to teach to meet targets set within the curriculum and provide evidence demonstrating targets have been achieved. They saw the amount of curriculum to cover, the objectives to meet and the lack of adequate time, as barriers to encourage creativity. Though the teachers are pleased with the governments' call to encourage creativity, they felt the constraints within the system are acting as significant barriers to its effective incorporation (Dobbins, 2009). Overloaded curriculum (Dobbins, 2009; Wang & Kokotsaki, 2018), lack of time (Alsahou & Alsammari, 2019; Dobbins, 2009; Longshaw, 2009; Wang & Kokotsaki, 2018), teachers' lack of adequate theoretical knowledge (Coates, 2006) and practical skills to nurture creativity due to lack of training opportunities and adequate resources and exam pressure were reported as main barriers in promoting creativity in education (Bereczki & Kárpáti, 2018; Wang & Kokotsaki, 2018). Alsahou & Alsammari (2019) explored 152 pre-service teachers' beliefs about scientific creativity and found they viewed lack of time and effort as the most common barriers toward encouraging creativity. Lack of time allowed for music in primary school and the priority given to other subjects like literacy and numeracy was reported as concerns for pre-service teachers in promoting children's musical creativity (Kokotsaki, 2012).

Suggestions like inclusion of research-based definitions and conceptualizations of creativity across the curriculum in the policy documents, curriculum adjustment to allow more time for encouraging creativity, checking on national assessments to include creativity, issuing guidance documents with clear instructions on the development and assessment of creativity across all subjects, provision of initial and in-service teacher training programs, development of resources and materials for teachers to promote creativity and opportunities for sharing best practices were made by a recent study (Bereczki & Kárpáti, 2018).

To summarise, under higher education, particularly in the teacher education context, there is a need for creating awareness on what counts as creativity in different subjects (Manning et al., 2009). There appears to be confusion between teaching creatively and teaching for creativity among teachers and student teachers and this should be dealt with the provision of training programs focused on encouraging creative thinking in different subjects. Though teachers generally, hold a democratic view of creativity (Bereczki & Kárpáti, 2018) there are some who still hold a narrow view of creativity as an inborn gift of a few and not a trait found in all (Diakidoy & Kanari, 1999; Ndeke et al., 2016; L. D. Newton & Newton, 2010a). Most teachers share an art-based view of creativity focusing on teaching creatively rather than teaching for creativity (Bereczki & Kárpáti, 2018; Bolden et al., 2010; Diakidoy & Kanari, 1999; Kokotsaki, 2012; D. P. Newton & Newton, 2009b; L. D. Newton & Newton, 2010a; Wang & Kokotsaki, 2018). All subjects in the English National Curriculum have the potential for creativity and teachers are expected to foster creativity in specific subjects. For this they must have secure subject knowledge and a clear understanding of what counts as creative learning in that subject (D. P. Newton & Newton, 2009b). Most student teachers seemed to have narrow conceptions of scientific creativity focussing on fact finding practical investigations and application of scientific knowledge to solve practical problems (Alsahou & Alsammari, 2019; D. P. Newton & Newton, 2009b). Similar narrow conceptions of scientific creative thought among primary teachers were reported by Newton & Newton (L. D. Newton & Newton, 2010a). Majority of Biology teachers saw creativity as associated with problem-solving using the application of scientific knowledge. They were of the view creative thinking cannot be encouraged without subject knowledge (Diakidoy & Kanari, 1999; Ndeke et al., 2016). Teachers' beliefs about creativity influence learning activities in their classrooms (D. P. Newton & Newton, 2009b; Odena, 2006). Therefore, training for creativity should address teachers' conceptions of creative thinking (Bereczki & Kárpáti, 2018; Bolden et al., 2010; L. D. Newton & Newton, 2010a) and demonstrate different ways to foster it. This is again supported by a recent study which recommends areas where teachers needing more support include, identifying original and appropriate creative products, understanding subject-specific conceptions of creativity, identifying learner's creativity and generating more awareness on pedagogical practices promoting creativity across different subjects in the curriculum and at different education levels. Also stressed the need for providing strategies, activities, materials and examples of promoting creativity informed by field research (Bereczki & Kárpáti, 2018). All these point towards the urgent need for providing training programmes on fostering creative thinking in different subjects to both student teachers and in-service teachers in both primary and secondary schools.

3.1.2 **Secondary Education**

Music

Creativity can be encouraged in all phases of education. To encourage creativity, secondary school subject teachers need to have a clear understanding of what counts as creativity in their subject. A study that investigated the place of creativity in the school curricula of member states in the EU and in the UK showed that the incidence of creativity varied widely. It was found that creativity was more represented in arts subjects and relatively neglected in reading and writing. In the UK, a shift from emphasis of creativity in primary to secondary settings was noted by Ferrari and Wise (Wyse & Ferrari, 2015). In the English National Curriculum for Music, the word creativity is used as a desirable thinking style for activities such as improvisation and composition of musical ideas (DfE, 2021). Creative group instrumental music learning activity in a secondary school facilitated collaborative creativity, by encouraging learners to make music together (Burnard & Dragovic, 2014). The school provides a democratic environment where co-creation, togetherness, making mistakes, risk taking are valued, resulting in collaborative music creation and student empowerment. They recommend that the music curriculum and music education in schools should place more emphasis on pupils making music, rather than learning it. In another study conducted among English secondary school music teachers to illustrate a practical methodology to be used when enquiring their views of creativity, Odena (2006) suggested that the use of videotaped extracts of music lessons for the purpose of discussion with the teachers involved, helped to gather teachers' views of creativity. It was found that teachers have their own concept of creativity and it can influence their teaching approach and assessment of activities involving creativity like composition and improvisation (Odena, 2006). It appears that music teachers have specific conceptions about incidents of musical creativity in secondary schools. It would be interesting to know if all secondary schools allow their children to make their own music or are a few enthusiasts doing this?

Mathematics

While studying high school students' creativity in mathematics by analysing their problem posing abilities in geometrics, it was found that even those students who were good at routine algorithmic mathematical problems had trouble posing good quality and novel mathematical problems (Van Harpen & Sriraman, 2013). Van Harpen and Sriraman (2013) pointed that problem posing as an aspect of mathematical creativity has received scant attention as compared to other areas like problem-solving. It has already been shown that creativity and problem-solving are closely related concepts. Recent studies show creativity is also associated with problem finding.

Science

Pupils' decrease in interest in science combined with a decline in learning during the transition from primary to secondary school are two challenges faced by science education in the UK according to Bore (Bore, 2006). He noted two key ingredients to ensure pupil engagement in learning: bridging work and teacher creativity. Bore studied the experiences of primary and secondary teachers, while designing a bridging work for pupils in science and proposed a four-stage bottom-up model for curriculum development to encourage creativity. The four stages are: (a) uncertainty (getting used with the removal of boundaries),

(b) visioning (idea generation),

(c) combinatorial calm (ideas achieving structure, and)

(d) readiness (ready to act/practise ideas).

The model was found to be an effective method of professional development to promote creative science teaching (Bore, 2006). Though this seems to be an effective model, how many teachers use it to foster creativity is to be found. It seems, the aim of encouraging creativity in different subject domains by all teachers and all schools still remains an unfulfilled dream. A study by Hoang (2007) explored how student's motivation and interest in creative curriculum-based, investigative activities affect their conceptual understanding of science. Creative activities can be exciting, motivating and are more accessible to students in a risk-free environment, where there is little control. According to Hoang (2007) creative activities are open-ended, allow students to explore and be in control of their learning and nurture an environment that has an impact on student goals. As creative science products require understanding of science concepts, there exists a natural connection between creative products and conceptual understanding in science (Hoang, 2007). Ideally during science lessons, students should be active and fully engaged as independent investigators. Therefore, in a creative classroom, thinking is valued more than memory and the student is expected to make a valuable contribution. With teacher's use of probing question and right feedback these activities can make lessons more engaging by encouraging children to think, question and learn. In the classroom, I have seen a mnemonic RODIN used to sort questions or ideas into types. This highlights a focus on Research; Observation; Demonstration; Investigation; None of these. A study conducted by Nickerson (2009) indicates that students benefit during the process of translating facts into movement and drama, which requires a deeper understanding of science concepts. Both participants and the audience can learn from drama and it encourages questioning scientific concepts. Nickerson suggests many qualities required for investigative science are developed through dramatisation. It was found that the science drama experience alone gave Y8 students a thorough understanding of the learning material (Nickerson, 2009). Some science topics are those that cannot be taught through investigations, demonstrations, observations and field trips. It would be worth trying if those topics can be taught by encouraging children to conduct research or using dramatisation. For example, the topic Evolution can be made more interesting if children can read and do a drama about it. This approach would also be useful for teaching several topics in the primary science context. Prior to starting research on scientific creativity, the researcher as a science teacher, found drama useful while teaching topics like lifecycles, environmental issues like deforestation, pollution etc. Dramatisation encouraged children to read, question and debate, and develop a better understanding about the topic. Also learning together through movements generated more enjoyment.

Scientists use creative thinking to discover new problems. Can children find problems in science? Can children ask questions and find answers? The Science/Technology/Society curriculum for K-12 science students in USA provided an avenue for creativity through guided inquiry experience (Barrow, 2010). In this study students developed their own approach, decided the type of data to be collected and formulated a conclusion to the question, which in turn increased their motivation (Barrow, 2010). Yager, Dogan, Hacieminoglu, and Yager (2012) also noted an increase in students' creativity and positive attitude towards science after introducing STS (Science/ Technology/ Society) teaching. A previous study by Haigh (2003) had reported that investigative practical work in school science and biology programmes, promoted positive creative learning in students. The study stated that most students carry out a recipe following practical work in science and do not engage in higher level thinking. This study was conducted in New Zealand Biology classrooms and showed that the introduction of open investigative practical work provided opportunities for group possibility thinking and decision making, thereby enhancing creative thinking. Careful selection of activities and planning by the teacher was required and students and teachers worked together to construct knowledge (Haigh, 2003). It would be worth investigating to see if students can come up with their own problems to investigate in science with teacher's support. Teachers may encourage students to generate questions about a particular topic under study and jointly generate a problem (or more) to investigate in the classroom. Students can then investigate it and teacher can be a facilitator, thus encouraging students to be independent learners.

In summary, in the UK, a shift from emphasis of creativity in primary setting to secondary settings was noted by Ferrari and Wise (Wyse & Ferrari, 2015). Teachers have their own beliefs about creativity in different subjects under the National Curriculum and it can influence their practice (Odena, 2006). In the secondary school context, activities like improvisation and composition of musical ideas were considered as part of encouraging musical creativity (DfE, 2021). A study conducted by Burnard and Dragovic (2014) showed creative group instrumental music learning sessions in a secondary school encouraged collaborative music creation. Problem-solving is associated with creative thinking. In Mathematics, though problem posing requires one to think creatively, it hasn't received adequate attention as compared to problem-solving. Students who were good at solving routine algorithmic mathematical problems struggled posing good quality and novel mathematical problems (Van Harpen & Sriraman, 2013). They might need more training in problem posing. Are teachers equipped to support children's problem posing in Mathematics? Do they need more training?

Bore (2006) reported pupil s' decrease in interest in science combined with a decline in learning during the transition from primary to secondary school as two main challenges faced by science education in the UK. According to Bore (2006) bridging work and teacher creativity are the two key measures required to ensure pupil engagement in learning. Adding teaching for creativity or encouraging learners' creativity to the above suggestion would be fruitful (Jeffrey* & Craft, 2004). As creative science products require understanding of science concepts, there exists a natural connection between creative thinking and conceptual understanding in science (Hoang, 2007). Children should think creatively to find solutions to scientific problems and this depends on their understanding of the science concepts. Can children find problems in science? If scientific problem-solving requires prior knowledge and understanding, would problem finding need the same? It is interesting to know if secondary school students can find problems in science that could be answered by conducting simple investigations in the classroom. Would they find scientific problem finding difficult similar to Mathematics students? Do they have a strong scientific understanding to generate problems or questions in science out of their curiosity? There would be strategies that could support the development of children's conceptual understanding in science, which may improve their creative thinking and problem finding ability. Strategies like dramatisation of science concepts promoting deeper understanding (Nickerson, 2009) and investigative practical work are likely to promote creative thinking in students. The introduction of open investigative practical work provided opportunities for group possibility thinking and decision-making, thereby enhancing creative thinking (Haigh, 2003). A teacher can encourage children to think and ask questions after gaining some conceptual understanding about a science topic and help them turn their wonderings into science problems that could be answered in the classroom through investigations. This would give them opportunity to utilise their own personal interests and therefore may keep them intrinsically motivated along with fostering creativity.

3.1.3 **Early Years and Primary Education**

Art

Creative Partnerships was a UK Government's creative learning programme designed to develop skills of young people, raise aspirations, achievements and create more opportunities. The findings from two studies showed that the involvement in school-based creative arts projects opened up opportunities for children to talk each other and also with adults on wide range topics that incorporated personal, social, imaginary and real world themes which are normally rare in curriculum contexts and contributed to their language development. As schools encourage creative partnerships with artists and arts organisations, the study highlights on teacher's role in promoting experiences for pupils language development (Safford & Barrs, 2007). Through Creative Partnership Project, 4-7 year olds (KS1) worked with an artist and concentrated on drawing, painting and talking on three dimensional objects, portraits, still-life works, biographies, 3 or 4 syllable technical terms etc. Increase in manual and linguistic work demanding attention to detail, receptive understanding of complex terms and processes and familiarity with the analytical and sequential thinking gave children opportunities to solve problems (Heath & Wolf, 2005). A good piece of art is the one that provides feeling to our understanding (Eisner, 1993). Efficiency in teaching art is a strong predictor of shaping pupil's attitudes. It was found that art specialists were able to create a significant impact on low confident pupils (Pavlou & Kambouri, 2007). It shows that children’s involvement in school-based art projects supported the development of their language, problem-solving and creative thinking skills. Studying a work of art and engaging in creative talk about the art piece generated deeper understanding. Also, it can improve confidence and healthy attitudes in children.

Drama

Imagination seen as characteristic of creativity includes the ability to link ideas or sensations and is vital for drama. Social and cultural factors are part of imagination. In the words of M. Cremin (1998), creativity is a public process, which includes the original, when private imagination produces alternatives and extensions. O'Day (2001), through scaffolded plays integrated creative drama into language arts classrooms to help pupils build literacy. When she could not find any material to encourage first grade pupils reading in a fun way, she wrote her own play, including non-speaking parts for those limited readers. Children can be encouraged to be creative, by asking them how a character might look like or act or respond in a particular situation. Writing initial dialogue of an existing story and leaving the rest for pupils to complete or posing a question or a problem in the beginning of a story and leaving the rest for pupils, so that they can bring their own interests, experiences and interests to the story line (O'Day, 2001). Drama is closely associated with speaking and listening and can be used as an effective teaching learning strategy in primary schools (Prendiville, 2000). The results from a meta-analysis study on drama suggests drama as an effective tool for increasing achievement in story understanding, reading and writing. Use of drama during the instruction of native language in Y4 class in Turkey, improved the pronunciation skills of children (Ulas, 2008). In a primary school in Hong Kong, drama education proved to be effective in enhancing creative thinking and story-telling ability. This supports the benefits of drama education in primary schools and also the idea of integrating drama in subject teaching and learning (Hui & Lau, 2006). Hall and Thomson argued that creativity is more felt in projects rather than in the National Curriculum and in artists than in teachers. Here more emphasis is placed on enjoyment and inclusion and not on considerable curriculum change (Hall & Thomson, 2007). This points that there is more space for encouraging creativity under different subjects in the National Curriculum than just the arts. Another study explored the effect of drama on the creative imagination of children in different age groups and found that drama has a positive effect on the development of creative imagination of children. It had more effect on 10 year old than 13 year old children as they produced more original ideas and more elaborate drawings. This suggests the need to introduce drama in schools to encourage creative imagination from early ages (GÜNDOĞAN, Meziyet, & GÖNEN, 2013). In another study, participation in creative drama gave students opportunities to role play, analyse roles and to work cooperatively in creative tasks requiring emotional control (Freeman, Sullivan, & Fulton, 2003). Contrary to the above studies supporting drama experience Freeman et al (Freeman et al., 2003) noticed that creative drama experience did not significantly improve self-concept, problem behaviour or social skills of primary school children. In short, integrating creative drama into classrooms helped to develop children’s literacy by stimulating their creativity through story writing and storytelling. As drama is strongly associated with speaking and listening, it can act as an effective strategy to enhance creative thinking in children. Therefore, integrating drama to enhance creative thinking skills in other subjects under the National Curriculum would be worth investigating.

Music

According to Grogan and Martlew (2014) when designing a creative learning environment, one should ensure that children become familiar with opportunities, resources, and a confidence that the adult will support their creative thinking without over directing their learning in a specific manner. It allows children to take risks, discover new ways of thinking and exploring creatively (Grogan & Martlew, 2014). Though, students and teachers in Slovenian elementary schools are satisfied with creative musical activities in the classroom, there is a confusion regarding all aspects of creative musical thinking as well as the criteria for evaluating musical creativity (Kovačič & Črčinovič Rozman, 2014). A study that analysed specific instances of transactive communication among 10 to 11 year old children while engaging in paired melody writing using computers, showed transactive communication makes collaborative learning a valuable tool for learning and teaching. It was noticed that musical expertise or friendship within pairs has had no significant effect on the nature of transactive communication (Hewitt, 2008). M. Wong (2014) suggested that ICT has a strong potential to avoid traditional barriers to creativity. Increased use of ICT in music lessons can increase productivity and personal enjoyment (M. Wong, 2014). It appears more is to be done with regard to the encouragement of musical creativity at primary school level. There needs to be more clarity on what counts as creativity in music so that all music teachers can have a clear conception of musical creative thinking and thereby promote it. Also, increased use of ICT could contribute more towards the enhancement of children’s musical creativity.

Literacy and Language Arts

By far the area of the primary school curriculum that has been explored for creativity is that of literacy and language arts. Various meaning for creativity are seen in each stage of the English National Curriculum documents (Compton, 2007). Compton (2007) argues that for creativity to truly unfold in education there needs to be an agreed definition of creativity. In the National Curriculum, creativity is regarded as a 'key thinking skill', essential for meaningful learning. Creative thinking includes other skills like ideation, imagination, innovation, problem-solving, enquiry and evaluation (Compton, 2007). It could be argued that most of these behaviours are fundamental to the processes of problem-solving (Robert Fisher, 1987). During problem-solving one engages in creative thinking to generate solutions. Therefore, creative thinking is associated with problem-solving. Burke Hensley (2004) favours a classroom that follows active inquiry method for solving problems. He identifies the need for incorporating creativity and curiosity into literacy teaching and learning and suggested creating a questioning classroom climate to foster curiosity in learning. A study conducted by Wegerif (2005) showed that dialogical reasoning or exploratory talk, where creativity is opened up by the reflective use of language, promoted co-construction of shared knowledge. In the UK, emphasis on focused teaching to raise standards of writing has led to a suppression of creativity and enjoyment in writing. Evidence from a study conducted by Ros Fisher (2006) indicates teachers giving very specific guidance to pupil and scaffolding their learning. But during scaffolding teachers are expected to hand over the control to learners but little evidence of this was found from the present study. According to Ros Fisher (2006), handing over of control is necessary for children to learn the rules and also to develop confidence in using them in creative ways.

According to T. Cremin (2006) other than knowledge, skills and understanding, teaching for creativity in writing requires emotional capacity to tolerate uncertainty, take risks and engage artistically. To encourage children in creative writing, teachers need extended opportunities to engage artistically and creatively as writers themselves. Dadds (1999), in his study on teacher's values and beliefs about literacy, distinguished among functional or literacy for getting things done and expressive or literacy for one's personal, affective and creative needs and critical literacy or quarrelling with the text. He found that many of the teachers who participated in the study favoured literacy experiences that were open ended and creative (Dadds, 1999). But this does not necessarily mean that they are implementing this in classrooms. The ability to find a link between two or more unrelated ideas or concepts to solve a problem is central to the creative process. This feature is obvious in analogy and metaphor. In a study that focused on metaphorical writing with students in the primary school setting, Fraser (2006) found that, in order to promote creativity in literacy, teachers provided open ended lessons, encouraged variety and innovation and allowed time to play with ideas. Engaging students in writing their own metaphorical texts generated novel responses and multiple interpretations thereby promoting emotional exploration, imagination and enjoyment (Fraser, 2006). An exploratory, textual analysis of children's letter-writing texts suggested that imaginative strategies were integral to the construction of the texts (Brill, 2004). Open ended literacy experiences, provision of ideas and experiences from different sources and time to play with ideas helped children engage in better creative writing. According to Wilson (2007), the linguistic demands of poetry writing makes it the most demanding form of writing children come across in school. Recognising our natural capacity for creativity, reflecting on it and reconstructing it pedagogically can promote real learning. The real-life strategies and struggles of a creative writer in formulating a text can also lead to valid learning activities in the classroom, where authentic creation of poetic texts takes place (Spiro, 2007).

Myhill (2001) stressed that the teaching of writing involves double activities of creating (what to say) and crafting (how to say it). Pahl (2007) studied children's texts and possibilities within a text to ask different kinds of questions to understand creativity and concluded that children get their ideas for drawing and writing from their experiences at home and school. A primary school project that focused on the development of reading and writing using visual and performance arts, literature, music and crafts created opportunities for "art-full" reading and writing (Grant, Hutchinson, Hornsby, & Brooke, 2008). Vass (2007) investigated the nature of paired talk and the role of friendship in collaborative creative writing activities during joint poem writing. Discourse analysis was used to understand discourse patterns in different stages of paired writing. A longitudinal observation of classroom activities in Y3 and Y4 classrooms with 24 children in 12 pairs, aged 7-9 was conducted. The findings demonstrated that peer collaboration enhances creative writing through collective, imaginative brainstorming (Vass, 2007). A study conducted in a socio-cultural context, explored how primary children 'learn to collaborate' and 'collaborate to learn' on a creative writing project, using diverse cultural artefacts that include oracy, literacy and ICT. Children talked and worked together to promote social construction of knowledge among all participants. A selection of dialogues, texts and multimedia products of stories created by 9-10year old children were analysed and the setting was found to be dominated by socio-cultural concepts like: co-construction; collaborative creativity; inter-textuality and inter-contextuality among oracy, literacy and uses of ICT; strategies for the production of dialogue and text and artefacts for knowledge construction (Rojas-Drummond, Albarrán, & Littleton, 2008). All these support the value of collaborative learning to enhance creative thinking.

A small scale research project that allowed children to make their own films, taking the roles of director, film crew, sound technicians, illustrator and narrator, considers film as a creative, engaging and effective strategy for teaching reading (R. Watts, 2007). This seems to be a unique creative and learning experience for children with plenty of opportunities for productive thinking. It would be more rewarding if this film making experience can be integrated with the learning of other subjects in the National Curriculum particularly science, history and geography. Field trips used in literacy learning can encourage creative writing. For example, UbiComp-supported fieldtrip by Y5 children to the grounds of a historic English country house promoted creative writing (Halloran et al., 2006). The article 'Travel with a Time Lord: using media to enhance literacy' reports how *Doctor Who* was used as a means to encourage literacy achievement and raise writing standards among 8-11 year old children. More awareness of the effective use of media resources were given to a group of 10 primary teachers in Wales (Harrett & Benjamin, 2009). The above studies showed how field trips and media can be used for enhancing children's creative writing. It is essential to make teachers aware of these varied ways through which creative learning of literacy can be encouraged and may be extended to other subjects. Hilton (2006) argued that the primary English tests at the end of KS2 were invalid as a measuring instrument and had a damaging effect on pedagogy. They were based on a misleading one-dimensional conception of reading literacy attainment as it simply added together scores achieved for two very different cognitive skills - word reading and text comprehension, thereby damaging creativity and enterprise (Hilton, 2006). These suggests the need for more push for creative learning under the National Curriculum subjects particularly subjects other than arts and literacy where most work have been done.

History

In history, the results obtained from a comparative study conducted by Larsson et al (Larsson, Booth, & Matthews, 1998), to determine the attitudes to the teaching of History and the use of creative skills in Japan and England showed that Japanese students were not significantly worse than English students, for whom the questioning of sources and the use of creative thinking are a normal side of the history curriculum, while it is the opposite in Japan. Larsson et al. (1998) suggested that a change in the attitude about the nature of history, the way it is taught and assessed in Japan can bring a change in their student attainment. It appears as there is less research exploring creativity in learning History as a subject. The programme 'Horrible Histories' by the BBC channel for children (cbbc) has been very successful in presenting historical events in a fun and interesting way to children.

Geography

There is much less research exploring creativity in other areas of the curriculum, even though they do offer opportunity to foster creativity. Owens (2017) considers Geography as a creative subject as it offers relevant contexts for enquiry. Within creative teaching and learning, creative thinking and critical thinking work together when pupils apply their learning in original real-world issue (Owens, 2017). According to Scoffham (2013) creativity is a key element in the teaching and learning of geography, nature of geographical thinking. Teaching for creativity focuses on developing contexts where children have space to generate ideas and develop them. By adopting a questioning approach teachers can nurture children's imagination. Teaching Geography becomes more meaningful when children engage with problems and use their imagination to produce new ideas and solutions (Scoffham, 2013). The results from a study conducted by Flanagan and Walshe (Flanagan & Walshe, 2001) to compare teaching of geography in the primary school setting using internet and a conventional approach, showed that the children taught by the internet site scored significantly better than those taught by conventional methods. As many children with learning difficulties find it difficult to partake in Geography classes, due to reading difficulty, a website with emphasis on sound, graphic and games and having the same content as the geography book, would be beneficial (Flanagan & Walshe, 2001). This appears to me as an example of creative teaching or teaching creatively, where teacher uses a creative approach to make learning interesting. Has this provided children opportunity to think creatively? Or engage with problems? Landscape is the common link in geography and the arts, inspiring paintings, photographs, literature, poetry, maps and fieldwork. Mackintosh (2003) points out that encouraging children to develop a pictorial representation of their own journey or activity by inventing their own symbols and a key promotes self-expression and also an opportunity to talk about and learn geography. Also, it is actually related to real life experience and maps. Do teachers know what creative thinking in geography means? It will be interesting to know what teachers see as incidents of creative thinking, in geography.

Mathematics

When teachers' conceptions of creativity in mathematics were analysed, it was found that while teachers declarative conceptions seemed to be very similar, their conceptions-in-action varied dramatically (Lev-Zamir & Leikin, 2013). It is important to maintain an appropriate classroom environment, where questioning and risk-taking are encouraged and mistakes are viewed as opportunities to greater understanding, to promote children's creativity in mathematics (D. P. Newton, 2012b). Tabach and Friedlander (2013) evaluated students' mathematical creativity as expressed in the solution methods of three problems for groups of students in different grades. The findings showed that at elementary school level, the number of solutions and creativity scores increased with age. An increased level of creativity was observed with an increase in mathematical knowledge. A decrease in creativity in eighth grade was associated with the exclusive use of algebra at school (Tabach & Friedlander, 2013). Leikin and Pitta-Pantazi (2013) stressed the need for advancement of creativity research in mathematics education. Problem posing and algorithmic problem-solving are important components of learning mathematics. A study that investigated problem posing using real world artefacts, found that 6-9 year old pupils with no prior experience in problem posing, generated a range of problems linked to the real world although in a superficial sense (Downton, 2013). When problem posing was implemented using real-life artefacts, it was noticed that the artefacts provided useful contexts for finding problems (Bonotto & Dal Santo, 2014). Many mathematical problems produced by the students were similar to those found in their textbooks. Some students produced original problems, open problems or problems that allowed more than one solution. It was noted that the problem-solving phase when combined with group discussions, allowed students to reflect on several types of problems and to explore new possibilities, which in turn helped them to realise that mathematical problems do not always require a numerical solution and some problems are not solvable (Bonotto & Dal Santo, 2014). When students were asked to write problem stories, they integrated mathematics and literacy to pose problems and to create stories enhancing their creativity (Sardinha, Palhares, & Azevedo, 2014). Problem-solving and problem posing are associated with creative thinking in Mathematics. It would be interesting to know teachers' conceptions of creativity in Mathematics.

Information and Communication Technology

ICT can act as a tool and a medium for children's engagement in the creative processes. According to Loveless (2003) the interaction between ICT capability and creativity offers learners and teachers opportunities like designing stimulating environments that can offer a variety of experiences, tools, techniques and media to challenge children's creative imagination and engagement. ICT offered positive social and collaborative experiences with interaction, support and scaffolding between peers or between learners and teachers in foundation stage classes of two state schools in the UK (O'Hara, 2008). Children had opportunities to explore new outlets for inventiveness and creativity and problem-solving. It enhances provision for children to be creative, to acquire generic learning skills and to practice social skills. Much depends on the teacher's judgement about what to use, when and how to use it, to achieve the best out of it (O'Hara, 2008). Therefore, a teacher's role is crucial in encouraging creative thinking and if he or she does not have a clear conception of what creativity is, in different subjects and ways to promote it, he or she may not be able to judge when, where, and how to make the best use of ICT in different subjects though ICT is a great tool for enhancing creativity. Code club, a network of after-school clubs introduced in selected primary schools, in the UK, provided easy and fun introduction to digital creation. The main aim of Code club is to introduce children to the realm of programming and digital creativity in an enjoyable way (Smith, Sutcliffe, & Sandvik, 2014). From the researcher’s point of view, it would be better if children could learn coding as part of their ICT learning within the specified school timetable rather than as an after-school activity. Children in schools spent most of their day (6-7 hours) in front of interactive white boards, computers, and other screens. After school clubs can act as venues for physical activity, creativity, self-expression, and socialisation for children through physical play, sports, artwork, board games, music, science activities and cooking, thus help them evolve as more rounded well-balanced individuals. It would be more fruitful if this provision is accessible to all children irrespective of financial and economic background. Although technology has made learning interesting by bringing the world to the classrooms its increased use has been attributed to sedentary lifestyle, loneliness, poorer mental health and safety issues, a great concern for today’s parents and teachers. This is stated in the report generated by the Durham Commission on Creativity and Education (James et al., 2019) a recent proposal to encourage creative thinking in children not only through the arts but also through the teaching of other subjects in the National Curriculum. Although, technology has made learning possible during the past two years of lockdown due to Covid 19, the heavy reliance on it has affected children's as well as adults' mental health considerably. This might give head teachers an opportunity to reflect on ways of balancing the use of technology by incorporating other creative ways of delivering the curriculum to children for promoting better mental health and improved engagement in learning.

Physical Education

A physical education programme implemented to encourage pre-school children's creativity, noted an improvement in pupil's creative fluency and imagination (Zachopoulou, Trevlas, Konstadinidou, & Group, 2006). Teachers can encourage children's curiosity and imagination by giving them chances through movement, to imagine, explore and discover. The findings have implications while designing in-service professional development and teacher training programmes to encourage the development of creativity in children through movement and play (Zachopoulou et al., 2006). Griggs (2009) argued that due to the increased focus on performance, creativity continues to be ignored in primary schools, even in areas such as Physical Education, which has great scope for fostering it due to an endless range of movement possibilities. A recent survey by Varkey Foundation (Broadbent, Gougoulis, Lui, Pota, & Simons, 2017) reported that young people in Japan and the UK have the poorest mental wellbeing out of the twenty major countries. Physical education teachers can shape creative activities that contribute towards children’s physical fitness, mental and emotional wellbeing and help them to become more resilient. They can also run different after-school clubs, which include activities focussing on creative body movements like games, dance and mime. Schools can ask parents from different cultures to volunteer to share their knowledge of specific creative talents (e.g., dance, music, art). Thus after-school clubs can act as venues for cultural exchange of creative talents. It would be interesting to know what teachers see as creative thought in physical education as a subject.

Play

Play has an important place in the instruction of reading and writing in the primary school. Children whose early literacy experiences include pleasurable activities are more motivated to learn and are more likely to develop a life-long love for reading and writing. Children's literature is filled with creative elements which includes the skilled writing of the author and the attractive images contributed by the imagination of the illustrator (Giorgis & Johnson, 2001). Some playful ideas suggested for literacy learning are playing with phonics, read aloud, expository writing, field trips and classroom guests (Scully & Roberts, 2002). The findings from a study that investigated young children's humorous activity as a form of play, suggested that during humorous events children are involved in play activity with materials, language, pretend play, physical play and they are then turned into humorous events, due to the creativity that children exert during the play (Loizou, 2005). Children should be provided with time and space to explore their environment, test the rules and use materials in novel and creative manner (Loizou, 2005). When children work with different materials they learn about the material and also appreciate their affordances. Each material invites opportunities for orientation in certain directions when they use it (Edwards & Willis, 2000). Teachers can encourage children to:

- Design and create complex products.
- Set up a resource studio with many materials and resources and allow children to sort and arrange them.
- Offer unusual combinations of materials to stimulate imagination and problem-solving ability.
- Offer graded exploration and experimentation.
- Help children to understand the properties of materials.

- Take photos to document children's use of materials (Edwards & Willis, 2000). This would be very useful with younger children and play can be integrated with the learning of other subjects.

Design and Technology

Design and technology can enable pupils to be creative by providing lessons in which pupils can use different strategies to produce a wide range of design ideas. Pupils can choose and turn some of these ideas into useful applications and use them in their designing and making task in hand (Davies, 2009). The way this is meant to be taught in Western schools is through practical problem-solving, which opens the task to creative responses. Nevertheless, this depends on the teacher providing this kind of approach and not simply offering 'follow the steps' activities (Haigh, 2003; L. D. Newton, 2012). Davies suggests that design and technology offers opportunities for the development of problem-solving skills through sorting, comparing and analysing data; researching; understanding patterns or viewing connections; explaining the working of a system or features of a design; formulating and testing ideas; suggesting approaches; selecting options; predicting or making judgements; applying their ideas in a creative way both in innovative designing and ingenious making; developing and refining ideas for product success and evaluating their products (Davies, 2009). Lewis (2005) has suggested that technology education teachers should also be able to assess creativity and give feedback to students like teachers of art and music, to help students to refine their designs. So, teachers should be trained to see opportunities for creativity in the curriculum and instruction (Lewis, 2005). When project based learning was employed among primary school-aged children with social, emotional and behavioural difficulties, it was found that children progressed in their thinking, problem-solving, creative and organisational skills and their behavioural problems in the learning situation reduced. A 'Project Hour' was set up during which children were allowed to choose a four week project and work with adult support (Massey & Burnard, 2006). This shows that project based learning has an effect on emotions. The findings from a study which investigated the relationship between creativity development and the implementation of the Discovering Intellectual Strengths and Capabilities while Observing Varied Ethnic Responses (DISCOVER) curriculum model showed that creativity development is supported through active learning, student choice, access to varied materials, exploration, self-evaluation, problem finding and problem-solving. The study suggested that teachers can provide a balance of teacher-directed and student-directed learning experiences as children develop more understanding in their subjects. According to Maker, Jo, and Muammar (2008) by teaching creative thinking skills, teachers are adding depth and richness to children's understanding of the subject by giving them opportunities to apply their knowledge in the development of unique products . This promotes creative thinking by the application of scientific knowledge to solve practical problems or generates creative thinking in the application space (D. P. Newton & Newton, 2009b).

Science

Research studies of creativity in the context of primary science education in England are limited. Most of the studies gathered on scientific creativity were those looking at teachers' and student teachers' conceptions of creative thinking, therefore, included under the higher education section given at the beginning of this chapter. Student teachers (D. P. Newton & Newton, 2009b) and teachers (L. D. Newton & Newton, 2010a) showed narrow conceptions of creativity in science focussing on fact finding practical investigations and application of scientific knowledge to solve practical problems. There is evidence that the lack of adequate science knowledge lowers teacher's confidence and so they do not let children to explore through investigations. How a teacher teaches a subject depends a lot on teacher's knowledge in it (Coates, 2006). This has great implication on promoting creative thinking skills. According to Kind and Kind (2007) to promote students' creative thinking, teachers should provide opportunities to ask questions, do open-ended scientific tasks and suggest explanations, and test them. Using prescribed curriculum as a guideline, each teacher should apply his or her creativity while teaching the content. Teachers are often hesitant to step outside the comfort zone due to the fear of discipline issues (Longshaw, 2009). To develop creativity the classroom environment should be friendly and open questioning should be encouraged.

Teachers are enthusiastic about promoting creativity, but many are uncertain about what creativity means, how to promote it or how to assess it (L. D. Newton, 2012). What creativity means from a primary school perspective? From an educational perspective promoting creativity focuses on encouraging the creative potential in all children (little 'c') rather than focussing on a few gifted ones. According to Newton (L. D. Newton, 2012) children cannot be expected to be creating something new to the world (big 'C' view). When a child understands something with the help of a teacher, he or she creates new mental connections between ideas. This is new to the child (little 'c' view). Creating an understanding about a particular concept or idea is a personal creative process and the product is often new to that person (L. D. Newton, 2012). Though, creative behaviour is seen as associated with arts, it can be exercised in all subjects.

Newton & Newton (D. P. Newton & Newton, 2009b) identified the key areas of creative thinking in science and the associated behaviours in the primary school context. In science, children can be creative in:

i. The hypothesis space when they are asked to construct tentative explanations in the form of reasons or causes (for e.g. when asked to say the reason why the ice cube kept in the kitchen has become water);

ii. The experimental space when asked to construct a practical way to find reliable descriptive information (for e.g. a test to see if different shoe soles have a different effect on slippery surfaces) or a practical way to test a tentative explanation of an event (for e.g. a test to find out if my idea that shoes with rubber soles having grooves and ridges have the best grip on wet road); and,

iii. The application space (which comes under Science in curricula in some countries and under Design and Technology in other countries' curricula). This is when children apply their scientific ideas to solve practical problems (for e.g., when a child uses his or her knowledge of properties of materials to design a waterproof roof for the doll's house). Also, asking children to generate tentative descriptions of properties, scenarios, trends and patterns (for e.g., when a child uses science knowledge to imagine living on a space station) provides opportunity to be creative in the pre-hypothesis space that can be considered as weaker constructive thinking (D. P. Newton & Newton, 2009b). In science, children develop their own understandings and ways of testing them. In technology, children use their understandings to solve practical problems. They also have opportunities to do activities like model making, writing story or poems and painting, but they are not considered as scientific creative thinking activities. They are examples of creative reproductive activities (D. P. Newton & Newton, 2009b).

In science, mathematics and technology creative thinking is more likely to be seen as problem-solving (D. P. Newton, 2010). In science, there is:

- A problem- usually in the form of a puzzling observation or event which requires an explanation;
- Creative thought in the hypothesis space- applied to raise one or more plausible causal explanations;
- Creative thought in the experimental space - applied in the design of tests of the possible explanations (D. P. Newton, 2010, 2012a). There is also the potential for creative thought in

the application space, where science knowledge is used to solve practical problems. In England, this comes under the Design and Technology Education, the application side of science (D. P. Newton, 2010).

These creative activities are part of any scientific enquiry, whether this is the investigation of young children in a primary classroom or the research undertaken by scientists as a team or independently. The movement from the problem to the practical testing of explanations may not be smooth and in practice, there may be some backtracking with notions being revisited, clarified, redefined or reinterpreted, with consequences for later thinking. School aged children cannot be expected to engage in creative thinking that matches that of the scientist. As beginners in the world of science, children's thinking may rarely generate novel, plausible ideas, but it can be novel and plausible to them (instances of what was called 'little-c' in the previous section, new to the person or personal creativity as opposed to 'Big-C', new to world creativity(Boden, 2004). Here the child was *presented with* or *given* the problem to solve, a common classroom practice. If children can *notice* or *find* a scientific problem to solve themselves, the benefits are at least twofold. There is the opportunity for a fuller educational experience of the scientific creative process and there is the potential for arousing interest and engagement in satisfying child's curiosity (Jarman, 1991; Ritchie, Shore, LaBanca, & Newman, 2011; Ryan & Deci, 2002). Also, problem finding is partly an emotional activity (Mark A Runco & Nemiro, 1994). But, can children do this?

In short, there were more studies on promoting creative thought through art, drama, music and literacy. More clarity is needed on what counts as creativity in music, so that all teachers in primary schools can promote it. There should be more push for encouraging creativity under the National Curriculum subjects particularly subjects other than arts and literacy where most work have been done. In order to teach students creative thinking skills teachers should have a clear understanding of what counts as incidents of creative thinking in different disciplines and ways of promoting it. They should be given training on understanding subject-specific conceptions of creativity, identifying learner's creativity and generating more awareness on pedagogical practices promoting creativity across different subjects in the curriculum. Teachers are asking for strategies, activities, materials and examples of promoting creativity informed by field research (Bereczki & Kárpáti, 2018). Availability of such training programmes and resources is an issue that needs to be addressed and dealt with (L. D. Newton & Newton, 2014).

3.2 In Summary

Key points from this chapter on creative thinking in different phases of education and subject areas include:

- Open ended investigative and practical work in science promotes creativity (Haigh, 2003; Kind & Kind, 2007)
- Question asking and answering for creative thinking (Jeffrey, 2008)
- The benefits of children raising their own questions or finding their own problems in science (Jarman, 1991; Ritchie et al., 2011; Ryan & Deci, 2002)
- The need for opportunities for problem posing by pupils in classrooms (Van Harpen & Sriraman, 2013)
- A lot of work has been done into creativity in the areas of primary school:
- English (Burke Hensley, 2004; T. Cremin, 2006; Dadds, 1999; Fraser, 2006; R. Watts, 2007; Wegerif, 2005)
- language arts (Grant et al., 2008; Halloran et al., 2006; Harrett & Benjamin, 2009; O'Day, 2001; Rojas-Drummond et al., 2008; R. Watts, 2007)
- drama (Freeman et al., 2003; GÜNDOĞAN et al., 2013; Hall & Thomson, 2007; Hui & Lau, 2006; Prendiville, 2000; Ulas, 2008)
- Music (Hewitt, 2008; Kokotsaki, 2012; Kovačič & Črčinovič Rozman, 2014; M. Wong, 2014) and
- the arts (Heath & Wolf, 2005; Pavlou & Kambouri, 2007; Safford & Barrs, 2007).
- Very little research into other areas of the curriculum including:

Science (Boden, 2004; Coates, 2006; Kind & Kind, 2007; Longshaw, 2009; D. P. Newton, 2010; D. P. Newton & Newton, 2009b; L. D. Newton & Newton, 2010a; Ryan & Deci, 2002)

Geography (Flanagan & Walshe, 2001; Mackintosh, 2003; Owens, 2013)

History (Larsson et al., 1998)

Physical Education (Griggs, 2009; Zachopoulou et al., 2006)

Design and Technology (Davies, 2009; Lewis, 2005; Maker et al., 2008; Massey & Burnard, 2006)

4 Chapter 4: Creativity, Children's Question Asking, Problem Finding in Primary Science

Scientific enquiry is a creative process which often begins with a question that generates several possible ideas which are then tested to finally reach an answer. It is a common practice in the classroom that a ready-made question, possibly in the form of a problem is given by the teacher for the students to solve. Instead of the teacher giving students questions to find answers to, can students be encouraged to find their questions in science? If students could generate their own science questions to test in the classroom, would they be able to experience the scientific process to the fullest? Can we use strategies to engage children in question asking for problem finding in science?

4.1 Definitions of Problem Finding and Associated Terms

Problem finding is applied in different fields of education. Since 1960, different terms like problem discovery, problem formulation, problem identification, problem construction, problem posing, etc have been used to refer to the process of finding a problem (Abdulla & Cramond, 2018). Different definitions of problem finding have been suggested by different authors. Getzels and Csikszentmihalyi (1976) in their study of creativity in fine arts described problem finding as a talent, a cognitive skill that can lead to creativity. Similar to solving problems, to find problems, one has to think from different angles or use divergent thinking. Hu, Shi, Han, Wang, and Adey (2010) defined problem finding as students' ability to generate problems for themselves, either generally or within a particular subject domain (e.g., art, science).According to LaBanca and Ritchie (2011) problem finding is the ability to identify a problem and consider its alternative views or definitions. Lee and Cho (2007) defines problem finding as the ability to think, initiate and formulate questions or problems in an ill or moderately structured problem situation, which leads one to consider important types of problem situations when studying problem finding. From the above definitions, it appears that problem finding is the ability to think and generate problems or questions either generally, or in specific subjects or situations. In this study, problem finding refers to a child's ability to generate scientific questions that can be turned into a problem to solve in the class.

4.2 Creative Teaching, Teaching for Creativity or Creative Learning

Pupils' decrease in interest in science combined with a decline in learning during the transition from primary to secondary school are two challenges faced by science education in the UK according to Bore (Bore, 2006). He noted two key ingredients to ensure pupil engagement in learning: bridging work and teacher creativity. According to Robert Fisher

(2004) creative teachers do not merely follow the same lesson plan, they add to them and have the courage to take risk to be different. Grainger and Barnes (2006) have noted that creative teachers utilise their own creative thinking ability while planning their lesson to make it more interesting to learners. This is what Jeffrey* and Craft (2004) has described as creative teaching or teaching creatively, an approach to make learning more engaging (NACCCE, 1999). Teaching for creativity on the other hand has been distinguished as teaching in such a way to stimulate children's creative thinking by encouraging them to take ownership and control of the learning situation (Jeffrey* & Craft, 2004). A recent critical review of literature on creative pedagogies between 1990 and 2018 by T. Cremin and Chappell (2021) reported seven interrelated features of creative pedagogical practice in school. They were generating ideas and exploring, group work, promoting learner autonomy and agency, focused play, problem solving, risk-taking and teacher creativity. Among the seven, the most frequently evidenced characteristic was coming up with ideas and investigating them within a climate of openness. For this to happen, I think it requires collaboration between the teacher and the pupils and some subject knowledge base. In short, creative teaching is the use of teacher's creative thinking while teaching for creativity is more learner focused. As reported in 2.1, this distinction has been reported by the National Advisory Committee on Creative and Cultural Education (NACCCE, 1999) to promote creativity in education. According to Jeffrey* and Craft (2004) though the National Advisory Committee on Creative and Cultural Education (NACCCE, 1999) distinction between teaching creatively and teaching for creativity has been useful as a tool for analysing practice, a more fruitful distinction for studying creative pedagogies would be the connection between creative teaching and creative learning. Creative learning involves features like questioning, exploring, generating and evaluating ideas, risk taking and making new connections with what you already knew (Grainger & Barnes, 2006). In short, teaching for creativity or creative learning implies the same thing, fostering children's creative thinking.

4.3 Creative Thinking, Problem Solving and Problem Finding

Many people assume that creativity is often associated with Arts, however, people can be creative in any area of human endeavour (L. D. Newton & Newton, 2010a). In science, mathematics and technology creative behaviour is more likely to be seen as problem solving (D. P. Newton, 2010). Problem finding is also regarded as an important aspect of creativity (Chand & Runco, 1993; Singer, Ellerton, & Cai, 2013; Wakefield, 1985). According to Robert Fisher and Williams (2004):

> *"What promotes creativity is a questioning classroom, where teachers and pupils ask unusual and challenging questions; where new connections are made; where ideas are*

*represented in different ways - visually, physically and verbally; where there are fresh approaches and solutions to problems; and where the effects of ideas and actions are critically evaluated" (*Fisher & Williams, 2012, p2).

Robert Fisher and Williams (2004) stressed the importance of a question friendly classroom environment where children are encouraged to ask questions and generate ideas to answer their questions through critical discussion and evaluation. Thus, creativity in science implies imaginative use of science ideas to solve scientific problems which involves transfer of ideas to a novel situation. Open-ended investigations give students opportunities for the creative use of science ideas (Roberts, 2009). Garrett (1987) considered problems as a group of activities in which the means of a solution are not immediately known, where the path to the solution might require the discovery of new information or by the rethinking and rearrangement of the old ideas into new forms. So, problem-solving is said to be a creative act (Garrett, 1987). He emphasised that the ability to recognise a problem depends on the knowledge, interests and experiences of the individual. Mark A Runco and Chand (1995) argued that problems are not just discovered, but individuals should identify them, define and at last work to solve them. Children when finding their own problems to solve may also be intrinsically motivated to solve them (Mark A Runco & Chand, 1995). Lee and Cho (2007) emphasised that problem finding includes the behaviours, attitudes and thoughts directed towards posing, formulating and creating problems. It was reported that in the traditional models of problem solving, problem finding, or problem definition was cited as the first step one must complete before proceeding to the consequent problem solving. Problem finding leads to more creative problem solving as the problem solver searches for new problems and sub-problems continuously during the process of problem solving. Lee and Cho (2007) reminded that though problem finding was the first step in the traditional models of problem solving, it is not compulsory in all kinds of problem situations. Some researchers claim that identifying and defining a problem is as important as solving it (Mark A Runco & Chand, 1995) but there are some who argues that the ability to find problems is more important than solving them (Garrett, 1987). If one can apply creative thinking to find solutions to problems, the same may be used to find problems. Teachers and textbooks provide questions or problems for children to answer. It will be interesting to see if they provide children opportunities to raise questions or find problems in science.

Biggers (2018) explored the varied sources of investigation questions from a dataset of 120 elementary science lesson videos and associated lesson plans from 40 teachers across 21 elementary schools. He concluded that investigation questions were predominantly teacher-

directed, with students having no opportunity to find problems for investigation. This study calls for attention to the teacher-directed nature of the investigation questions in the existing science curriculum materials and the need for training teachers on strategies for adapting the teacher-directed questions in a way to allow students more opportunities to raise questions that would serve as investigative problems. More research should be carried out on the development of curriculum materials and in-service training sessions to help teachers to gradually move across the continuum of teacher-directed to student-directed investigation questions in science. According to Biggers (2018) the teacher should develop sufficient skills to support children to find problems and solve them.
Science textbooks normally provide questions for children to answer. It is interesting to see how text materials support the fostering of creative thinking and problem solving in science. Do text materials provide children opportunities for problem finding or question asking in science?

In normal classrooms, most students tend to carry out recipe following practical work in science and do not engage in higher level thinking. Investigative practical work in school science and biology programmes, promoted positive creative learning in students (Haigh, 2003). A New Zealand study showed the introduction of open investigative practical work in biology provided opportunities for group possibility thinking and decision making, thereby enhancing creative thinking. Careful planning and selection of activities by the teacher was required and students and teachers worked together to construct knowledge (Haigh, 2003). Teacher may ask children to raise questions they are curious to know about in connection with a particular science topic. Teachers may help children shape their simple questions to problems to investigate in the classroom through prompting.

The Science/Technology/Society curriculum in USA offered K-12 science students opportunity for fostering creativity through guided inquiry experience. Students developed their own approach, decided on the data to be collected and formulated a conclusion to the question leading to an increased motivation (Barrow, 2010). Yager et al. (2012) also noted an increase in students' creativity and positive attitude towards science after introducing Science/ Technology/ Society curriculum which follows guided inquiry. A study which examined the problem finding strategies employed by highly successful secondary school science students concluded that open inquiry experience fostered creative thinking skills by allowing them to problem find (Litchfield, 2012).

In Mathematics, students who were good at solving routine algorithmic mathematical problems struggled posing good quality novel mathematical problems (Van Harpen & Sriraman, 2013). Though, traditionally scientific creative thinking is associated to problem solving, it also thrives in a friendly classroom environment where open questioning is encouraged. According to Han, Hu, Liu, Jia, and Adey (2013) problem finding is also a key component of creativity. Research has started looking at creative problem-finding ability (CPFA). A study that used two teaching tasks of high and low difficulty levels against three group member construction (homogenous, heterogeneous and voluntary group) between subjects' design to study how group member construction affected peer interaction and creative problem-finding ability. The findings revealed that teaching tasks had no significant impact on improving students' creative problem finding ability while peer interaction had a positive relationship with students' creative problem-finding ability. It was found that lower ability students performed better in heterogeneous groups while medium ability students performed better in homogeneous groups and high ability student performed equally well in both homogeneous and heterogeneous groups (Han et al., 2013). This study shows more scope for research into creative problem finding in different disciplines(Mathematics, Science and Literacy). Creative activities that are open-ended, allow students to explore in a risk-free environment, where mistakes are allowed (Hoang, 2007). As creative science products require understanding of science concepts, there exists a natural connection between creative thought and conceptual understanding in science (Hoang, 2007). Ideally, during science lesson, students should be active and fully engaged as an independent investigator. There are several challenges to allow primary school children to do independent investigations in the science classroom. Maintaining class discipline is a major challenge for a teacher, particularly when there are children with attention and behavioural issues. Still, it is worth thinking on ways to encourage primary school children to engage in independent investigation in science to encourage creativity. Dramatisation of science concepts or science drama experience helped students develop a deeper understanding of scientific concepts. Both participants and the audience can learn from drama and it encourages questioning of scientific concepts (Nickerson, 2009). It could be worth trying the use of science drama to help children think creatively to generate questions on scientific topics that cannot be tested in the classroom like evolution, environmental issues like pollution, deforestation, global warming and climate change and cruelty against animals. Scientists use creative thinking to discover new problems. It would be worth investigating to see if students can come up with their own problems to investigate in science with teacher’s support. Children can be encouraged to ask scientific questions about things they are curious about. It can also be applied to generate questions, concerning facts and explanations on scientific issues children are interested in. In this study, we are particularly interested in children coming up with science questions with the potential to become a problem to solve in the class.

4.4 Students Questions in Science

Student questioning has multiple benefits for teaching and learning and teachers need support to align student questioning to curricular goals (Stokhof et al., 2017). Students' questions give teachers an insight into their understanding about the scientific concepts (White & Gunstone, 2014), student's level of thinking (C. Chin & Brown, 2000b) and also exposes the gaps in their knowledge (C. Chin & Osborne, 2008). Therefore, student's question-posing ability can also be used as an alternative evaluative tool for assessing their understanding of a topic and higher-order thinking (Dori & Herscovitz, 1999). Teachers can use students' questions to initiate classroom discussions (C. Chin, Brown, D.E., & Bruce, B.C. (in press)), debate or argumentation, practical investigations in the classroom or laboratory (C. Chin & Osborne, 2008; Jarman, 1991) further reference to experts, encyclopaedias, books and internet (Jarman, 1991), problem-based learning and project work (C. Chin & Osborne, 2008). Student's questions help teachers to reflect on their teaching, subject knowledge, classroom practice and attitude towards students' questions (Jarman, 1991). Through questioning, students explore their ideas by thinking in specific directions and by linking them with their prior knowledge leading to an improved understanding of scientific concepts (C. Chin & Osborne, 2008). Jarman (Jarman, 1991) points out that encouraging children to ask questions not only help them to acquire knowledge but also the ability and aptitude to gain new knowledge. Thus children's questions can act as excellent starting points in science. When we encourage children to ask and answer their questions by practical investigation, we are allowing them to experience the excitement and limitations of science. Asking questions and answering them by oneself creates more interest and motivation in that topic and develops curiosity (Jarman, 1991). Questions lead learners through a cascade of generative activity by initiating hypothesising, predicting, thought experimenting and explaining to construct understanding and resolve conflicts. Thus, questions stimulate students to generate explanations for things that perplex them and to propose solutions to problems (C. Chin & Brown, 2000a). By encouraging children to ask and answer their questions we help pupils to develop creative thinking and problem-solving skills. Therefore, encouraging children's questioning in science for finding problems to solve in the classroom would be rewarding.

4.5 Children's Scientific Questions and Higher Level Thinking

Scardamalia & Bereiter (Scardamalia & Bereiter, 1992) studied the nature of questions generated by primary school children and came up with two different categories of children's questions: text-based questions and knowledge-based questions. Text-based questions are those generated in response to reading a given text while knowledge-based questions are those questions that are generated in advance of instruction. Knowledge-based questions were spontaneous questions emerged from children's curiosity, wonder or from a desire to extend their knowledge. Knowledge-based questions posed by Y5-6 students in advance of studying the topic 'endangered species' generally reflected what they genuinely wondered about and were more superior than text-based questions produced after reading text materials. Knowledge-based questions generated were of a higher order as they focused on explanations and causes instead of facts and required incorporation of more complex information from diverse sources leading to better conceptual development. Miyake and Norman (1979) claimed that it requires a considerable amount of domain-specific knowledge for students to ask good questions. Therefore, they might find it difficult to ask educationally productive questions, particularly at the start of a topic, which is the point at which questions could have the most directive effect. Keeping in mind the question of whether asking educationally fruitful knowledge-based questions requires significant prior knowledge, Scardamalia and Bereiter (1992) also compared the nature of student questions generated for the topic 'fossil fuels', one in which children had little prior knowledge with that of a more familiar topic, 'endangered species'. Though the lack of subject-specific prior knowledge did not affect student's capacity to ask questions as the number of questions posed were almost the same under both conditions, there was a qualitative difference in the type of questions asked. Students asked mainly basic information questions for the less familiar topic and wonderment questions for the familiar topic. In other words, unfamiliar topics may produce requests for factual information, while familiar topics for which facts are known may produce more speculative questions of the 'I wonder....' kind. The study concluded that a lack of subject-specific prior knowledge may influence the type of questions that students ask (Scardamalia & Bereiter, 1992) thereby supporting the conclusion made by Miyake and Norman (Miyake & Norman, 1979). This means children's domain-specific knowledge is vital. This should be taken into consideration while designing strategies for problem finding. Does this also raise questions about when it would be better to plan question asking as a learning activity in the classroom? Would it be better at the start of a lesson when they have very less prior knowledge or at the end of the unit when they have mastered some of the concepts? It would be worth exploring the nature of questions children ask at the start of a new topic and also at the end of the unit. Other contextual factors like nature of the topic in hand, difficulty level and connection to children's daily real-life experiences should be kept in mind while planning for questioning.

Scardamalia and Bereiter (1992) further argued that wonderment questions originating from one's curiosity, puzzlement and knowledge-based assumption have greater potential for progress in conceptual understanding compared to basic information questions, which ask for facts. Another study conducted by Chin, Brown & Bruce (C. Chin, Brown, D.E., & Bruce, B.C. (in press)) on the types of questions students asked during science learning reported that they included wonderment questions and basic information questions. They noticed that wonderment questions could lead to a cascade of generative activity and initiate a fruitful discussion by stimulating students to hypothesize, predict, thought experiment and generate explanations. Basic information questions, on the other hand, generated little productive discussion. This study also supports the educational value of students' questions especially wonderment questions in the development of understanding. Both types of questions may lead to investigations in the classroom. According to Piaget (1978/ 2013), causal explanations being central to the scientific process are the most important as they make the world predictable by encouraging thinking in the hypothesis space. Questions asking for explanations encourage children to predict about the world, they lead to a cascade of generative activity and initiate a fruitful discussion (C. Chin & Brown, 2000a; C. Chin, Brown, D.E., & Bruce, B.C. (in press)). M. Watts, Gould, and Alsop (1997) proposed three types of students' questions based on the periods of their conceptual growth: consolidation questions where learners tried to confirm explanations and consolidate understanding of new concepts in science; exploration questions, where students attempted to stretch knowledge and test constructs; and elaborative questions ('Well...if that's the case, then...why not...?', 'But what happens if....?' and 'Why, then, is it not possible to....?') where they tried to examine claims and counterclaims, reconcile different understandings, resolve conflicts, test situations, track in and around the ideas and their consequences. Here, they used the term 'elaborative questions' to refer to explanatory questions and consider them as superior as they lead to productive discussion. From time to time, children become curious or puzzled about the world around them and they ask questions to satisfy their curiosity or puzzlement. These questions may ask for factual information or explanations. When the importance was on acquiring knowledge, questions requested for 'basic information'. When it was aimed at making mental connections and understanding, there were more 'thoughtful' ideas (C. Chin, Brown, D.E., & Bruce, B.C. (in press)). Therefore, it is crucial to encourage children to pose explanatory questions stemming from one's curiosity, puzzlement and a deep interest in the world around them. Are there any specific topics in science in which children are generally interested? Can understanding children's interests in science inform us to develop better strategies to encourage student's questioning for problem finding in science?

To understand children's spontaneous interests in science and technology outside the classroom, Baram-Tsabari and Yarden (2005) analysed questions submitted by Israeli children to a series of television programmes. The study found that questions related to biology, technology and astrophysics were popular. Biology questions were the most popular (49.6%) and a majority of them were from zoology, specifically focusing on areas like physiology and anatomy of animals, relationships between animals and humans, animal behaviour, taxonomy and biodiversity. A decrease in the number of biological questions and a simultaneous increase in the number of technological questions was observed among the older students (Baram-Tsabari, Sethi, Bry, & Yarden, 2006). A subsequent study by Baram-Tsabari et al. (2006) analysed children's science-related questions sent to an international Ask-A-Scientist internet site also found biology questions to be the most popular. Students asked more questions related to their school curriculum and assignments (extrinsically motivated) as they got older compared to 'spontaneous' questions that emerged from one's curiosity and intrinsic motivation.

Jarman (1991)also reported that when posing investigative questions, older boys in primary and secondary schools, preferred physical science topics while their female counterparts chose topics related to biological sciences. Girls asked more reassurance-seeking questions and more information questions relating to compassionate issues. Girls were willing to ask more questions in girls-only groups (Jarman, 1991). Conversely, when primary school children were asked to generate questions for investigations, they asked questions from a wide variety of topics and lot of questions were from topics not covered under the formal school science curriculum (aerodynamics, communications technology, evolution and religion) or only some aspects were covered (the solar system, universe and weather)(C. Chin & Kayalvizhi, 2002). Younger children appeared to pose more questions about those topics which they are curious about and found more interesting, than from the school curriculum. Children's questions outside of school show what children are genuinely interested in knowing. Children's science interests manifested through their questions could be valuable information for teachers to use in the classroom for curriculum development (Baram-Tsabari & Yarden, 2007). Also, it would be fruitful if teachers could identify areas of students' science interest and use that information while planning for student questioning. Children may find it easier to generate questions when they are asked to pose questions from topics which they are genuinely interested in. This might also produce a different set of questions, maybe more wonderment or/ and researchable or investigative question. Jarman (1991) asked primary and secondary teachers from selected schools in Northern Ireland to keep a diary in which they recorded the children's questions for four weeks. She concluded that though children asked science-related questions, they were few. Mostly children posed questions to seek direction, reassurance, information and clarification. Only a few questions lent themselves to practical investigations in the classroom. They were not in a form that directly led to investigations and therefore, needed teacher's help to reformulate it (Jarman, 1991). A similar study that explored the types of questions generated by Danish university students concluded that the vast majority of student-generated questions are basic information type. It was also noted that reflective wonderment questions were rarely asked (Madsen & Nielsen, 2013). Eshach, Dor-Ziderman, and Yefroimsky (2014) also reported that questions in primary school science were few in number and low in level. A study by Biggers (2018) explored the variation in the sources of investigation questions from a dataset of 120 elementary science lesson videos and associated lesson plans from 40 teachers across 21 elementary schools. Results showed that investigation questions were predominantly teacher-directed in nature, with students having no opportunity to generate their questions for investigation. The study calls for training teachers on instructional strategies to adapt the existing curriculum in a way to encourage student questioning (Biggers, 2018). C. Chin and Kayalvizhi (2002) asked 39 primary school year six pupils to generate questions or problems feasible for investigations, first individually and then in groups. When pupils generated questions individually without any examples shown, they asked only a small proportion (11.7%) of investigative questions, though from a wide variety of topics. Children were more interested in knowing why certain things exist or happen than exploring scientifically. When questions were generated in groups after examples were shown, there was a significant increase in the number of investigable questions generated (71%), but they related to a narrow range of topics covered in the school science curriculum (chemistry, energy, force, heat light, plants). Students should be taught to distinguish between investigable and non-investigable questions (C. Chin & Kayalvizhi, 2002). Many topics may not be suited to generate investigative questions. It is not easier for children to spontaneously generate questions that lead to practical investigations in the classroom. It would be worthwhile if teachers could provide children with examples of investigative and non-investigative questions and also help children in reframing their non-investigative questions to make them more investigative. Can teachers do this without extra training and support?

C. Chin and Kayalvizhi (2002) have come up with different categories of investigable and non-investigable questions along with examples of each. According to C. Chin and Kayalvizhi (2002) 'investigable' questions are those questions whose answers can be obtained by designing and performing hands-on investigations ('When does lime water turns chalky?'). They allow children to collect original data, analyse and interpret their findings and reach a conclusion that answers the question posed, based on the first-hand evidence collected. C. Chin and Kayalvizhi (2002)came up with five different categories of investigable questions which included most of the questions posed by children. They are comparison questions e.g. 'Which type of material is best for keeping water hot?',' cause-and-effect questions e.g. 'How does concentration affect the rate at which salt dissolves in water?', prediction questions e.g. 'What would happen to the distance travelled by a toy car if I raise the height of the inclined plane?', design -and-make questions e.g. 'How to make the solar car move faster?' and exploratory questions e.g. 'What are some factors that affect...?'. Cause and effect questions focus on the relationship between variables and pupils are expected to design a fair test while prediction questions focus on the observational outcome of an event. In addition to the above, the authors suggested a few more plausible categories of investigable questions children might ask if given more opportunities for question-asking. They include: descriptive questions 'What kinds of insects live in our garden?', pattern seeking questions e.g. 'What is the relationship, if any, between the length of one's foot and the distance between his or her wrist and elbow?'. 'What is the relationship between the type of plants and where they are found in the forest?', problem-solving questions e.g. 'How can I find a way to identify and distinguish these three unknown powders?' and 'validation of mental model' questions e.g. 'How can the working of a burglar alarm be modelled?'The above list includes some questions that can be answered by detailed observation of nature and natural phenomenon over some time, while others may need experimentation, conducting surveys etc. In my view, these varied examples of investigative questions would be a valuable source of information for primary school science teachers and children. Some teachers may have a limited view of scientific investigations and may associate investigations with fair testing in the lab or classroom. Having a list of different types and examples of investigable questions in hand for reference as suggested by Chin & Kayalvizhi would be a good start for teachers to model asking of such questions. According to C. Chin and Kayalvizhi (2002), 'non-investigable' questions are questions that could be answered by asking someone or looking up in a book or other secondary sources of information (e.g., 'Why does a chicken lay egg?'). They include:

(a) basic information questions asking for simple information or basic facts and could be answered by referring books, searching the internet or by asking someone.

(b) complex information questions that require complex information and explanation, mostly the explanative 'Why' questions asking for explanation or the 'How' questions asking for an underlying mechanism; and,

(c) philosophical or religious questions that may not be answerable by science (C. Chin & Kayalvizhi, 2002; Harlen, 1993).

All topics may not be feasible for generating questions leading to investigations but may generate questions that stretch children's thinking leading to the construction of understanding.

Such questions would encourage children to look up for information in books and other online sources. Also, having an understanding of questions encouraging deep thinking would be an added advantage for teachers.

C. Chin (2006) suggested providing students with sample self-questions that focus on specific cognitive processes linked to the learning task in hand, for example, comparing, explaining, hypothesising, predicting, analysing, and inferring. According to C. Chin (2006) explanation-based questions tap causal thinking and encourage children to generate reasons or logical justifications, hypothetical questions allow students test their suppositions, analytical questions focus on finding patterns and relationships in data and evaluative questions guide to make comparisons and reflect on the pros and cons. Raising different types of questions including vague questions is important as it helps children to make links between one experience to another and thus create their sense of the world. Children's questions in school may sometimes be unheard or ignored by teachers. A little encouragement from the teacher's side can stimulate children's questioning. Harlen (1993) has reported different types of children's questions like i) science-related questions, those that cannot be answered by scientific experiments, those that can be tested by investigations or by consulting others or books and ii) philosophical questions that cannot be answered by observations. Another classification identified four types of questions: questions asking for factual information (e.g., Where did all these rocks come from?); questions raised out of interest (e.g., Why is it raining today?); questions requiring complex answers or explanations (e.g., Why rocks are hard?) and questions leading to investigations (e.g., What happens if we plant a bean seed the other way up?). 'Why?' questions ask for an explanation. According to Harlen (1993), teachers should try to see these questions as opportunities to help children to frame a series of investigable questions that can be answered by investigations. For example, the question 'Why are rocks sometimes smooth and flat?' could be used to lead to investigable questions like 'Does rubbing one rock against another make them smooth?' or 'Does putting in water make a rock smooth?' by asking several questions in between. Harlen (1993) suggested that knowing how to answer different types of questions is more important than knowing the answers and this could be achieved only by raising questions and discussing the ways of answering them. Explanatory questions or questions asking for reasons are of special interest as they require the construction of powerful understandings which can lead to prediction. Having an understanding of the categories of investigative questions as well as those non-investigative questions which promote deep thinking is beneficial for teachers. It would be interesting to know if there are any personal factors that affect children's question-asking behaviour. The next section presents some favourable personal attributes affecting children's questioning.

4.6 Favourable Personal Attributes/ Child Factors

4.6.1 Subject-Specific Prior Knowledge

To encourage children's questioning, it is important to understand the personal attributes associated with question asking. Asking productive questions may not be an easy task for students, especially, with some topics as it requires a considerable amount of domain-specific knowledge to ask good questions (Miyake & Norman, 1979). Scardamalia and Bereiter (1992) studied the nature of student questions generated for the less familiar topic 'fossil fuels', with that of a more familiar topic, 'endangered species'. Unfamiliar topics produced questions asking for factual information, while familiar topics for which facts were known generated more wonderment questions. The study concluded that a lack of subject-specific prior knowledge may influence the type of questions that students ask (Scardamalia & Bereiter, 1992). Baumfield and Mroz (2002) studied the questions generated by primary aged children in response to a narrative text and found that unfamiliar text elicited basic clarification questions. The text should be engaging for children to generate superior questions and teacher's knowledge of the children's interests, their prior knowledge and the curriculum content is crucial. Therefore, questioning may become more fruitful when conducted after gaining some preliminary understanding of the topic. Lee and Cho (2007) after giving students an ill-structured and a moderately structured problem context noticed that the degree of structure of the problem situation influenced the variables affecting problem finding. In the ill-structured problem situation, students were provided with a real-world problem with minimal information, so, they had to use their science knowledge to problem find. Therefore, students who had good science knowledge could find more valuable problems in the ill-structured task. In a moderately structured problem situation, even the students who did not have sufficient scientific knowledge could gather necessary information from the problem itself and pose problems. Therefore, science knowledge didn't have a great role in a moderately structured situation. It was concluded that science knowledge mainly declarative knowledge in the form of facts, concepts, notions and principles is necessary to find problems in both ill and moderately structured problem finding situations. Therefore, to problem find students need to learn and understand scientific knowledge rather than science process skills (Lee & Cho, 2007). The ill-structured problem finding situation being similar to a real-world problem gave students more freedom to think about the problem from a wider perspective and they came up with more appropriate, original and elaborate problems. Though in the ill-structured situation participants were easily motivated to find problems they felt difficult to find problems with insufficient data. Therefore, personality traits such as energy to persuade oneself to find problems continuously could play a major role in the ill-structured tasks than in the, moderately structured tasks (Lee & Cho, 2007). Similar recommendations regarding providing conceptual structure concerning practical investigation were made by Cavalcante et al., (Cavalcante, Newton, & Newton, 1997). They concluded that investigation may become more productive when conducted after gaining some initial understanding of the topic, particularly with less familiar topics. An immediate practical investigation might work for familiar topics with prior experience (Cavalcante et al., 1997). When planning contexts for stimulating children's question asking, it would be useful if a teacher could sense the difficulty level of the topic and children's familiarity with it. For less familiar topics, a problem situation which provides some background conceptual knowledge before questioning may prove more productive. A problem situation similar to a real-world problem with very minimal information might work for familiar topics with prior knowledge.

A recent study by Gu, Chen, Zhu, and Lin (2015) reported that primary school students, problem solved better in science when question prompts were used to make plans and evidence-based arguments while working in groups. Structuring evidence-based argumentation is a crucial component of problem-solving. Though question prompts helped students in asking questions and generating reasons and evidence for what they say, they felt difficulty in doing so. To interpret the problem to be solved and identify necessary information, one has to have a good grasp of subject-specific knowledge (Gu et al., 2015). Therefore, the development of children's conceptual understanding in science should not be ignored. It would be fruitful if teachers could utilise pupils' prior knowledge and interests and help them to link what they already know to what they would like to find out (C. Chin & Kayalvizhi, 2002). Hu et al. (2010) reported that under closed instruction condition, the number of students' problems will depend on how rapidly and creatively students use existing knowledge of a topic. King (1994) studied primary school children's knowledge construction in a science classroom through guided questioning under two different conditions; questions designed to promote connections among ideas within a lesson; lesson-based questions as well as questions designed to access prior knowledge/experience and promote connections between the lesson and that knowledge. Students were also trained to generate explanations, a manifestation of knowledge construction. Analysis of the students' post-lesson knowledge maps and verbal interaction during the study revealed that students trained to ask both kinds of questions occupied in more complex knowledge construction than those trained in lesson-based questions alone and the control group. It was found that though both kinds of questions encourage complex knowledge construction, questions designed to access prior knowledge/experience are more effective in enhancing learning (King, 1994). It would be better if teachers have some idea about pupils' prior knowledge and use this information when designing problem finding tasks for eliciting children's questions. It would be more productive if teachers could generate problem situations from those topic areas where pupils have some basic prior knowledge.

4.6.2 Student Interest and Motivation

Interest seems to have typical characteristics of emotions. According to Silvia (2008) interest motivates people to try new things or learn something new but after learning and understanding the new thing, it seems not interesting anymore. This new knowledge, in turn, creates interest in several new things. Sylvia has explained the difference between interest and happiness, interest encourages people to try new experiences, while happiness builds an attachment to things or experiences that gave rewards in the past. When people were allowed to rate paintings, those paintings commented to be interesting were judged as complex, unfamiliar, negative and disturbing while simple, positive and calming paintings were rated as enjoyable (Turner Jr & Silvia, 2006). As interest motivates learning, its application in the primary science classrooms to enhance learning should be worth considering. It would be worth exploring children's areas of interests in science, as it could be used to encourage children's questioning. Piaget also suggested that teachers should utilise children's spontaneous interests' whenever possible as they manifest a high level of motivation (Wadsworth, 1978).

Children's interests can be identified and utilised to encourage them to find scientific problems to solve in the class. As reported in section 4.6.1 by Lee and Cho (2007), ill-structured problem situations where students are more free to ask questions about what interests them from the given topic in science, might prove more effective in enhancing problem finding performance, as they will be intrinsically motivated to find problems. Though ill-structured problem situation will give children more freedom of choice to ask questions, they have to use their prior knowledge to generate questions. Therefore, when providing ill-structured problems, it might be better if teachers use familiar and less complex topics so that children may find it easier to come up with original questions that stem from their interests and curiosity. A similar study by Hu et al. (2010) found that open instruction condition generated more original science-related questions from primary, middle and high school students in China. The study suggested that as students are free to list any questions related to science under open condition, the number of problems they ask will depend on how observant they are and how much attention they pay to science-related issues in daily life. Under the closed condition, the number of students' problems will depend on how rapidly and creatively students use existing knowledge of a topic (Hu et al., 2010). When planning for children's question asking it might be wiser to include problem situations from real life which have some connection to what children learn in their science lesson. This may ensure children having some prior knowledge to generate questions and keep their motivation alive.

A study by C. Chin and Li-Gek (2005) revealed that majority of students expressed a liking for ill-structured problems, as they were given the freedom to choose problems they were interested in knowing, which in turn increased their motivation. This allowed those unenthusiastic students and students whose interests lay outside science, to become more motivated, as they could integrate their other interests with science, thus making it more lively (C. Chin & Li-Gek, 2005). It appears that ill-structured problems proved to be useful in engaging unenthusiastic and dispassionate students by integrating their other interests with science. Therefore, a teacher can choose the degree of the structure of the problem situation depending on the scientific interests and enthusiasm of the pupils in the class. A science project (2011-2014), that explored the teaching and learning of science and creativity identified several pedagogical synergies that existed between inquiry-based science and creativity-based approaches in Early Years education and questioning and curiosity was one among them (T. Cremin, Glauert, Craft, Compton, & Stylianidou, 2015). It recognised the importance of utilising children's science interest to generate questions. The teachers under the project generated motivating learning contexts based on children's interests and acknowledged the potential of outdoor activities for sustained engagement with the environment to generate children's interest and questions (T. Cremin et al., 2015). LaBanca and Ritchie (2011) suggested it would be useful if teachers have an idea of their students' interests as they are linked to their motivations, experiences and skills, which they bring to the problem finding process. Students should be encouraged to pursue their area of interest and use them to find problems which in turn make them self-motivated and independent learners (LaBanca & Ritchie, 2011). Cuccio-Schirripa and Steiner (2000) also acknowledged that science topic interest motivates students to ask questions. They suggested, providing students opportunity to select a topic of interest and encouraging posing questions related to that topic would be a better way to enhance the development of students' researchable question. C. Chin and Kayalvizhi (2002) also stressed the idea of teachers utilising pupils' interests to help them to move from the known to the unknown. Eshach et al. (2014) studied science teachers' attitudes towards question asking and reported that primary and middle school teachers emphasized the value of students' questions as a tool for developing interest and curiosity. On the other hand, high school teachers pointed out that they are disruptive and cause deviation from the lesson plan. This may be due to time constraints and focus on matriculation examinations (Eshach et al., 2014). Allowing children to ask questions about the particular topic teacher is following in the classroom might be a better option to try in the high school classes as this may reduce getting deviated from the topic area.

4.6.3 **Self directed learning through questioning (known to unknown)**

Questions or problems encourage children to think and reason. Encouraging children to ask questions and find answers on their own can promote self directed learning in science by leading children from known to unknown. Asking children to produce their own questions can reveal their interests, prior knowledge as well as their mis-conceptions in science. Visual stimuli can act as starting points for discussions allowing them to open up their misunderstandings (Knight, 2009).

4.6.4 **Stimulus Novelty, Students' Curiosity and Prior Knowledge**

Children are curious and this curiosity forces them to learn more about the subject of their curiosity by asking questions. Berlyne (1954a) has differentiated between 'perceptual curiosity', when a stimulus is novel and catches attention and 'epistemic curiosity', a desire for knowledge. According to Loewenstein (1994) when a student knows a basic concept but not the specific details (gap) then he or she would be curious about the missing information and be motivated to fill the gap in the knowledge. His information gap theory suggested that the closer the individual feels that he is to attain knowledge the stronger will be the curiosity. Also, a feeling of satisfaction happens when information gaps are resolved. Gentry et al. (2002) suggested that when the information gap is small or have a basic knowledge about the concept, then the curiosity will be high and when the gap is large, the curiosity will be low. This suggests, when children have some basic knowledge about a concept, their information gap is small and would be more curious. When the curiosity is high, children may ask more wonderment or 'Why...?' questions asking for explanations. This would be kept in mind when planning for children's questioning. The teacher should be cautious about the amount of domain-specific knowledge supplied to children, it shouldn't be too much or too little, but just enough, to keep their curiosity alive. It would be worth trying to provide stimulus which has some amount of novelty and catches children's attention to satisfy their 'epistemic curiosity' while encouraging children to think and generate scientific problems.

4.6.5 **The Stimulus for Problem Finding**

Children ask questions to seek information to learn about the world. According to Chouinard, Harris, and Maratsos (2007), children begin by asking questions that collect isolated factual knowledge leading to explanatory questions that relate facts to one another creating a whole. They begin to show evidence of conceptual shifts in their understandings of biological phenomena normally around the age of four. It was found that children, when engaged with real animals, asked for more biological information questions, specifically, explanatory information that is useful for their conceptual development. When representations of real objects were used children produced fewer as well as different kinds of questions producing a different learning engagement. In other words, children seemed to generate fewer explanatory questions when representations of real objects were used as question provoking stimulus. The study concluded that the stimulus type affects the questions asked by children and their engagement in learning in the domain of biology. Therefore, we have to be careful when choosing the stimulus to encourage children's learning by asking questions (Chouinard et al., 2007). They also reported that factual questions were generated by children at all ages, but more explanatory questions were asked by the older age groups. He suggested that real objects have a richer source of cues that help to tap into one's conceptual knowledge more effectively producing a better engagement. According to Chouinard et al. (2007) children can ask questions that allow them to gather information to solve the problems they face. Through question asking children develop an adult-like understanding of the world. To summarise, real objects stimulated children to produce a superior set of questions, allowing a different kind of engagement. They allowed the pupil to tap into their conceptual knowledge more efficiently because they had a richer source of cues. The above study predicted that pictures or replicas would have fewer cues that tap into the child's conceptual knowledge and those missing cues would be highly important to the task, making it harder to produce questions. Therefore, it would be more productive using real objects or specimens whenever possible when encouraging questioning for problem finding in science.

4.6.6 Teachers' Pedagogy of Engagement (Instructional and Relational Pedagogy)

Darby (2005) explored teachers' pedagogy from the student perspective and reported that both instructional pedagogy or the instructional dialogue teacher use to enable students to understand science and relational pedagogy or the characteristics teacher should have to create a productive and secure learning environment, play an important role in assuring a conducive environment for student engagement in science learning. A teacher's efforts to *explain* relevant science concepts, draw information from students through focussed questioning (scaffolding) during *class discussion* and *clarify* and confirm student understanding by repeating for those who didn't understand, were characteristics acknowledged by students under instructional pedagogy. The main characteristics students valued under relational pedagogy are a teacher who is enthusiastic about the subject, friendly and non-threatening, attentive, encouraging and understanding what a student need. It was noted that the way a teacher teaches and relates to his/her pupils has a marked effect on their engagement in science learning (Darby, 2005). An empathetic teacher will create a caring classroom climate where students' naive concepts are heard and valued (Oldfather, 1994). Abrahams and Millar (2008) reported that students were able to recollect practical tasks better when they had one or more of these characteristics: a distinctive visual, aural or olfactory component, novelty and 'gore' factor. They reported that practical work in science should help students to develop connections between ideas and observations. Ideas should be introduced to students first and should be in use while doing practical work. Therefore, to develop strong conceptual understanding in students, practical work together with teacher scaffolding is necessary (Abrahams & Millar, 2008).

A similar study by Cavalcante et al. (1997) prepared three forms of science lessons based on the same topics and compared their effects on the development of children's understanding of the scientific concepts. These were similar versions of lessons teachers use with older primary school pupils in their normal teaching. In the first version (P) the teacher provided conceptual structure to develop an understanding about the topic along with a worksheet showing data from a practical investigation of the topic and children had to write about what the data told them. The second version (W) withheld the conceptual structure and provided a problem to solve using hands-on practical work along with worksheets to answer. The third version (C) was a combination of both the first two versions with conceptual structure, practical problem solving investigation and worksheet. Though all three lesson versions gave the same information, it was concluded that the lessons which gave pupils an initial conceptual structure could be more effective than those which withheld the conceptual structure and gave a practical investigative task. This could be applied for those topics where the pupil's prior knowledge and understanding is low. Cavalcante et al. (1997) pointed out that teachers cannot blindly believe that a practical investigative task would improve conceptual knowledge along with the development of scientific enquiry skills. An investigation may become more productive when conducted after gaining some initial understanding of the topic. It was suggested that the teachers should be sensitive to understand how complex the topic is and the child's familiarity with it and wisely plan the lesson. The study stressed the need for introducing the scientific concepts to the children before moving to practical investigation for less familiar topics. For familiar topics with prior experience, an immediate practical investigation might work (Cavalcante et al., 1997). A recent study showed a mixed teaching method that includes both lecture and inquiry-based teaching was found to be superior to the lecture-based or inquiry-based methods when used separately on improving students' creative problem finding ability. The mixed teaching showed the strongest improvements in students’ flexibility and originality on the problem finding tasks (Jia et al., 2017). When encouraging children's question asking, the teacher should consider the instructional pedagogy and the relational pedagogy of the class. Children's initial ideas and questions may not be in a form that will lead to a problem that could be investigated straight away. A teacher through the process of scaffolding can help students refine their original questions to a form that will lead to investigations. Quieter children can also be encouraged to generate ideas and formulate questions through teacher's use of focused questioning and feedback. Having some knowledge about the theoretical background behind children's thinking, question asking and problem finding would enable one to have a deeper understanding about the basic principles to be considered when developing and using some strategies to encourage children's questioning. The next section explains the constructivists' ideas on children's thinking.

4.7 Theoretical Background on Children's Thinking

Constructivist theorists like Piaget and Vygotsky offered their views on how children constructed knowledge by themselves or with adult support. Piaget saw learning as a process of intellectual development happening as a result of the child's interactions with the environment (Loxley, Dawes, Nicholls, & Dore, 2017). According to Piaget, children learn through hands-on practical experiences, which are then incorporated into their cognition and later expressed as their thoughts. Piaget considered language as a channel to communicate children's thoughts but not for constructing them. The learner constructs knowledge through practical work while the teacher acts as a stage setter (Wadsworth, 1978). Piaget believed that children's understanding of the natural world is mostly based on their behaviour or actions. According to Loxley et al. (2017) not all the topics in science are suitable to be explored through the first-hand experience. They argued that the way children see the natural world might be different from the way adults see the world. For example, bees might appear to children as having two eyes like other common organisms, but they have five eyes which could detect ultraviolet light. Therefore, these scientific facts should be told to students as a science story by a teacher, though its meaning could be made clearer through first hand and secondary sources of information (Loxley et al., 2017). Piaget also stressed the importance of teacher's questions to prompt children to move ahead in their thinking (Wadsworth, 1978).

Pursuing the ideas of Piaget, there has been too much stress on practical work in primary schools. Practical work without students' mental engagement does not make learning effective. Therefore, it was suggested that teachers should try to engage student minds by allowing them to discuss, think and reflect before practical work. Piaget suggested that teachers should utilise children's spontaneous interests whenever possible as they manifest a high level of motivation (Piaget, 1959; Wadsworth, 1978). Children should be allowed to manipulate concrete objects or materials and they do not have to be expensive or ordered from shops. They could be any objects like metals, glass, plastic containers, stones that are easily available (Wadsworth, 1978). Piaget's theory suggests teachers to use concrete materials to construct enriching learning environment for children to interact and learn individually leading to increased confidence in oneself (Shayer, 1997). Piaget's theory is focused on individual cognition while Vygotsky explained cognition as a social process. The zone of proximal development (ZPD) put forward by Vygotsky (Vygotsky, 1978) facilitates cognitive development with adult guidance or through peer collaboration utilising children's prior knowledge to evolve to a higher-level cognition to generate questions. Teacher, scaffolding and modelling children's thinking and questioning underpins Vygotsky's principle of social learning (Sylva, 1997). Vygotsky's theory paid special attention to the role of language in learning. According to Vygotsky, to understand science concepts children are required to build mental representations or models of them. For this to happen, children should interpret scientific ideas based on their prior knowledge. Children may need to rethink and modify their existing knowledge to accommodate scientific ideas. They need cognitive tools which include ways of talking such as explaining, persuading, negotiating, arguing and summarising. Strategies like creative writing, modelling through role-play, making physical models, thinking of analogies and drawing pictures could be used to visualise the scientific ideas (Loxley et al., 2017). A teacher's role is crucial to support children with using these cognitive and creative tools leading to conceptual growth.

Unlike Piagetian theory, in which teachers' role was often seem to be reduced to a facilitator, Vygotskian theory gives teacher an important role, the one who leads children to improved levels of conceptual and procedural understanding through collective interaction (Hodson, 1999). Both these theories support the importance of modelling and joint participation of both teacher and children in learning and solving problems. Johnson-Laird (2010) argued that reasoning relies on one's ability to foresee the possibilities consistent with the starting point- a perception, a set of assertions, a memory or some mixture of them. Mental models corresponding to each distinct possibility were constructed and conclusions were generated from them. The theory predicts systemic errors in our reasoning and the evidence confirms this prediction. However, our capacity to use counterexamples to contradict a theory (to understand that an inference is not good) provides a foundation for rational thinking. Therefore, reasoning can be considered as a simulation of the world created by adding more details from our prior knowledge ('reasoning is a simulation of the world fleshed out with our knowledge')(Johnson-Laird, 2010). Johnson-Laird (2010), reasoning involves the use of induction, the ability to formulate explanations. Unlike validations, it uses prior knowledge to go beyond the strict premises of the content and therefore increases information. The knowledge of causal relations helps one to formulate explanations (Johnson-Laird, 2010). Providing children with real and concrete objects, teacher scaffold, use of prior knowledge and its use in generating explanations are some of the important ideas generated from the theories, useful in the development of strategies for encouraging question asking. Are there already available strategies to encourage children to come up with their science questions? How can this be achieved in a primary school setting where teachers are already under pressure due to time constraints and meeting targets? The next section of the literature collected deals with different strategies on encouraging children's question asking.

4.8 Strategies Encouraging Question-Asking

4.8.1 Providing Examples of Questions

As reported in section 4.5, C. Chin and Kayalvizhi (2002) recommended teaching pupils different types of investigable questions to support children to raise generate more investigable questions in science. Textbooks and other curriculum resources could also offer information on different possible types of investigative as well as non-investigative questions. A similar study by Marbach-Ad & Sokolove Marbach-Ad and Sokolove (2000) also found that more undergraduate biology students who followed an active learning style were able to pose better-written questions after a taxonomy of questions was presented to them. C. Chin (2006) also suggested providing students with sample self-questions that focus on specific cognitive processes linked to the learning task in hand, for example, comparing, explaining, hypothesising, predicting, analysing, and inferring. According to Chin, explanation-based questions tap causal thinking and encourage children to generate reasons or logical justifications, hypothetical questions allow students test their suppositions, analytical questions focus on finding patterns and relationships in data and evaluative questions guide to make comparisons and reflect on the pros and cons. According to C. Chin (2006) for a decision-making task where students have to select an option from among several possible alternatives, the overarching question would be 'Which option is best after taking everything into consideration?' (evaluating). Related subordinate questions include: 'What are the options?', 'What criteria are relevant and important to help me decide which option to choose?' 'What are the likely consequences of each option?' (predicting), 'How important are the consequences?' (evaluating), and 'What are the pros and cons of each option?' (comparing). Use of such questions has the potential to direct students' thinking towards specific goals and sub goals and to focus attention on different related aspects of the task in question (C. Chin, 2006). Teachers' heavy reliance on lower order factual recall questions were reported by several authors (L. D. Newton, 1996; Smart & Marshall, 2013). Teachers using higher order questions which forces students to extend their thinking in everyday classroom teaching might encourage students to use those questions more, due to their daily exposure and informal learning.

4.8.2 Teacher Modelling

Jarman (1991) suggested the idea of teacher modelling asking different types of science questions in the classroom as children learn their questioning skills from their teachers. Teachers can help students by asking appropriate guiding questions, scaffolding (C. Chin & Li-Gek, 2005) especially using strategies like teacher modelling and monitoring (Ge & Land, 2003). It would be worthwhile if teachers could guide pupils through questioning and discussion to transform their non-investigable questions to investigable ones (C. Chin & Kayalvizhi, 2002). Jarman (1991) also reported that within particular topics in science, pupils may come up with questions that could lead to practical activities but not in the form and may often need teacher's help to re-frame their initial question or statement into relevant problems for investigations. This requires considerable ingenuity on the part of the teacher. Teachers, especially those from non-science backgrounds might need more information and training on this.

4.8.3 Teacher Scaffolding Questioning

Student-centred, dialogic and interactive teaching strategy may improve students' ability to ask research questions (Bielik & Yarden, 2016). Bielik and Yarden (2016), to understand the process leading to the development of students' question-posing ability compared two case studies of lessons (student-centred and teacher-focused) in which students were asked to formulate their research questions. The teacher focused lesson followed an authoritative and non-interactive approach where the teacher first explained the characteristics of research questions and gave a few examples and included a few teacher questions (2 closed and 1 open). Those students came up with 13 questions most of which asked for clarification of the taught topic. The student-centred lesson followed a dialogic and interactive approach encouraging students to voice their opinions and prompting them to elaborate on their ideas. For example, the teacher asked, "What are the characteristics of a good research question?"Here the teacher asked 77 questions (56 open & 21 closed) that prompted students to think through. This teacher used student-centred moves like prompting questions, re-voicing students' ideas and tossing back some of the students' questions to the other students. Most of the 21 questions asked by the students were clarification or requests for further explanation or elaboration from the teacher. The teacher sometimes gave direct answers, but in some cases bounced back the question to the students. The teacher used interactive talk moves such as re-voicing of students' answers, writing students' suggestions on the board and asking them to think and elaborate on their answers. It was noted that students' ability to ask research questions improved under the interactive student-centred approach and most of the research questions generated by students were subsequently used for student inquiries (Bielik & Yarden, 2016). Here teachers' use of thought-provoking questions and simple traditional interactive strategies supported students in generating researchable questions. Another recent study by Y.-C. Chen, Hand, and Norton-Meier (2017) collected data from 30 science lessons of three elementary teachers after implementing a 4-year CPD on a questioning-based inquiry approach. It showed that teachers increasingly used multiple roles: dispenser, moderator, coach and participant to encourage questioning discourse during the four years rather than being a dispenser of knowledge alone. Students' cognitive responses improved as teacher's role progressed from a dispenser (teacher owned ideas) to a participant (student-owned ideas) or from teacher-centred roles to pupil-centred roles. In other words, when teachers were trained to use questioning strategy (different kinds of questions) to scaffold students' discourse, student responses improved from low-level cognition (such as recall and expression of ideas) to high-level cognition (such as defending, challenging, synthesizing and justifying ideas). A shift in children's cognition from retrieving and expressing ideas to elaborating, reframing (medium level cognition), defending, challenging, synthesizing and justifying ideas was observed as teachers questioning discourse improved. Teacher questioning plays a pivotal role in promoting dialogic interaction in argumentative practice for the development of conceptual understanding in children (Y.-C. Chen et al., 2017). The above study by Bielik and Yarden (2016) showed that teacher's use of traditional, interactive communication strategies like probing questions, re-voicing students' ideas and tossing back some of the students' questions to the other students to prompt thinking, improved the posing of research problems by students. Teachers were trained to use questioning strategy to scaffold student discourse, improved their cognition from low level recall and expression of ideas to high-level defending, challenging, synthesizing and justifying ideas (Y.-C. Chen et al., 2017). These strategies should be taken seriously into consideration when planning training programmes for teachers to encourage children's creative thinking and problem finding, as teacher scaffolding plays a crucial role. Teacher's wise use of probing questions can prompt children to think in different directions to shape their own scientific questions to solve in the classroom. Specific scenarios connected to science curriculum topics could be designed and provided to teachers with example questions to prompt children's thinking.

4.8.4 **Specific Question Times**

Some studies reported that including specific time for questioning like a 'question of the week' (Jarman, 1991; Jelly, 1985) along with a question of the week poster stimulated more questions. C. Chin and Brown (2002) observed that students who typically did not ask higher-level wonderment questions were capable of asking thoughtful questions when the time was specifically set aside for them to ask questions about things that puzzled them. M. Watts et al. (1997) also suggested strategies like having specific times for questions like a 'free question time' within a lesson, a question 'brainstorm' at the start of a topic, turn-taking questioning around the class where each student or group of students must prepare a question to be asked of others and 'question-making' homework to encourage children's question asking (M. Watts et al., 1997). Having specific time for questioning when combined with providing pupils question prompts to ask questions increased opportunities for students to develop their skills in asking questions (K. Y. Wong & Quek, 2006). Though some teachers found this time consuming, it would be worth trying as it encouraged not only the smart kids but also the shy ones to pose questions.

4.8.5 **Question Prompts/ Stems/ Starters**

Several studies reported using question prompts on its own proved useful in helping children to generate a question. Teachers who participated in Jarman's study (Jarman, 1991) found the use of Question Starters very effective in encouraging children to think and ask questions. For example, What would happen if...; What happens when....; Which is best for......; Will it......if we....; proved surprisingly effective in producing questions which could be followed up in the classroom and laboratory(Jarman, 1991). A study which looked at the effect of guided co-operative questioning on students' knowledge construction revealed that students who used highly elaborated question stems outperformed those using less elaborated question stems and the unguided questioners, on explanations given during discussion, post-test comprehension and knowledge mapping (King & Rosenshine, 1993). It appeared that the students who used highly elaborated question stems constructed a more complete and accurate mental representation of the material than their peers with specific connections between ideas which are more stable and less subject to decay over time. Also, the rate of questioning for the unguided questioners was lower than the two groups trained in questioning and they asked factual questions. This shows the need for teacher guidance during questioning (King & Rosenshine, 1993). Ge and Land (2003) examined the effects of question prompts and peer interactions in scaffolding undergraduate students' problem-solving process in an ill-structured task. They concluded that question prompts had significant effects on student problem solving, while peer interaction didn't show any effect. The study suggested that peer interaction should be guided and monitored with different strategies, including question prompts to get the most out of it (Ge & Land, 2003). In a school setting, children may not have the subject-specific knowledge to solve as well as find problems without adult guidance. Therefore when encouraging children to find problems, it would be useful to try strategies as question prompts along with teacher guidance and scaffolding to make it more effective. A recent study by Gu et al., Gu et al. (2015) among primary school students in Shangai reported a significantly better performance by the treatment group in collaborative problem solving when "question prompts'' were used to make plans and evidence-based arguments. The study found question prompts were useful in scaffolding problem solving by generating scientific reasons and explanations (Gu et al., 2015). Although the treatment group showed better performance in problem-solving, it was found that both groups felt difficulty in giving reasons and evidence to support what they say. This may be because, in schools, students were more used to giving correct answers than to provide reasons for what they believed to be true. So, it was suggested that while developing future interventions more consideration should be placed on scaffolding students to think. According to Gu et al. (2015) structuring evidence-based argumentation is an important step in the problem-solving process as it equips students with the cognitive and meta-cognitive strategies that help them to develop a skill of argumentation. To represent and interpret the problem to be solved and identify necessary information, one has to have a good grasp of subject-specific knowledge. So, it was recommended that future interventions should aim at considering this aspect of incorporating domain-specific knowledge (Gu et al., 2015). This supports the view of Raes et al.,(Raes, Schellens, De Wever, & Vanderhoven, 2012) who indicated the need for a combined intervention with teacher-enhanced scaffolding, when domain-specific knowledge is involved (Raes et al., 2012). As stated earlier, children are more used to giving answers than to ask questions. To encourage children to generate reasons or explanations, we should encourage them to ask 'Why..?' questions and think in causal terms. It would be worth exploring using question starters like 'Why...?' and 'What happens if...?' to encourage causal thinking to generate explanations and predictions, an important science skill. This also requires a good understanding of science concepts.

4.8.6 **Providing Problem Situation**

Providing children with a problem situation from which they could generate questions may make it easier for them. A study by C. Chin and Chia (2006) explored how ill-structured problems in Year 9 Biology project work facilitated independent inquiry. They revealed that ill-structured problems encouraged students to pose questions which in turn developed a plan of action leading to an independent inquiry. It was found that students felt an initial difficulty in generating questions from the given theme, but they were able to generate questions after discussing with family members and friends. Some students read local newspapers and paid attention to articles related to the theme given. Majority of students expressed a liking for ill-structured problems, as they were given the freedom to choose problems they were interested in which in turn increased their motivation. They suggested giving students time to think outside the classroom, discussion with friends and family etc can help them to identify problems from real-life (C. Chin & Chia, 2006). In my view reading newspapers and discussing with family and friends to make questions may generate interesting questions out of curiosity. Parents can also use their experience and support children in generating questions when given as a homework activity. This may increase children's motivation to think and generate questions as well as to look up for answers.

4.8.7 **Providing Stimuli**

Jarman (1991) suggested providing appropriate stimuli for encouraging pupils to ask questions. They may include materials, organisms, devices, phenomena, interesting data, pictures, stories, school's broadcasts, problem-solving activities and of course, excursions beyond the classroom. Children should interact with such stimuli by observing, handling, describing, wondering, questioning, discussing, arguing and finding answers to their queries (Jarman, 1991). C. Chin and Chia (2006) suggested teachers demonstrating an activity to provide "seed" ideas to trigger questioning from students. A science project (2011-2014), that explored the teaching and learning of science and creativity identified several pedagogical synergies that existed between inquiry-based science and creativity-based approaches in Early Years education and questioning and curiosity was one among them (T. Cremin et al., 2015). The project generated motivating learning contexts based on children's interests and used everyday household materials and natural resources to build a rich physical learning environment. The study acknowledged the potential of outdoor activities for sustained engagement with the environment and living things to generate children's interest and questions (T. Cremin et al., 2015). Nicholson (2015) also suggested that when planning science activities, one should see that they are inexpensive and flexible to implement to engage students. As reported in section 4.6.4, (Chouinard et al., 2007) pointed out how stimulus type affects the questions asked by children and their engagement in learning of biology. The study confirms the potential for real specimens over representations in stimulating children's asking of explanatory questions useful for their conceptual development. Photographs, pictures, cartoons etc can be used as stimuli to provide scientific problem scenarios for encouraging children to ask questions. A study which used scenarios in problem-based learning course for undergraduate students in environmental science identified five different categories of questions: encyclopaedic, meaning-oriented, relational, value-oriented and solution-oriented. All scenarios evoked questions belonging to all five categories in all groups with varying emphasis. Comic strips, photographs, paintings, newspaper headlines and articles containing authentic or constructed environmental cases were used as scenarios, which initiated discussion on problems and solutions (Dahlgren & Öberg, 2001). After receiving the scenario from the tutor, the group generated ideas in the form of single words or sentences through brainstorming. The group discussed the ideas to clarify their pre-conceptions and tutor acted as a facilitator. These ideas were developed and arranged as themes and questions, depending on the learning needs of the group. Then the students sought information in the library or on the internet or from experts, individually or in pairs or smaller groups. The students then discussed, synthesised and evaluated what they had found out and their final learning needs were reformulated into new questions. It was found that scenarios that evoked emotional involvement by having a certain opinion or contrast or tension were powerful triggers. Also, encyclopaedic questions indicated a surface approach to learning, looking for the lexical meaning of a word or a concept, while meaning oriented, relational and value-oriented questions indicated a deep approach to learning. A back-and-forth movement between encyclopaedic questions and meaning-oriented or relational questions were observed. Thus, scenarios generated a context in which encyclopaedic questions were naturally linked to meaning-oriented and relational questions (Dahlgren & Öberg, 2001). Mark A. Runco (1993) suggested the use of visual arts to help with problem identification. Share (2015) also supported the use of visual images, especially photographs in learning about problems. The power of photographic images in educating people about problems and evoking their feelings is evident in these words of Share (2015): "*My photographs contributed to positive change, educated some people about problems, and caused others to feel joy, pain, compassion, and outrage" (Share, J. 2015, p97).*

4.8.8 **Science Stories**

According to Newton & Newton (L. D. Newton & Newton, 1993), primary school science has got three main aspects: science as a body of knowledge in the form of facts, explanations, laws, principles and generalisation; science as a process, a way of thinking and working attained through the practice of skills; science has relevance to lives of people. Though teachers are there to support children, learners themselves have to build their conceptual understanding in science. Teachers can provide children with varied learning experiences and processes (observing, questioning, hypothesizing, analysing, investigating, interpreting etc) to help them construct their scientific understanding (L. D. Newton & Newton, 1993). According to Loxley et al. (2017) children find learning facts and scientific terminologies difficult. Giving them opportunities to discuss and debate ideas and issues would make learning more engaging and enjoyable. Scientific knowledge helps one to transform the way he or she sees the world. This occurs when learning has been set in contexts that require the generation of scientific explanations. These contexts should be familiar to children but at the same time hold the potential to create problems which can be resolved by the development of conceptual understanding. Puzzling contexts to encourage children to ask questions about the natural world should be generated. Storytellers arouse curiosity, create tension and resolution by answering questions. Teachers could use storytelling as a strategy to plan stimulating lessons with a strong science base (Loxley et al., 2017). Stories with an interesting twist or puzzling situation like those written by Anthony Browne, Maurice Sendak and moral stories from Folk tales and Aesop fables were found to be useful in stimulating children's questions (Baumfield & Mroz, 2002). Science is about finding solutions to nature's questions and its stories can be fascinating as well as informative. Though a wide range of science storybooks are available for young children (up to the age of seven years), good science stories of older children (up to the age of 11 years) are difficult to find. Therefore, it was suggested, teachers invest time to develop their own science stories using information sources to help children gain science knowledge and understanding (Loxley et al., 2017). As teachers struggle to find time and resources to encourage creativity due to curriculum and target pressures, it would be fruitful if readymade science stories related to school science topics are available for teachers to support students.

4.8.9 Ways of Collecting Children's Science Questions in the Classroom

Jarman (1991) placed a question box with pencils and paper in the corner of a classroom and collected children's questions. Collecting children's questions at the end of a learning task when associated with practical activity seemed productive. Jarman (1991) recommends teachers using Question-charts, Question-folders, Question-lists, or Question-diaries to collect children's questions so that at regular intervals teacher and children can sit together, discuss the questions and select those that could be followed up in the classroom or laboratory. Dixon (1996) suggested using a 'Question board' to display student's questions relating to the topic being taught. C. Chin and Chia (2006) put forward the idea of teachers forming "idea circles" where students in groups can generate ideas and questions during the problem identification stage. Teachers could support students to frame their ideas into problems that could be solved by conducting research, nature observations, demonstrations and investigations in the classroom. Teachers could choose one or two important ideas and ask students to phrase them into questions. From the questions they generate, teachers could short list a few and collectively generate one or two problems to investigate in the science lesson. Teachers can also demonstrate a simple experiment and then invite questions from children.

4.8.10 **Creating a Favourable Classroom Climate**

Creating a favourable classroom environment that encourages students to ask and answer their questions is very important (C. Chin & Kayalvizhi, 2002; Jarman, 1991). According to Jarman (1991), maintaining a question friendly classroom climate where children feel comfortable to share their ideas without any fear of being ignored, criticised or ridiculed is very important. Teachers should develop a welcoming attitude to children's curiosity. This attitude should be expressed in the classroom by recognising when a question is being posed and responding positively to reinforce that behaviour. Group work encouraged to talk (T. Cremin et al., 2015), especially working in small groups elicited questions from shy children (Jarman, 1991). From the literature reviewed several strategies have been addressed here to encourage children to think creatively and raise their own scientific questions or ideas that can be turned into questions or problems with a teacher's help. Application of these strategies in the classroom would depend on several other factors like teachers' attitude towards encouraging children's creative thinking and question asking, teaching targets, assessment and accountability pressures, school policies etc. These have been addressed in the next section.

4.9 **Teachers' Attitudes towards Student Questioning/ Problem Finding**

It is important to understand what teachers think about encouraging student questioning. Akay and Boz (2009) studied prospective science teachers' views about problem-posing activities when attending a problem-posing oriented mathematics course, showed that the majority of them supported problem posing oriented teaching. 20% of the prospective teachers supported problem-posing because problem-posing moves away from rote learning encourage creative thinking, connects to real life and gives the ability to view problems from different angles. 10% of them believes problem-posing initiates thinking to produce real understanding and increases judgement ability. There is a dearth of research dealing with problem-posing teaching with university students (Akay & Boz, 2009). According to Eshach et al. (2014) even though all the science teacher participants emphasized the importance of students' questions, they are still few in number and low in level. He concluded that a gap still exists between the high potential attributed to students' questions and their actual level as viewed by teachers. He added, while primary and middle school teachers emphasized the value of students' questions as a tool for developing interest and curiosity, high school teachers pointed out that they are disruptive and cause deviation from the lesson plan. This may be due to time constraints and focus on matriculation examinations (Eshach et al., 2014).

4.10 **Need for Training Teachers & Students**

Several authors addressed the need to help teachers to improve their own as well as their students' questioning practice. Reinsvold and Cochran (2012) analysed classroom science discourse in two Year 3 classrooms and reported that teachers need help with creating open-ended questions and specific contexts in which those questions can be asked. They also indicated that teachers are asking for this type of information, but it is not being supplied (Reinsvold & Cochran, 2012). Another study conducted in a middle school science classroom reported teachers' heavy reliance on lower-order factual/ procedural questions resulted in lower student engagement and cognition. Student engagement in science improved when higher-order questions were used by the teachers (Smart & Marshall, 2013). A previous study also reported similar predominance of factual questions among teachers (L. D. Newton, 1996). Teachers should be provided with opportunities to integrate the development of competencies for science teaching throughout their career. Only limited research has been done to understand how professional development programmes can help to achieve inquiry-based science teaching competencies among teacher trainees (Alake-Tuenter, Biemans, Tobi, & Mulder, 2013). The findings from the STEPS project raised concerns about primary teachers' lack of confidence to teach science and also about the effectiveness of teacher education programmes (Kenny et al., 2014). Student questioning has multiple benefits and teachers need support to align student questioning to curricular goals (Stokhof et al., 2017). A Canadian study observed how students and scientists posed environmental problems while trying to solve the problem of sedimentation in a watershed. Although both groups considered various causes and effects of the problem, the scientists discussed more details and obstacles to action and their solutions were more realistic (e.g., planting trees) while students' solutions were normative type like 'do not cut trees'. Some students were concerned about the impacts on animals, but scientists were concerned about the long-term impacts on humans. The students demonstrated limited reflective, critical and creative thinking and the process of solving real problems seems to be applied very little, even though it is recommended in Canadian schools. The findings suggested that more training should be given to students to pose problems completely and to propose original solutions (Pruneau et al., 2007). C. Chin and Osborne (2008) review on student questioning reported that teaching of question-asking skills to students could lead to improved performance on a range of science-related tasks which includes formulating researchable questions for science investigations, mastering new content through group discussions and posing higher-order questions. Questions do not always emerge spontaneously and therefore, teachers should prompt students to ask questions using strategies (C. Chin & Osborne, 2008). Also teachers' use of higher-order questions may encourage children to use similar questions in their classroom talk. All these suggest the need for extending more support to teachers to promote productive thought through the provision of CPD programmes and textual resources like textbooks and online resources which acts as surrogate teachers.

4.11 School Policies & Practice

Though the need to encourage primary school students' questioning in science is educationally beneficial, much contemporary classroom practice does not utilise the opportunity for effective question asking. Teachers who feel less confident about their subject knowledge base may strategically avoid children's questions. Teachers who perceive science teaching as the transmission of factual knowledge are also unlikely to encourage children's questions. Many primary science teachers require guidance and training to develop their own and their pupils' question-asking strategies. Provision should be made for primary teachers to reflect on their current practice (Woodward, 1992). According to T. Cremin et al. (2015) contextual factors such as wider policies, planning and assessment are found to influence the employment of particular teaching and learning approaches in primary schools which in turn interacts with the fostering of children's inquiry and creativity. Time pressures and policy expectations were reported as constraints on their professional practice by some teachers of older learners (T. Cremin et al., 2015). Jarman (1991) suggested the need to refer explicitly to the development of questioning skill in the policy statements so that all schools and will value children's questioning. She also recommended designing schemes of work in such a way that they will provide a structure for children's conceptual growth whilst promoting opportunities for child-initiated investigations. It is important to see if text books and other textual resources provide children opportunities to exercise creative thought. Do textbooks offer children opportunities to think and raise questions? Do textual resources provide guidance to teachers on encouraging creative thinking in science?

4.12 In Summary

Finally, from this chapter, the main messages are:

- promoting creative thinking by encouraging pupils to ask scientific questions (Jeffrey, 2008);
- asking of explanation-based questions tap causal thinking and encourage children to generate reasons or logical justifications (C. Chin, 2006) stimulates creative thinking; teachers need support to align student questioning to curricular goals (Stokhof et al., 2017);
- children's subject-specific knowledge (science knowledge) is vital for asking questions (Miyake & Norman, 1979; Scardamalia & Bereiter, 1992) to find problems (Lee & Cho,

2007) and to interpret the problems to be solved and identify necessary information (Gu et al., 2015);

- investigative questions were mostly teacher-directed, with students having no opportunity to find problems for investigation (Biggers, 2018);
- need for training teachers on strategies for adapting the teacher questions to allow children more opportunities to raise questions that would serve as investigative problems (Biggers, 2018);
- problem finding as an important aspect of creativity (Chand & Runco, 1993; M. Liu, Hu, Adey, Cheng, & Zhang, 2013; Singer et al., 2013; Wakefield, 1985);
- encouraging students to pursue their science areas of interest and use them to find problems (C. Chin & Kayalvizhi, 2002) would enhance the generation of students' researchable question (Cuccio-Schirripa & Steiner, 2000) leading to the development of self-motivated and independent learners (LaBanca & Ritchie, 2011); and
- scarcity of problem finding opportunities in primary school Mathematics textbooks (Divrik, Tas, & Pilten, 2020) and tasks encouraging divergent thinking in high-school Physics textbooks (Klieger & Sherman, 2015).

4.13 **Summary of the Literature Review (Chapter 2, 3 and 4)**

There are three literature review chapters altogether (Chapter 2, 3 and 4). The previous chapters (Chapters 2 and 3) have given a review of relevant literature on creative thinking in general and creative thinking in education with particular reference to primary school science. This chapter has presented a review of significant studies on students' question-asking and problem finding in science in relation to scientific creative thinking. Several studies showing the potential for children's questions, both factual and wonderment questions in encouraging deep thinking have been reviewed. Some studies showed attempts to encourage students to ask questions by providing specific questioning times, question starters, teacher modelling etc. Some studies recognised the scarcity of students' questions in the classroom, especially questions that encourage deep thinking and questions that can be answered through investigations. Several studies addressed the need to guide students to generate productive questions. Some studies addressed the need for updating or designing textual resources to promote children's question asking in science. This is an attempt to see if we can encourage children to generate science questions with the potential to become problems that can be solved in the class. From the three literature review chapters, six aims have emerged for the study. Please see section 5.3 in the Methods chapter for the aims of the study in detail.

5 Chapter 5: Method

5.1 Introduction

This chapter outlines the research design and methods used to address the research study. The research design section includes a short description of the three paradigms quantitative, qualitative and mixed methods, and reliability and validity. The study mainly follows an interpretivist approach but various data collection methods have been employed to explore the role of question asking or problem finding to stimulate children's creativity in primary science teaching. Participants were primary school teachers, student teachers and children. An overview of the research issues are discussed with the aim of setting the context to justify the chosen methodology and how the threats to validity, reliability and objectivity are addressed for each research component. The methods section includes, the research aims, questions and the general methods used and the specific strategies used for the trials in schools.

5.2 Methodology in General

A broad approach to scientific enquiry which indicates how a research question should be asked and answered is referred as research methodology. The term research methods denote the specific strategies used to implement a specific research design into action, which involves sampling, data collection, analysis and interpretation of the findings (Teddlie & Tashakkori, 2009). Social research focused on people in a social setting fall traditionally into quantitative and qualitative research. The quantitative researchers follow the path adopted by the researchers in the natural sciences field and claim that scientific approach was the only means to conduct research. On the other hand, qualitative researchers claim that the use of numbers and statistics are not worthwhile to understand the interactions between people in their social setting (Collin, 2011). The quantitative approach stems from positivism and believes that every scientist looking at the same bit of reality sees the same thing, ignoring the observer effect. Post-positivist accepted that what an observer sees is not only determined by the characteristics of that thing alone but also of the characteristics of the observer (Collin, 2011). Quantitative research is driven by a theory which helps to frame hypotheses that are then tested by conducting experiments and analysed using statistics (confirmatory in nature). Deductive reasoning or a hypothetico-deductive model is employed. Probability sampling and generalisability (internal and external validity) are features associated with quantitative methods (Teddlie & Tashakkori, 2009).

The **qualitative approach** has its roots in social constructivism or interpretivism. They believe that truth doesn't exist as such rather it is constructed by humans. According to them reality is socially constructed by those involved in it (Collin, 2011). Qualitative researchers use inductive reasoning which allows the researcher to argue from particular data to a general theory (Teddlie & Tashakkori, 2009). Qualitative research adopts purposive sampling involving a small number of individuals providing valuable and in-depth data. Trustworthiness (validity), credibility and transferability (external validity) are features associated with qualitative studies. Qualitative data analysis use categorical strategies and contextualising (holistic) strategies. Categorical strategies break narrative data into several units and then group them to develop categories to produce a better picture of the research question. Contextual strategies interpret narrative data from a whole "text" perspective (Teddlie & Tashakkori, 2009).

Mixed methods research has been considered as the third methodological movement after quantitative and qualitative movements (Teddlie & Tashakkori, 2009). Mixed methods follow both inductive and deductive logic and uses both numeric and narrative data. Probability, purposive and mixed sampling procedures are adopted. Inference quality and inference transferability(validity) are features of mixed method research (Teddlie & Tashakkori, 2009). When a phenomenon of interest is too complex and involves answering multiple questions that cannot be answered by quantitative or qualitative techniques alone, we use mixed methods (Mertens, 2015).

This study is largely supported by the interpretivist paradigm established to some extent by the use of phenomenography for the analysis of the data. Mixed methods were employed to collect data. (Please see section 5.6.2 for more about phenomenography.)

5.3 Research Aims, Issues and Methods

The general research aims of this thesis can be summarised as:

- the first aim is to explore primary teachers' conceptions of creative thinking, problem-solving and problem finding in science;
- the second aim is to explore student teachers' conceptions of creative thinking, problem-solving and problem finding in science;
- the third aim is to gain an insight into the strategies primary teachers use to promote creative thinking, problem-solving and problem finding in science;
- the fourth aim is to know if textual materials (schemes of works, textbooks and an online textual resource) are available in school or online, for teachers to support creative thinking, problem-solving and problem finding

- the fifth aim is to determine how textual materials (schemes of works and textbooks and an online textual resource) support creative thinking, problem-solving and problem finding;

- the sixth and the final aim is to see if we can use strategies to engage children in question asking for problem finding in science

The overarching research issue is to use strategies to engage children in question asking to generate scientific questions that can serve as problems to solve in the class. During this process children are encouraged to exercise scientific creative thought. This generates a number of sub-questions as shown in the Table 5.1 given below.

Table 5.1 Research Design to Address the Issue

No.	Research Questions	Data Collection Method	Location in the Thesis
1.	What are **primary teachers' conceptions** of creative thinking, problem -solving and problem finding in science? (SAY)	Descriptive Questionnaire Survey (Online)	Chapter Six
2.	What are **student teachers' conceptions** of creative thinking, problem -solving and problem finding in science? (SAY)	Descriptive Questionnaire Survey (Hardcopies)	Chapter Seven
3.	What are the **strategies primary teachers use** to promote creative thinking, problem -solving and problem finding in science? (DO)	Classroom Observations	Chapter Eight
4.	**Are textual resources available** in the school, or online, for teachers to support creative thinking, problem -solving and problem finding in science? (TEXT)	Teacher interviews	Chapter Eight
5.	**Do textual resources support** creative thinking, problem -solving and problem finding in science? (TEXT)	Content analysis	Chapter Eight
6.	**What strategies can be used** to engage children in question asking to raise scientific questions that can serve as problems to solve in the classroom? (STRATEGIES)	Controlled intervention/ Strategy trials	Chapter Nine

5.4 Ethics Approval

Ethics approval for the study was obtained from the Ethics Committee of the School of Education, Durham University. Separate ethics applications were submitted for the two stages of the study, stage one involving the questionnaire survey (both online and paper format) and the follow up classroom observations and teacher interviews and, stage two involving the strategy trials with children. See Appendix 1a and 2a. The researcher followed the recommendations of British Educational Research Association, BERA (2011) along with the ethical standards observed by the university during the time of data collection and analysis. The researcher also read through the fourth edition of British Educational Research Association ethical guidelines published in 2018 (BERA, 2018) and updated her understanding on the topic. Separate participant information sheets with a brief synopsis of the study with details of the methods of data collection, storage and presentation of the results and, ethics approval forms were e mailed to the Head teachers of schools beforehand. Part of the BERA requirements included protecting participant privacy. To ensure anonymity, participants were informed that their names and the names of the schools would be changed and the data would be stored securely on a password protected storage device/ laptop that could only be accessed by the researcher. Participants were also informed about what the research entailed and their rights surrounding their participation which includes the right to decide whether or not to participate and the rights to withdraw during the process without any negative consequences. The researcher also explained that although audio recordings of sessions would be required but there would be no recording of video content. A copy of the participant information sheets and the voluntary informed consent forms provided in the appendix (see Appendix 1b and 2b) were given to the participant teachers. All participants were volunteers and gave informed consent. The link to the online version of the questionnaire survey was emailed to the head teachers (see appendix 3a for the copy of the email). The online version also had information for the participants about what the research entailed, their rights surrounding their participation, the rights to withdraw during the process and a consent form to complete. The online version of the survey was open for nearly a year and it gave participants the option to complete it at their own convenience from anywhere with internet access, without needing to hurry.

The researcher sought permission from the head teachers to work alongside the teacher in the classroom with small groups of children to try out to test some teaching strategies to encourage pupils to ask questions in science. Another responsibility of the researcher according to BERA guidelines was regarding respecting children's right to consent in relation to their participation in the study. As the researcher did not have previous access to children, the science co-ordinator gave children a brief description about the activities beforehand and the purpose and obtained their verbal consent. The strategies planned were similar to classroom learning activities and did not involve asking of any personal questions/ collecting personal information from children or, recording of their video data, which requires parental consent.

The researcher explained to children about each activity (strategies to encourage raising science related questions) and no child was forced to participate. When a child expressed unwillingness during an activity, he was allowed to leave. Also, names of pupils and schools were anonymised and kept confidential.

5.5 Participant Schools

The study used mixed methods to collect data. Children from eight primary schools (School A, B, C, D, E, F, G and H) participated in the strategy trials. Observations of teachers teaching science were carried out in two schools (School E and H). The participant schools included both urban and rural schools. There was a mix of large, medium and small schools. Details of the participant schools are given in the table 5.2 below. The study had several elements intended to inform or extend one another. Each is now described in turn.

Table 5.2 Details of the Schools Participated in the Study

School	Study Stage	No. of Pupils	School Action	SEN	Pupil Premium	Free School Meals	English as Add. Language	Rural/ Urban	Extra Information
A	ST	200+	Above average	Average	Above average	Average	Few	Rural	Community
B	ST	50+		Average	Average	Higher than average	Few	Rural	Voluntary Aided
C	ST	100+		Above average		Higher than average	None	Rural	Community
D	ST	200+		Broadly Average			Very small %	Urban/ Town	Voluntary Aided
E	ST & O	200+		Below average		Well Below average	A minority	Urban	Voluntary controlled
F	ST	100+	Twice the National Average	Above average	Very few		Few	Rural	Academy
G	ST	200+		Lower than average		Lower than average	Few	Urban/ Town	Voluntary Aided
H	ST & O	200+	Below average	National average	Above average		Very few	Rural	Voluntary controlled

Abbreviations used in the table for Study Stages: ST- Strategy Trials, O- Observations of Science Teaching

5.6 Components of the Study

5.6.1 SAY: What do primary teachers say they do about encouraging creative thinking, problem-solving and problem finding?

Data collection Method: Online open-ended questionnaire survey

5.6.2 SAY: What do student teachers say they do about encouraging creative thinking, problem-solving and problem finding in science?

Data collection Method: Open-ended questionnaire survey

Surveys gather data at a particular point in time about the existing conditions or identifying standards against which existing conditions can be compared (Cohen & Manion, 1994). Questionnaires are very useful when the respondents are scattered over a wide geographical area. Hard copies and online versions of the questionnaire were prepared and distributed. Hard copies of the questionnaire were administered to student teachers at the end of a workshop to ensure maximum response rate. Web based surveys can reach greater number of participants and they show fewer missing entries than paper and open surveys (Cohen, Manion, & Morrison, 2011). Online surveys are convenient for respondents as they can complete it from home or work place and at any time that suits them. This explains why most of the primary school teachers opted the online version of the questionnaire. Questionnaires give a rough idea of the likely responses and how common some of them are (Breakwell, Hammond, Fife-Schaw, & Smith, 2006). When studying the insights, attitudes and perceptions of people, it is often worthwhile to allow them to make open-ended responses so that they are not constrained by the researcher's prior expectations of classes of useful responses. The researcher can later develop any number of categories at the time of analysis. Open-ended responses provide in-depth information and reduce investigator bias. Though analysis of open-ended questions is difficult (Breakwell et al., 2006)(content analysis)they allow respondents to express their opinion in any terms and allow multiple responses. The closed-ended items forces the respondent to make artificial choices but also assume that the respondent shares the same meanings attached to words used and causes bias (Breakwell et al., 2006). All the above points justifies why an open-ended questionnaire survey approach was adopted to understand student teachers' and teachers' conceptions of creative thinking, problem-solving and problem finding in science.

- **Preparation of the Questionnaire**

An online open-ended questionnaire was adapted from the already existing questionnaire on creative thinking and problem-solving created by Newton & Newton (D. P. Newton & Newton, 2009b). A third section on problem finding was added to the original questionnaire. The questionnaire has five sections. **Section A** contains questions on biographical and contextual information of the respondents. **Section B** consists of questions on teachers' conceptions of creative thinking in science. There are four questions under this, two of them are closed questions with options given to choose. 'Don't know' is given as a choice to improve data quality. The question number three and four, both open-ended has sub-questions asking for justification on the main question choice. This is to collect in-depth information from the participants and to avoid making up answers. Leading questions that lead respondents to answer in a certain direction were minimised (Fife-Schaw, 2006). **Section C has** questions aimed to understand teachers' conceptions of problem-solving and problem finding in science respectively. There are three questions under section C with sub-questions to penetrate deep in to the topic. Respondents were asked to give examples wherever necessary to get a real understanding of their conceptions. **Section D** is focused on problem finding in science. It is the longest with five questions. Some questions with yes/ no alternatives are followed by sub-questions asking for the reason for the chosen response. **Section E** has a list of science topics in the National Curriculum and the respondents were asked to choose three topics that offer the best and worst opportunities for problem finding along with reasons. The final form of the questionnaire has four sections detailed in table 5.3 below.

Table 5.3 Questionnaire Design

Sections in the Questionnaire	**Details**
Section A	Biographical/ contextual information
Section B	Questions to determine conceptions of creative thinking in science
Section C	Questions to determine conceptions of problem-solving in science
Section D	Questions to determine conceptions of problem finding in science
Section E	Questions on opportunities for problem finding in key stage two national curriculum science topics

- **Pilot Study**

Questionnaire was **piloted with two peers**. A few alterations were made to improve clarity and to ensure they mean the same to all respondents. Instructions were re-worded to avoid confusion. In the **section E** of the draft questionnaire, the respondents were first asked to order the science topics in the National Curriculum from the best to the worst for problem finding. As it took a longer time for them to order all the topics and people didn't complete it, this question was altered to 'which three topics offer the best opportunities for problem finding' and 'which three offer the worst opportunities for problem finding' in the final questionnaire. Three drafts of the questionnaire were prepared and piloted before making the final one. Bristol online survey software was used to create the online version of the questionnaire. The online version of the questionnaire was also piloted to a lay person and a few changes were made particularly in the numbering and the order of questions. A copy of the questionnaire (see Appendix 3b) and a copy of the e mail sent to schools with the link to the online survey is provided in the appendix (see Appendix 3a).

- **Administration (Online & Paper copies)**

The questionnaire was administered online using the Bristol online survey platform. Majority of the participant teachers favoured the online version as they could answer the descriptive questions at their convenience from home. The platform gave the respondents the choice of completing the questionnaire with complete anonymity and at their own convenience. Twenty nine teachers completed the online version of the questionnaire. All student teachers completed paper copies of the questionnaire. 58 student teachers completed the paper copies of the questionnaire.

- **Participant Characteristics**

Twenty nine primary school teachers voluntarily completed the online questionnaire survey. There were 22 female and seven male participants. Most of them were from primary schools in the UK (School D, E, H, I, J, K) but not all. Table 5.4 and table 5.5 present the details of the teachers who participated in the survey.

Table 5.4 Number of Teacher Participants and their Years of Teaching Experience

Years of Teaching Experience	Number of Teachers
0-5	11
6-10	5
11-15	7
16-20	2
21-25	2
26-30	1
30+	1

Table 5.5 Role of the Teacher Participants in the Questionnaire Survey

Role of the Teacher	Number of Teachers
Class Teachers	23
Science Co-ordinators	3
Class Teacher and Science Co-ordinator	26
Trainee Teacher	1
Head Teacher	2

- **Method of Analysis - Phenomenography**

A phenomenographic approach was used to analyse the data. Marton's (1981) phenomenography studies the qualitatively different ways in which people experience, think or believe about a phenomenon. It shouldn't be confused with phenomenology, which studies the relations existing between people and the world surrounding them. Phenomenography's focus is on the content of thinking or what is perceived and thought about and also in understanding misconceptions of reality. Phenomenography has been shaped as a research approach to answer some questions regarding cognition and learning (F Marton, 1986). It works by distinguishing between two perspectives. From a first-order perspective it aims at describing different aspects of the world and from a second-order perspective it focuses on describing people's experience of different aspects of the world. It is the empirical study of qualitatively different ways in which people experience, interpret, apprehend, understand and conceptualise various aspects of, and phenomenon around them (F Marton, 1986). It aims to develop categories of responses which reflect the range of conceptions (Ference Marton, 1981). In Marton's words:

*Conceptions of reality are considered rather as categories of description to be used in facilitating the grasp of concrete cases of human functioning. Since the same categories of description appear in different situations, the set of categories is thus stable and generalizable between the situations even if individuals move from one category to another on different occasions. The totality of such categories of description denotes a kind of collective intellect, an evolutionary tool in continual development. (*Marton, 1981, p. 177)

According to Marton (1981) when studying the conceptions of a phenomenon in a group of individuals, we may able to describe the different categories of conceptions and also to know the distribution of each category among the group under study. Marton (1986) reported that once the categories are revealed, it is possible to reach a high degree of inter-subjective agreement about their presence or absence in the data, if other researchers are able to use them. During the first phase of analysis, utterances found to be of interest in relation to the question being asked were selected and marked. Based on their similarities quotes were brought together into categories. Different piles or categories of quotes were formed in terms of their differences.

In concrete terms, the process looks like this: quotes are sorted into piles, borderline cases are examined, and eventually the criterion attributes for each group are made explicit. In this way, the groups of quotes are arranged and rearranged, are narrowed into categories, and finally are defined in terms of core meanings, on one hand, and borderline cases on the other. Each category is illustrated by quotes from the data. (Marton, 1986, p. 43)

According to F Marton (1986) in this type of analysis, meanings emerge in the process of bringing quotes together and comparing them. On the other hand, in traditional content analysis the categories, into which the quotes are sorted, are determined in advance. Though it is tedious and time consuming the process is interactive. Åkerlind (2005) reported that the data analysis stage of the phenomenographic research is often misunderstood. It focuses on collective rather than individual experiences. The categories of description that emerges are different ways of experiencing a phenomenon and therefore considered as representing a structured set, referred as 'outcome space'.

Categories of descriptions that eventually emerged from the questionnaire survey in this study reveal the various conceptions held by teachers and student teachers. Please see appendix 3c for the details. Though classroom observations proceeded by looking for specific behavioural cues linked to the promotion of creative thought, problem solving and finding in science, the different learning activities and their descriptions (like prediction, practical fair testing, giving explanations) gave more clarity about the conceptions teachers hold. Please see section 8.2 for details of the lessons observed. Here the descriptions of events in science lessons were analysed and the researcher returned to the categories of conceptions and quotes emerged from teachers' questionnaire survey, to see what teachers do in the classroom match with what they say they do in the survey. The short interviews with teachers after lesson observations were meant to collect information about the text resources (online or text books) they used to plan the lesson and their availability in schools. Please go to section 8.3 for the brief summary on this. The content analysis of different text books and an online resource specifically looking at the opportunities for creative thinking, problem solving and problem finding and their descriptions (like design a fair test, plan an investigation) revealed what text resources offered to support teachers. See appendix 5a for the details of opportunities. The researcher could compare between these descriptions generated from different sources to answer the questions in the study. Also, the similarities noticed between some descriptions emerged from different data sources strengthened the categories of conceptions. The analysis process was extremely time consuming and the researcher had to go back and forth between different data, quotes and categories of descriptions several times to check and recheck until reaching the conclusions.

5.6.3 DO: What are the strategies primary teachers use, to promote creative thinking, problem-solving and problem finding in science?

Data collection method: Semi structured non participant observation

Observations of teachers teaching science were carried out to see what strategies teachers use in the classroom to encourage children's creative thinking, problem-solving and problem finding in science. In other words, observations were carried out to see what do teachers do to support children's creativity in science. The researcher looked for strategies used by teachers to engage children in scientific productive thought. The observations were carried out not only to gain more insight into teachers' conceptions on productive thought but also to see if teachers do what they say they do (in the questionnaire survey). Also, teachers were interviewed to find out if they use any textual resources like schemes of work, text books or online textual resources to plan their lesson. Copies of lesson plans were collected. According to Robson (Collin, 2011) observation method gives an option for a reality check as it allows one to check if people do something the same way as they say they do. It is the observer who has to decide what kind of evidence to look for (Cohen et al., 2011, p456).

Observation

Observation is commonly used to explore what is happening in a situation. It can also be useful as a method to supplement data collected by other means (Collin, 2011), here it is used to add on to the survey data. The main advantage is that the researcher can directly observe what is happening instead of relying on second-hand data. The directness and accessibility to real world are the two main advantages of observation method (Collin, 2011). The main disadvantage is the reactivity or the extent to which the observer's presence affects the situation under observation (Collin, 2011). Observation being a very time consuming process (Collin, 2011) in this study it was carried out only in two schools (School E and H). See Table 5.2 for the details of the schools. Also, factors like time constraints, difficulty in accessing schools and teachers and lack of funding put a limit to the number and duration of the observations.

A **semi-structured** observation will have a list of issues but data collection will proceed in a less systematic way and will be hypotheses-generating (Patton, 1990). During observation, one can be a *peripheral member* who observes and interacts closely enough with members to get an insider's view but do not take part in their activities or (non- participant observation), an *active member* who participates in the group activities without committing fully into the program or a *complete member* who evaluates a program with which you are already fully involved (e.g. as a staff member) or ought to be fully involved (Adler & Adler, 1987). According to Cohen et al., (Cohen et al., 2011) a structured observation is systematic and helps to generate numerical data which in turn facilitates comparisons between settings, frequencies, trends etc. Observer would adopt a passive, non-intrusive position noting down the key factors on an observation schedule (Cohen et al., 2011). After piloting the observation, the researcher will decide on the foci of the observation, the frequency of the observations, the length of the observation period, what counts as evidence and the nature of entry (coding). Decisions are made considering the criterion of 'fitness of purpose'. The preparation time for structured observations will be long but analysis would be fast as the categories for analysis are already clear (Cohen et al., 2011).

- **Peer Lesson Observation**

The researcher volunteered to observe a creative science lesson taught by a peer researcher who is also an experienced teacher and a teacher trainer (ten plus years teaching and ten years training teachers). The teacher used his creativity to plan the lesson in a creative way beginning with a story, an example of creative teaching. It is likely that there exist a misconception among teachers on what counts as creative thought in science.

- **Preparation of Observation Cue List, Observation Schedule and Textual Materials Form**

<u>How can children be creative in science?</u>

Scientists working on creativity focus their attention particularly on three thinking spaces: the hypothesis space, the experimental space (Klahr & Dunbar, 1988) and the application space (D. P. Newton & Newton, 2009a). It is summarised in the table 5.5 given below. Although scientists are interested in the hypotheses space, the experimental space and the application space, a fourth space, the pre-hypothesis space has been included because it can act as a starting point for the other three particularly in a primary school setting. Opportunities for description (where a child notices some features and describes about it (pre-hypothesis space)can act as a starting point for making tentative explanations based on his/ her understanding in science (hypothesis space) and then move forward to test the tentative explanation (experimental space).In England and Wales, science and design and technology (D & T) in the primary National Curriculum are taught as separate subjects, while in Scotland, design and technology is included under science. In England, opportunities for creative thinking under the hypothesis space and the experiment space, comes under science, while the application space is mainly under design and technology, although it is possible to include thinking about applications in science lessons. In Scotland all three comes under science (D&T is included in science).

Newton& Newton (D. P. Newton & Newton, 2009a) has clearly explained evidence of creative thinking in primary school science. When a child constructs tentative explanations (reasons, causes, hypotheses, theories, functional models and analogies) or similar thought processes, they have opportunities to exhibit creative thinking in the *hypothesis space*. When a child constructs a test (a practical method) to find trustworthy descriptive information or a practical method to test a provisional explanation of an event they observed, they exhibit creative thinking in the *experimental space*. When a child has opportunities to apply ideas in new contexts and solve practical problems he/ she exhibits creative thinking in the *application space*. Examples of creative thinking under different thinking spaces are given in the table. See Table 5.6 for details. It is evident from these examples that in science children have opportunities to create their own causal explanations and they can put their causal explanations to test. In technology they have opportunities to use their understanding to solve practical problems. Newton & Newton (D. P. Newton & Newton, 2009a) added that science lessons offer productive activities like model making, painting and poetry writing but they generally do not offer opportunities for *scientific* creative thinking. See Figure 5.1 below illustrating the creative thinking spaces in primary science.

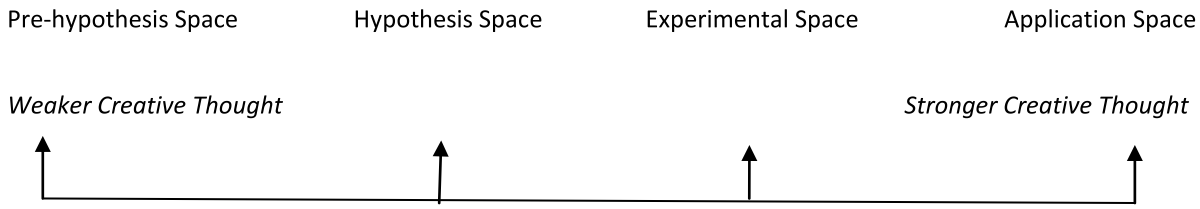


Figure 5.1 Creative Thinking Spaces in Primary Science and Design & Technology in England

Table 5.6 Opportunities for Creative Thinking in Primary Science and Design & Technology in England

Scientific Creativity Thinking Spaces	**Behaviour Cues**	**Examples**
0) Pre-hypothesis space Weaker constructive thinking (noticing, understanding, creating)	A child constructs : • *tentative descriptions* (e.g. properties, scenarios, patterns, structural models and analogies)	1) Example for tentative descriptions: A child notices a pattern on how bigger children able to hold their breath for a longer time. A child uses science knowledge to imagine living on a space station? (Description based on science knowledge) *"My shoe soles are made of rubber. The rubber sole has grooves and ridges. It gives better grip on a wet road".*
1)Hypothesis space Constructs explanations and theories	A child constructs: • *tentative explanations (why?)* (e.g. reasons, causes, hypotheses, theories, functional models and analogies)	2) Examples for tentative explanations: A child explains why the ice cube kept in the kitchen has become water. *Or "My shoes have more grip because......"*

2)Experimental space Test hypotheses, explanations and theories (Under Science)	A child constructs *a practical way*: • to find reliable descriptive information (Make a test to descriptive information) • to test a tentative explanation of an event	1) Example for constructing a test to find descriptive information- A child suggests a practical way to see whether different shoe soles have a different effect on slippery surfaces. *"I will make a test to find out if different shoes have different grip on a wet road"?* 2) Example for constructing a method to test an explanation- • A child come up with a method to test their idea that all metallic objects do not stick to magnets "I will make a test to find out if my explanation works"! *"I will make a test to test my idea that shoes with rubber soles having grooves and ridges have the best grip on a wet road"?*
3)Application space (Apply knowledge) (under **Design & Technology** in England)	*A child applies his or her ideas in new situations* and solves practical problems. (Applies ideas in new day to day	1)Example for applying ideas in new situation- • A child uses his knowledge of properties of materials to make a water resistant roof for the doll's house *"If I want to make a pair of running*

	situations to solve practical problems)	*shoes, I would do ------ soles to make them grip better"*

Maker et al., (Maker et al., 2008) noted that productive thinking and problem-solving were encouraged when children were provided with a challenge, allowed to set goals and discuss about options to meet them, allowed to work independently or collaboratively, teacher scaffolding by asking probing questions, teacher helping pupils to define what the result needs to do, pupils interact and produce a presentation about the result (Maker et al., 2008). Observation cues for creative thinking were prepared based on the above views. Observation cues for problem-solving and problem finding were also drafted after considering studies on problem-solving and problem finding. The final version (A3) of the **observation cue list** for creative thinking, problem-solving and problem finding in science has three sections. Section one, for observation statements connected to creative thinking, section two, for problem-solving and section three for problem finding. Under section one, five statements to do with creative thinking and all associated with pupil's behaviour were provided. Under section two, five statements to do with problem-solving connected to the teacher were given. Section three, has seven statements related to problem finding, four of them associated with pupil and three with teacher, were given. By looking at these behavioural cues the observer could fill in the specified number of the behaviour noted in the observation schedule. Three drafts of the observation cue list were prepared. The first version had eight cues under creative thinking, seven under problem-solving and six under problem finding. Similar or overlapping cues were removed and a version two cue list was prepared. After piloting it a slight alteration in the layout was made and thus a refined third version was prepared (see Appendix 4b).

The **observation schedule** has nine sections (rows).First section for 'Who', teacher (T) or pupil (P). Then there is space for recording the time. Three sections for creative thinking, problem-solving and problem finding were provided each divided into sub rows numbered according to the behavioural cues given in the cue list. Also, rows for entering other contextual factors and comments were given. A section titled 'other' was added to note down anything extra ordinary happened during the observation. As the first version had a small space for entering the details of textual materials used by the teacher, a separate sheet for writing down the details of textual materials was also added after the pilot study. A final copy of the observation schedules (see Appendix 4c), the textual material sheet (see Appendix 4d) and, the checklist used for classroom observations (see Appendix 4a) are provided in the appendix. According to Lofland, (Lofland, Snow, Anderson, & Lofland, 1971) writing notes soon after the observation of the event can reduce the problems of reliability. Therefore detailed field notes were entered soon after the lesson observation to ensure reliability. All the lessons were voice recorded to assist with data analysis.

- **Pilot Observation**

A pilot lesson observation of teacher (T1) teaching science in an upper key stage two year group (Year 6, School E, Circuits-Investigative lesson) was conducted. Slight modifications were made in the lay out of the observation schedule and a separate sheet for adding details about the textual resources was introduced after the pilot study.

- **Observation of teachers teaching science**

According to Collin (Collin, 2011) spending time within a program by keeping one's eyes and ears open gives a real feel of what is happening there. The greater the observer's participation, the more likely to have an effect on the program. Getting closer to have an insider view but to remain behind or be an 'unobtrusive' or not very noticeable insider helps to reduce the observer effect (Collin, 2011). Therefore, a non-participant observation was followed. Robson suggested that it will be very useful if one combines observations with an informal interview or a questionnaire because it gives the opportunity to discuss what one has observed with the people involved (Collin, 2011). This justifies why a short interview was conducted with the teacher after the lesson observation. A convenient sampling method of data collection was followed. Observations were conducted in two schools as it was very difficult to access teachers due to their busy schedule. The researcher tried to observe more than one lesson of the same teacher whenever possible to ensure quality of the data and also to reduce the observer effect but it was very hard to get the teacher's permission. A short list of teacher and pupil behaviours associated with creative thinking, problem-solving and problem finding to observe, was prepared. An observation schedule, a behaviour cue list to look out and a template to enter information about the textual materials were used to make it more structured and to reduce personal bias. The observer adopted a passive, non-intrusive observation positioning in the corner of the classroom checking on the behaviour cues manifested by the teacher and the pupils (associated with creative thinking, problem-solving and problem finding) and recording them as and when it happened. The observations were designed and conducted in a way to have little effect as possible on the classroom practices. The observer also noted down the time and other key factors in the observation schedule. A short informal interview was conducted soon after the lesson to know if teachers used any textual resources like schemes of work, text books or web resources to plan the lesson and this information was written on a separate sheet attached to the observation schedule (please see textual materials form provided in the appendix). Brief field notes were also written and voice recordings of the lessons were conducted. It should be recalled that observations were carried out to explore teachers' conceptions and strategies (what teachers say they do match what they actually do?) and not to test a hypothesis, minimising the likelihood of personal bias in the data collection.

- **Methodology**

Semi-structured non-participant observation (see the description above)

Participant Characteristics

The details about the two schools where classroom observations were conducted are given here. Please see the table 5.2 under section 5.5. First school **(School E):** The school was a larger than average sized primary school which serves the locality of relatively high social advantage. **Class/ Pupils:** A well below average proportion of pupils were eligible for free school meals. The proportion of pupils with learning difficulties and/ or disabilities, including those with a statement of special educational need is below average. Second school **(School H):** This is an average-sized primary school. The proportion of pupils supported through school action is below average. The proportion supported at school action plus or with a statement of special educational needs is broadly in line with the national average. Currently, an above average proportion of pupils are known to be eligible for pupil-premium funding, which is provided by the government to support the learning of pupils who are entitled to free school meals, in the care of the local authority or the children of members of the armed forces.

A convenience sampling procedure was adopted. Eight science lessons delivered by six teachers in two schools (T1, T2, T3 in school E and T4, T5, T6 in school H) were observed as part of this study. The table 5.7 below has the details of the lessons observed. All these teachers were interviewed to find if they use any textual or online resources to support children's learning or, if the school provides any of them.

Table 5.7 Details of the Lesson Observations

Number of Lessons Observed	School	Primary School Key stage2	Teacher	Topic
1(Pilot Lesson)	E	Upper KS2 (Y6)	T1	Electricity- Circuits
2	E	Upper KS2 (Y5)	T2	Living Things & Habitats- Adaptations of plants and animals
3	E	Upper KS2 (Y5)	T2	Living Things & Habitats- Food chains and food webs
4	E	Lower KS2 (Y4)	T3	Sounds- Introduction
5	E	Lower KS2 (Y4)	T3	Sounds- Vibrations
6	H	Upper KS2 (Y6)	T4	Living Things & Habitats- How animals adapt to environment?
7	H	Upper KS2 (Y5)	T5	Living Things & Habitats- Seed Dispersal
8	H	Lower KS2 (Y4)	T6	Animals, Including Humans- Skeletons

- **Method of Data Analysis- Phenomenography**

Data was analysed using phenomenography (see the description given under the questionnaire survey data analysis, for details).

5.6.4 TEXT: Are <u>textual materials available</u> in school or online for teachers to support creative thinking, problem-solving and problem finding in science?

Data collection method: Short interviews with teachers

A short informal interview was carried out with the teacher after the lesson observation to know weather they use any textual resources (hard copies or online) to plan their science lessons. Also, the researcher wanted to know if these resources were available in schools or online for teachers to use.

5.6.5 TEXT: Do <u>textual resources</u> (schemes of work, text books and web resources) encourage creative thinking, problem solving and problem finding in primary school science?

Data collection method: Content analysis of textual resources

According to Robson (Collin, 2011) when we analyse documents like text books, schemes of work and web resources we are dealing with something produced with a different purpose in mind. When we conduct an observation, there is always a risk of the observer's presence affecting whatever is observed. This risk is removed when we analyse documents like text books or Ofsted reports as the usage doesn't affect or alter their content (Collin, 2011). Therefore, a content analysis of textual resources was conducted. Collin (Collin, 2011) recommends, the quantitative analysis of documents is normally done by measuring the number and type of different features given in the text. The main advantages of document analysis are: it is unobtrusive, as the data is in a permanent form it can be analysed again and again for ensuring reliability (Collin, 2011). Sometimes documents are difficult to access and the researcher might be required to travel, which utilises time and money (Creswell, 2012). Creswell (Creswell, 2012) has suggested to follow these steps for collecting documents: identify the documents that can provide necessary information, seek permission, examine if they are accurate in answering the research questions and record information from them by taking notes, scanning etc.

Methodology- Content Analysis of Textual Resources

In England there exist a variety of text book series developed for different age groups like key stage one, key stage two etc. As this study focuses on key stage two(7 to 11 years) a sample of key stage two level text books following the national curriculum were selected for analysis from the university library. Most of these text books were available in the market for parents and teachers to buy. A convenience sampling procedure was adopted as there is no intention to generalise the results. The series of texts analysed were:

1. Collins Science Directions,
2. Folens science in Action,
3. Letts Teaching and Learning Science,
4. Pearson Longman Exploring science,
5. Scholastic Hundred science Lessons (Scottish NC) and
6. Hamilton Trust (web resources)

Unless the textbook is very short, looking for incidents of creative thinking, problem-solving and problem finding would be a time consuming process, therefore, sampling the text is an unavoidable task. The method followed was an inter quartile analysis of the text book according to the procedure suggested by Newton & Newton (D. P. Newton & Newton, 2009a). Qualitative analysis involved reporting the opportunities for creative thinking, problem-solving and problem finding under separate headings. Here, one chapter connected to the three branches of science, Biology, Chemistry and Physics was selected and analysed for incidents of creative thinking, problem-solving and problem finding. These incidents were reported. See Appendix 5a for the details of the opportunities for productive thought identified (mostly creative thinking and problem solving). An example for creative thinking opportunity in experimental field would be *'Plan a fair test to find out which type of soil can water flow through, more easily?'* An example for a problem-solving opportunity (applied field) found was *'Design and label a healthy balanced meal for a vegetarian'*. Counting the number of opportunities for creative thinking, problem-solving and problem finding formed the quantitative part (see Appendix 5b). There was overlap between the opportunities for problem-solving and creative thinking as both involved thinking creatively.

5.6.6 **STRATEGIES: <u>What strategies can be used</u> to stimulate children to think and raise scientific questions that can serve as problems to solve in the classroom?**

Data collection method: Controlled intervention or strategy trials with children

Strategies to Support Children's Problem Finding: some guidance from the literature

From the review of literature conducted by the current study there observed a scarcity of children's questions in the science classroom particularly questions encouraging deep thinking and questions that can lead to problems that could lead to investigations in the classroom. This study began with questions like 'Can primary school children ask questions/ find problems in science? Can teachers support children to ask questions that can serve as problems to investigate in science? Can teachers use strategies to stimulate children to think and raise scientific questions or problems to solve in the classroom?' One of the aims of this study is to explore the effect of some relatively simple strategies to stimulate children to think creatively to raise questions or problems related to science. The scenarios used for the strategies were linked to key stage two national curriculum science topics. The strategies are based on the some important theoretical aspects of questioning shared below.

- **Stimulus for Question Asking for Problem Finding**

As given under section 4.6.4, children when engaged with real animals asked higher order explanatory questions in Biology and therefore, the study predicted that real objects having richer cues that tap into child's conceptual knowledge more efficiently, can make question asking an easier task for children (Chouinard et al., 2007) .

- **Interest, Novelty, Curiosity, Prior Knowledge and Motivation**

As reported in 4.6.2, 4.6.4 and 4.6.1, a novel stimulus generates curiosity, interest and motivation to learn (Berlyne, 1954b). It was reported by Loewenstein (1994) that when a student has basic conceptual knowledge but not the specific details (gap) then he or she would be curious about the missing information and be motivated to fill the gap in the knowledge. When the information gap is small curiosity will be high and when the gap is large, curiosity will be low (Gentry et al., 2002). These principles were considered when designing problem contexts for strategies particularly science stories or scenarios to engage children in question asking in science.

- **Self directed learning through questioning (known to unknown)**

Under section 4.6.3, it was reported that encouraging children to ask questions and find answers on their own can promote self directed learning in science.

- **Pedagogy of Engagement**

As reported in section 4.6.5, the instructional dialogue teacher use to support student understanding and the characteristics teacher should have to create a productive and secure learning environment play a great role in promoting student engagement in science learning (Darby, 2005).

The above points were taken into consideration when planning the strategies described below. Five interventions were constructed prompted by the above guidance. These were:

1. Question Starters on Giant Dice
2. The 'Elephant Strategy'
3. Question Generation Workshop with Real Eggs and Bags
4. Science Stories
5. 'I Wonder' Board/ 'I Wonder' Folder

Three of them except the 'I Wonder Board' and the 'Elephant Strategy' were based on the same scenarios 'Birds' Eggs' and 'Bags made from different materials'. These two scenarios are linked to a natural science and a physical science topic under the key stage two National Curriculum, 'Animals and Habitats' and 'Materials and Properties' respectively. See Table 5.8 showing the strategies and the theory of curious questioning supporting each strategy. A description on each strategy along with photographs is provided after the table below.

Table 5.8 Strategies and Factors Promoting Curious Question Asking or Problem Finding

	Strategies	1)Question Starters on Giant Dice	2) 'I Wonder' Board (Wonder Folder)	3)Question Generation Workshop (Real Eggs Bags)	4) Science Stories	5) Elephant Strategy
	Theory of Curious Questioning					
1.	Real Objects as Stimulus			X		
2.	Novelty, Interest & Curiosity Intrinsic Motivation			X	X	X
3.	Pedagogy of Engagement	X		X	X	X
4.	Instructional Pedagogy/ Scaffolding	X		X	X	X
5.	Self-directed learning through questions	X	X	X	X	X

Strategy1: Question Starters on Giant Dice

During the Question Starter strategy trial, children were given worksheets with six question starters printed on them. They are: 'What would happen if...?', 'What happens when....?', 'How would you...?' 'Which.....is/ does....?' 'Which is best for.....?' and 'Will it.....if we....?'

The researcher had a giant dice with each question starter written on its face. Due to time restriction, the researcher rolled the dice in the above order of the question starters and children were asked to complete each question starter to make a question. Rolling the dice and saying the starter aloud made the activity more interesting and game like. For each starter the researcher gave an example questions to probe them. Pupils could write questions on the topics birds' eggs or bags made of different materials. The first question starter 'What would happen if...?' was meant to build an explanatory question encouraging children to extend their thinking and make predictions. Other question starters were focussed on building factual or descriptive questions. The strategy was conducted with small groups of children and they were given adequate time to complete each question starter provided on the worksheet one by one. The worksheets were collected at the end of the session and children's questions were entered in Microsoft excel sheet for further analysis. As reported under section 4.8.5, Chin (2004), White and Gunstone (1992) and Harlen (1991) supports the use of question starters to help children to generate science questions. See Figure 5.2 below displaying the photograph of the Question starter strategy. Voice recordings of the sessions were done and field notes were written (see Appendix 6a) on the school information sheet, the task information sheet and on the additional sheet.

Figure 5.2 Question Starters on the Giant Dice

Strategy 2: The 'Elephant Strategy'

The'Elephant Strategy' was carried out to investigate if primary school aged children can come up with their own scientific problems, when an interesting science topic (elephant) was given to them in the form of photographs along with a brief introduction by the researcher. See also section 4.8.7 which reports on providing stimulus for question asking. A novel and interesting stimulus can arouse curiosity and a desire for knowledge in children (Berlyne, 1954b). The 'Elephant Strategy' was designed based on this. 116 children aged 8 to 11 years (Key stage two) from three similar primary schools participated in the activity. This strategy was conducted in both upper and lower key stage two year groups of three primary schools as one school couldn't provide enough number of students with mixed ability groups. Children from each year group were divided into three mixed ability groups comprised of equal number of boys and girls. The researcher worked with one group at a time in a separate room. Three Elephant photographs: in captivity, in the wild and an elephant embryo in the womb were used to generate children's questions.Children were asked to write their initials on the sheet. These were later assigned numbers for anonymity and stored. The first group of children were shown the elephant in captivity photograph and were provided with the same worksheet to write their questions. The second group was provided with the elephant in the wild worksheet and the third group with the embryonic elephant worksheet respectively. A short verbal introduction about the animal was given by the investigator. Then pupils were asked to write some questions about the photograph on the worksheet provided.Same procedure was followed in all the schools and children were allowed to discuss with their peer next to them, if needed. Sessions were voice recorded after gaining permission. The researcher wrote brief notes about the task, including the start time and the end time and specific challenges faced during the activity. Also, information about the school was written on the school sheet as soon as the session was over. Please see Appendix (6a).The three photographs used are given below. See Figures 5.3, 5.4 and 5.5 displaying the Elephant in the Wild, Elephant in Captivity and Elephant Embryo in the Womb photogphs.

Figure 5.3 Elephants in the Wild

Sandesh Khadur, http://www.sandeshkadur.com/2012/04/secrets-of-wild-india-elephant-kingdom/, 2012, Nat Geo Wild UK – 06 February 2012

Figure 5.4: Elephant in Captivity (Dr Philip, S. 2016)

Figure 5.5 Elephant Embryo in the Womb

http://news.bbc.co.uk/1/shared/spl/hi/pop_ups/06/sci_nat_animals_in_the_womb/html/1.stm

- **Strategy 3: Question Generation Workshop with Real Eggs and Bags**

The Question Generation Workshop strategy has been conducted to see if children could produce their own questions in science when they were supplied with some concrete/ real specimens. For more details please see section 4.8.7. Here, different types of birds' eggs and bags made from different materials were used to elicit questions from children. Different types of birds' eggs available locally were collected, boiled and refrigerated for use with children. There were eggs from quail, hen, duck and goose available locally. A blown Ostrich egg was also included. Eggs were labelled. Children could notice the difference in colour, size and texture of them. Bags, mostly shopping bags made from different materials like paper, jute, cotton, plastic and leather collected from the local shops were used to stimulate children's questions. A small bag made of silk material from researcher's personal collection was also added to the display. The researcher gave a short introduction on eggs and bags. Pupils were then asked to write some science questions about eggs and bags on the worksheet provided. Some examples of questions were given to them. When the Question Generation Workshop was conducted, children were asked to generate questions for the eggs first and then for the bags. Questions written by each child were later entered manually in an excel file in the same order they wrote on the worksheet (i.e. questions on the eggs first and then the bags' questions). Same procedure was followed in all the four schools where the strategy was conducted. This strategy was conducted with small group (five or six pupils) of children at a time. Children were allowed to discuss with their peers next to them. It was observed that when real eggs and bags were used children showed more enthusiasm to observe them closely, feel them and questions started to emerge naturally. They appeared more curious and interested to ask questions particularly on the observable features of the display. See figures 5.5 and 5.6 displaying photographs of 'Question Generation Workshop' using real eggs and bags.

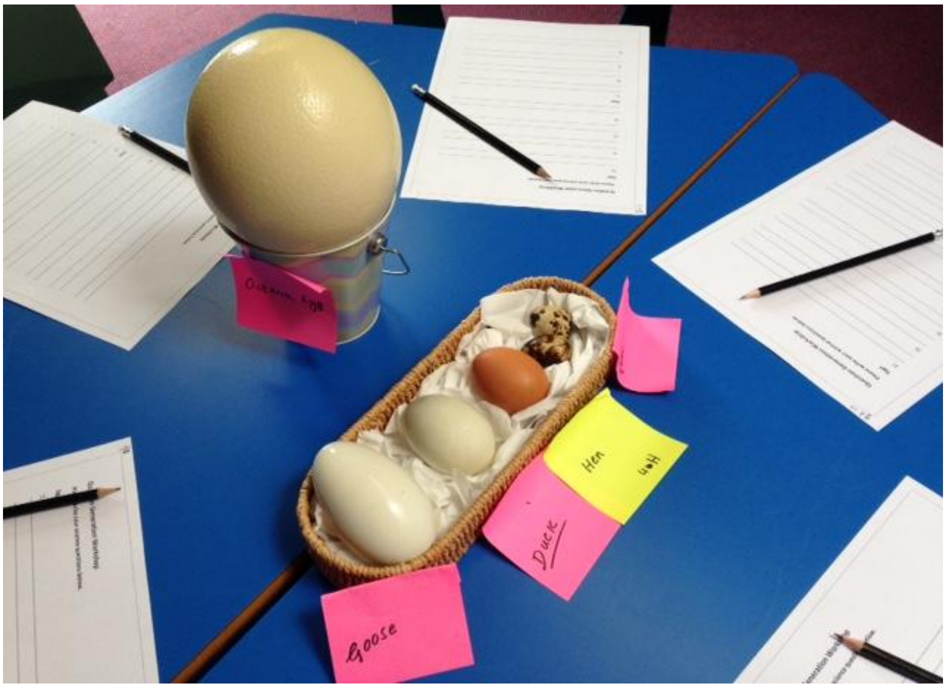


Figure 5.6 Eggs from birds like Ostrich, Goose Duck, Hen and Quail

Figure 5.7 Bags made from different materials like Paper, Jute, Cotton, Leather and Plastic

- **Strategy 4: Science Stories**

During the Science Stories strategy children were given worksheets with photographs of two real life situations in a story form, one from birds' eggs and the other based on bags made of different materials. The two situations chosen were a) A double yolk boiled egg and b) A cow foraging among the food and plastic wastes near a thrash in India (food waste disposal and plastic pollution).The twin egg photograph was from the researcher's own collection while the photo of the cow was taken from the PETA website (People for Ethical Treatment of Animals) meant to create awareness on the consequences of improper disposal of food wastes in plastic bags on animals. A short story with some factual information about the photographs was given under each photograph to give children some background information about the situations provided. After reading out the stories and showing the photographs to children, the investigator asked them to write some science questions on the worksheets. The worksheets were collected and later analysed. This strategy was also conducted with small groups of pupils (five or six pupils at a time) and followed a similar procedure with earlier strategies. The two science stories are given on the next page with photographs used. See figures 5.7 and 5.8 showing the photographs of the foraging cow and the boiled egg with double yolk. See section 4.8.8 for more information on science stories.

Science Story 1: Plastic bag, a blessing or curse? Please write a few science questions on these two topics. This is what happened to Gowri the street cow that used forage in and around a trash heap in a city in India. She died a few months back. In order to find the cause of her death a local animal welfare society autopsied the cow. They removed 40 kg (88 pounds) of plastic accumulated in her belly. Poor Gowri! She might have died painfully.

Figure 5.8 Plastic Bags a blessing or a curse? (Kelsi Nagi, 2011) (https://worldcowgirl.wordpress.com)

Science Story 2: Double Yoked Egg

Rahul was surprised when he saw two yolks in his boiled egg. "I got a twin egg!" he shouted with joy. The yolk has high amount of protein and fat and serves as the main source of food for the developing embryo. The egg white or albumin has mainly water and it protects the yolk. Have you seen one like this before? Do you have any questions? **Write one or two science questions.**

Figure 5.9 Egg with Double yolks (http://hoadsfarm.co.uk/)

- **Strategy 5: 'I Wonder' Board/ 'I Wonder' Folder**

The 'I Wonder' board/ folder strategy (also reported in section 4.8.9) was carried out as a plenary activity after a teacher introduced a topic. The children were asked to write their questions on individual sticky notes and attach them to the board. These were collected and sorted by the researcher. Different coloured sticky notes were given for boys and girls. Where class discipline is a challenge then using separate 'I Wonder' folders for each small group of pupils would be ideal. To make it easy to differentiate two different coloured folders can be used for boys and girls. The children then attach their individual sticky notes in the 'I Wonder' folder on their table after writing their questions on it for the teacher to sort and discuss later. This is a time saving strategy and every child can generate more number of questions based on the teacher's own topic content without providing any extra stimulus, like in a normal classroom. The sessions were voice recorded and field notes were taken down on the school information sheet and the task information sheet soon after the strategy.

5.7 The Testing Context and the Children Tested

The investigator through the university contacted the Head teachers of selected partnership primary schools to gain permission for trialling strategies and collecting data. Eight primary schools participated in the strategy trials. Meetings were arranged with the science co-ordinators to explain about the strategies and the trial requirements. List of students (initials) and their literacy ability levels (high, medium, and low) were collected from the teachers, prior to the trials though they were given codes to increase anonymity. A non-probability convenience sampling procedure was adopted in choosing schools for trialling the intervention and data collection. Most schools agreed to conduct the study in one lower key stage two (Year 3/4) and one upper key stage two (Year 5/6)year groups .Except the 'I Wonder' Board/ Folder and the 'Elephant Strategy' all the strategies were trialled in four upper and four lower key stage two year groups. 'I Wonder' Board/ Folder strategy and the 'Elephant strategy' were trialled in two upper and two lower key stage two year groups of three primary schools, though the 'Elephant Strategy' required children in three mixed ability groups. Details provided in Table 8.7.

- **Strategy 1: Question Starters on the Giant Dice**

The Question Starter strategy was conducted in four upper and four lower key stage two (KS2) year groups of four different primary schools. There were a total of one hundred and fifty nine participants from the whole key stage two. The details about the participant children which includes their year group, gender and ability levels in literacy (LA, MA, HA- Lower, medium and high ability in literacy) are given in the table 5.9 below. Please see table 5.15 showing the details of all strategies and the primary school year groups (key stage two (KS2)/ ages 7-11).

Table 5.9 Details of the Participants in the Question Starters strategy (strategy 1)

Schools	No. of Pupils	Males	Females	LA	MA	HA
LKS2	83	42	41	24	33	26
UKS2	76	30	46	21	28	27
Whole KS2	159	72	87	45	61	53

(LA- Lower Ability,MA- Medium Ability,HA- Higher Ability in Literacy)

- **Strategy 2: 'The Elephant Strategy'**

The 'Elephant strategy' was trialled in two lower and two upper key stage two (KS2) year groups of three similar primary schools in the UK. See table 5.15 showing the details of the strategies and the key stages.There were 58 participants from the lower and 58 from the upper key stage two thus forming a total of 116 participants in the KS2 whole group. The table 5.10 presents the design of the 'Elephant Strategy'. The table 5.11 summarise the participant details which includes details about the primary school key stage, gender and ability levels in literacy (LA, MA, HA- Lower, medium and high ability in literacy).

Table 5.10 Design of the Strategy

	Group A Photograph 1 Elephant in the Wild	**Group B Photograph 2** Elephant in the Captivity	**Group C Photograph 3** Elephant in the Womb
Lower KS2	1/3rd of pupils	1/3rd of pupils	1/3rd of pupils
Upper KS2	1/3rd of pupils	1/3rd of pupils	1/3rd of pupils

Table 5.11 Participant Information

	Elephant-Wild	Elephant-Captivity	Elephant-Embryo	Total	Males	Females	LA	MA	HA
LKS2	20	20	18	58	29	29	14	25	19
UKS2	20	19	19	58	29	29	14	26	18
Whole KS2	40	39	37	116	58	58	28	51	37

(LA- Lower Ability,MA- Medium Ability,HA- Higher Ability in Literacy)

- **Strategy 3: Question Generation Workshop (Real Eggs and Bags)**

The Question Generation Workshop strategy using real eggs and bags was trialled in four upper and four lower key stage two (KS2) year groups of four primary schools in the UK. Details provided in table 5.15. There were 76 participants from the lower key stage two and 84 participants from the upper key stage two adding to one hundred and sixty (160) pupils from the whole key stage two. The details of the number of pupils, gender and their literacy ability levels have been provided in the table 5.12 below.

Table 5.12 Participant Information

Schools	No. of Pupils	Males	Females	LA	MA	HA
LKS2	76	39	37	22	34	20
UKS2	84	38	46	17	34	33
Whole KS2	160	77	83	39	68	53

(LA- Lower Ability,MA- Medium Ability,HA- Higher Ability in Literacy)

- **Strategy 4: Science Stories**

The Science Stories strategy was trialled in four upper and four lower key stage two (KS2) year groups of four primary schools in the UK. See table 5.15 for details. There were eighty five participants from lower key stage two and eighty six participants from upper key stage two summing up to a total of one hundred and seventy one participants from the whole key stage two (KS2). See table 5.13 below for more details about the participants.

Table 5.13 Participant Information

Schools	No. of Pupils	Males	Females	LA	MA	HA
LKS2	85	42	43	21	38	26
UKS2	86	44	42	20	36	30
Whole KS2	171	86	85	41	74	56

(LA- Lower Ability,MA- Medium Ability,HA- Higher Ability in Literacy)

- **Strategy 5: 'I Wonder' Board/ 'I Wonder' Folder**

This strategy was conducted as a plenary activity. Children were asked to write down their questions on the sticky notes on the topic they were learning in science. The strategy was carried out in two lower key stage two year groups and two upper key stage two year groups of three primary schools. See table 5.14 for details. There were 45 participants from lower key stage two (KS2) and 38 participants from upper key stage two (KS2), 83 pupils altogether. The two lower key stage two year groups were learning Natural Science topics (Food chain and Plants) and the two upper key stage two year groups were learning Physical Science topics (Electricity and Earth & Space.The number of schools were limited. It was very difficult to access schools as teachers were very busy working. See table 5.14 below for details on of the number of students, gender and their literacy ability levels.

Table 5.14 Participant Information

Schools	No. of Pupils	Males	Females	LA	MA	HA
LKS2	45	18	27	11	18	16
UKS2	38	15	23	8	15	15
Whole KS2	83	33	50	19	33	31

(LA- Lower Ability,MA- Medium Ability,HA- Higher Ability in Literacy)

Table 5.15 Information on Strategies Trialled and their Testing Contexts

Schools	LKS2	UKS2	Question Generation Workshop (Real Eggs & Bags)	Question Starters on Giant Dice	Science Stories & Scenarios	'I Wonder' Board/ Folder	Elephant Strategy
A	x		LKS2	LKS2			
		X	UKS2	UKS2		UKS2	
B	x	X		UKS2	UKS2	UKS2	
	x		LKS2	LKS2	LKS2	LKS2	
C	x	X	LKS2 UKS2	LKS2 UKS2	LKS2 UKS2		
D		X	UKS2	UKS2	UKS2		UKS2
E		X	LKS2				
	x		UKS2	LKS2	LKS2	LKS2	
F	x				LKS2		
G		X			UKS2		
	x						LKS2
H	x	X					LKS2 UKS2

(LKS2/ Lower KS2- Year 3 & 4, UKS2/ Upper KS2- Year 5 & 6)

5.8 Method of Analysis of Children's Science Questions Generated from the Strategy Trials

Science questions generated from the five strategies were qualitatively analysed using two methods: i) by categorising them into factual or explanatory questions, and ii) by sorting them into questions that can be answered through research, observation, demonstration, investigation and none, based on the the acronym 'RODIN' . This porcess is described below.

- **Categorising Children's Questions into Factual and Explanatory Questions and Analysing their Pattern**

What questions are considered to be good science questions or those manifesting higher level of cognition in children? Literature shows that questions encouraging the generation of scientific explanations (Why...?,Why not...?) and prediction (What if...?,What....if...?) are higher level thinking questions while factual questions (What...? Where...? When...? How...? Who...? Which...?) promotes only recalling of facts. 'Why....?' questions were found to be more open ended and they encourage children to think in different directions (L. D. Newton, 1996).Based on this, children's science questions produced from six strategies were grouped into two categories viz factual and explanatory questions. 'What', 'When', 'How', 'Where', 'Who', 'Which'questions were grouped as factual questions.'What....if...?' and 'Why...?' questions were grouped as explanatory questions encouraging higher level thinking (prediction, explanation etc). Questions which were not related to science were grouped as non-science questions.There were also some ambiguous questions. Examples of each category of questions generated under each strategy are provided in the analysis chapters. Only science questions were analysed and taken into consideration.

To analyse the pattern of occurrence of factual and explanatory questions a particular method was followed. All the first questions generated by each child in one particular strategy were analysed first, i.e. were labelled as factual or explanatory questions, then all the second questions, then the third and so on. Graphs were prepared for each strategy. The question number (Question 1 or Q1, Q2, Q3 etc) were plotted on the X axis and the number of questions generated, on the Y axis. Therefore, on the X axis, for each question i.e Q1, Q2, etc, there will be two bars in two different colours, one showing the number of factual questions (blue bar) and the other showing the number of explanatory questions (brown bar).Separate graphs for whole key stage two (upper and lower key stage two), upper KS2 (older children/ aged 9-11 years) and lower KS2 (younger children/ aged 6.5/7-9 years) were prepared, to understand the pattern of occurrence of factual and explanatory questions. Also, topic wise analysis of questions were also done. The number and percentage of factual and explanatory question were caculated for each strategy. Also, total number of science questions were also counted for each strategy.Lower key stage two, upper key stage two and whole key stage two were analysed separtely for factual and explanatory analysis.No gender wise effect was observed.The different categories of factual and explanatory questions were studied and reported under each strategy with examples in the analysis chapters.

- **RODIN Analysis of Questions (into groups of Research, Observation, Demonstration, Investigation and None)**

Meyers and Jones (Meyers & Jones, 1993) stressed that active learning involves the use of cognitive activities, learning strategies and teaching resources to make learning more engaging to students. A study conducted in Turkish schools reported confusion among teachers on what constitutes as active learning strategies. An active learning classroom environment makes the lesson more engaging and interesting for children as teachers and children share the responsibility for instruction and involves the use of learning activities like demonstration, small group work, role plays, games, discussions and problem-solving (Karamustafaoglu, 2009). Some teachers may view active learning as lesson with hands on activity and may ignore the need for mental engagement. Children are mentally engaged when solving problems in science. Mostly teachers provide problems for children to solve, an attempt is made to see if children can be encouraged to generate their own scientific questions that can be answered through different methods. Therefore, a second type of analysis of questions was carried out using the acronym RODIN.Based on the RODIN scale, each science question was labelled as research (R), observation (O), demonstration (D), investigation (I) and none(N) depending on the method of inquiry each one leads to. Each letter in the term RODIN is in line with the National Curriculum definition of those terms. Research stands for finding information using secondary sources like books,photographs, online texts, audios, videos etc. Observations include observing real/ natural world phenomena and objects related to scientific ideas (Gott & Duggan, 1995). Demonstration stands for teacher demonstrations (experiment, objects of scientific importance like specimens, artefacts etc). Investigations include 'carrying out simple comparative and fair tests','acquiring a practical skill such as using a thermometer and discovering or illustrating a scientific concept, law or principle' (Gott & Duggan, 1995). Investigations could be joint investigations by the teacher and the pupils or pupils in small groups. If a question can be answered through research, observation and investigation, it would be labelled as an investigative question, i.e. it will be labelled based on the most superior method of enquiry, though it is the teacher's descretion to choose one of the three methods to use in the classroom. Teacher has the freedom to choose which method to employ considering factors like the class size,pupils' age,interest etc.RODIN analysis was done for the whole key stage two group i.e. both upper and lower key stage two combined as well separately (upper key stage two and lower key stage two). Please see Appendix 6b for the summary tables showing the details of the questions generated by each strategy, the question starters and their percentages and also, examples of factual and explanatory questions and RODIN questions generated from each startegy. Also see (in Appendix 6b), tables of data whose graphs summarises them in the text provided in Chapter 9, titled 'Results from Strategy Trials from Children'.

5.9 **Summary**

The chapter has explained the methodology chosen for the study and the justifications. It has explained the research design, methods, specific strategies and the justification for their use. In this way, Elements B and C (Figure 1.2) were addressed. The chapters six, seven, eight and nine presents the findings from the analysis of different sets of data collected as part of this study. The next chapter (Chapter six) presents the findings from the teachers' questionnaire survey.

6 Chapter 6: Results from Teachers' Questionnaire Survey

6.1 Introduction

This chapter presents the findings obtained from the questionnaire survey results from 29 experienced primary teachers, and relates to Research Question 1. What are primary teachers' (in-service) conceptions of creative thinking, problem-solving and problem finding in science?

6.2 Some Experienced Primary Teachers' Conceptions

Given below are the questions provided in the questionnaire and the responses obtained. The following tables 6.1 and 6.2 summarise the responses to the first two questions in the questionnaire. See Appendix 3c for the tables (extra tables) summarising the responses from the teachers' questionnaire survey.

- **Q1: Do you think science as a creative subject?**

Table 6.1 summarising the responses to question 10 in the questionnaire

	Yes	Sometimes	No
Do you think science as a creative subject?	23	6	0

- **Q2: Do you encourage scientific creative thinking in your classroom?**

Table 6.2 summarising the responses to question 11 in the questionnaire

	Yes	Don't Know
Do you encourage scientific creative thinking in your classroom?	28	1

Given below are the rest of the questions in the questionnaire.

- **Q3a: Give an example of a science lesson, which involves scientific creativity. (An example topic and a brief discussion.)**

Teachers were asked to give an example of a science lesson, which involves scientific creativity. This was to get an idea of what teachers perceive as a science lesson that encourages creative thinking. Four clusters of responses were generated, two of which had sub-clusters. Three main categories evolved that focussed on the children's creative thinking, which were the focus of this study. The last category, creative teaching or teacher's creativity focuses on teacher's ability to plan a lesson creatively, which is different from children's scientific creativity.

Category 1: Hands-on/ Do Task- In this category, a science lesson, which involves scientific creativity, was perceived as a lesson involving 'Hands-on/ Do' task. There were eight (28%) responses identified under this category. Children were perceived to be physically active. Two sub-categories were identified under this category.

Sub-categories:

1a: Model Making - Teachers perceived model making as an activity encouraging scientific creativity. For example, "children made a junk model of the human body, involving all the major organs involved in digestion". Three respondents out of the total twenty nine suggested this. Reproductive practical activities, where children recreated models using junk or other materials were seen as examples of scientific creativity which in reality aligns with creativity in arts.

1b: Practical Work - Under this sub-category, teachers perceived a science lesson involving hands-on practical activity as evidence of scientific creativity. For example, put in the words of a teacher *"During a topic on the Water Cycle the children had a range of activities to work through that tested their scientific knowledge".* Out of the total 29 respondents, five suggested this category.

Category 2: Think & Do task - In this category, a science lesson which involves scientific creativity was perceived as a lesson involving **Think & Do task**. Fourteen responses (48%) were identified under this category. Two sub-categories of responses were identified.

Sub-categories:2a: Practical Problem-solving - Five respondents came up with practical problem-solving and all from the same topic 'Materials and their Properties'. Thinking about the properties of the provided materials and ways of testing them to find a suitable material to solve the problem and practically testing them in the classroom were considered as an example of scientific creativity. Problems were given by teachers. For example, put in the words of a teacher "*Waterproof materials-Which material would be best to make a boat that would get the gingerbread man to the other side of the river safely?"*

2b: Constructing a method or a practical way - Two respondents saw constructing a practical method/ way to investigate a problem or to make a conclusion as an example of creativity in science. Example: *"Children were asked to find out how to get clean water from a puddle."*

2c: Applying ideas to construct something which works (which comes under Design and Technology) - Six respondent teachers suggested application of scientific ideas to create/ build something, which works as an evidence of creativity in science. Examples: *"Using electric circuits to create a board game."*

2d: Observation of nature and natural phenomena and hypothesising - This was suggested by a teacher as an example of a lesson involving scientific creativity. Example: *"Seasonal change-observation across the whole year - sun-dials, leaf fall, shadows, temperature, weather patterns* *etc, and then hypothesising how the world works to create such before considering what to observe to support theory."*

Category 3: Think (Mental Problem-solving) - Problem-solving or thinking of a solution to a given problem was suggested by a teacher (3%) as an evidence of creativity in science. For example, *"Materials- ask the children, which material would be the best to make a bucket."*

Category 4: Creative Teaching/ Teacher's Creativity - In this category, a creative science lesson which uses dramatisation or role playing to make children understand science concepts was perceived as an evidence of scientific creativity. Five teachers (17%) saw this as scientific creativity. For example, *"Lunar and Solar eclipse - To make the children understand the movement of the sun, earth and moon, we made three kids as the sun, moon and earth and explained how when they stand in a straight line the eclipse occurs."* Here the focus is on teacher's creativity and not children's creativity. Also, a lesson providing children opportunities for creative or imaginative writing (creativity in arts) was suggested by a respondent as an example of encouraging creativity in science.*"Cities in the country. Writing about an imaginative city."*

Q3b: Which was the creative part?

Teachers were asked to identify the creative part of the lesson. This was again an attempt to dig deep into teachers' conceptions of creativity in science and to extract their ideas by asking questions from different angles. Under this question, four main categories of responses evolved. The table given below shows these clusters, sub clusters and examples of responses. Out the four categories evolved, three are focussed on learner's creative thinking and one on teachers' creativity.

Category 1: Do/ Hands-on - Hands-on activities were considered as the creative part of the lesson by six teachers. Three teachers saw model making as the creative part of the lesson. Finding and collecting suitable material for the model and the use of junk material was seen as the creative part. Also, activities like preparation of pot and seeds for planting, children standing up and doing exercise were perceived as the creative incidents by some teachers. This shows that some teachers still hold a narrow artistic view of creativity in science.

Category 2: Think - Eight teachers saw the thinking part as the creative part of the lesson. Four sub-categories identified under this were: a) Thinking about properties of materials and the most suitable material (3); b) Planning and deciding how to investigate a problem (designing an investigation/ test/ observations of natural phenomenon) (4) and c) Children thinking of *"what will happen, if..."*questions and coming up with explanations (2). Three teachers responded, thinking about properties of materials and the most suitable material as the creative part of the lesson. Four respondents reported planning and deciding how to investigate a problem, may be an investigation, test or an observation as creative. Two respondents reported thinking about questions and coming up with their own explanations as the creative part. Out of the eight teachers who chose thinking, four opted planning how to investigate a problem as the creative part.

Category 3: Think & Do - Eight teachers thought opportunities for children to think and do practical work together forms the creative part of the lesson. Testing, thinking and finding out suitable material was considered as the creative part by three teachers. For e.g. put in the words of a teacher *"Testing materials to fix the leak in the boat. Thinking about how the objects in the sack could be used (linking to the materials and their properties)."* Applying scientific ideas, seeing a use and practically constructing it (application space) was considered as the creative part by five teachers. For e.g. put in by the words of a teacher, *"making, designing the spinner, linking the design to their science understanding".*

Category 4: Teacher's Creativity/ Creative Teaching - Seven teachers, out of the total twenty nine, saw science lesson involving opportunities for children to listen, recite, act and write or do role play (dramatisation), read related stories etc as a creative part. These are actually examples of teacher's creativity or a creative lesson planning. One respondent suggested the topic context as the creative part. The example lesson involving scientific creativity was suggested as *"Help Harry Potter with his potions- separating liquids and solids over a number of weeks - using sieves/ filter paper/ evaporation etc".*

- **Q 3c: What was creative about it?**

Four categories emerged for the responses received for the above question.

Category1: Hands-on/ Do Nine teachers from the total twenty nine respondents, responded suggesting hands-on/ do activities like using different materials or designs, testing different materials and finding the suitable one, collection and preparation activities as creative. One respondent under hands-on/ do category suggested skill development as creative, which doesn't match with creative thinking in science.

Category2: Think- Eight respondents saw thinking as creative. Children coming up with their own ideas (open ended), in groups, problem-solving and pursuing questions were suggested as creative. Children thinking how to prove which material is the best (designing a method) is an example suggested by another respondent. It belongs to the above group.

Category3: Think & Hands-on/ Do- Six teachers suggested thinking & hands-on, doing tasks as creative. Three sub-categories emerged are: testing, thinking and finding, applying ideas and practical construction, freedom to solve a problem or lead an investigation and generating creative solutions for practical issues while doing a practical task

Category4: Creative Lesson/ Creative Teaching- Five respondents saw lesson involving activities like listening, reciting, acting, writing, reading stories and role playing as creative. Some saw imaginative writing (writing about an imaginative city) and role play (children through movements representing states of matter) as incident of scientific creativity. There still exist a tendency to confuse between scientific creativity and artistic creativity.

Q 4a: Do you think encouraging creative thought in science is easy or hard?

Majority of the teachers (55%) reported it is easy to encourage creative thinking in science.

Q 4b: Why do you think this?

Encouraging creative thought is easy because.........

Category1: Inquisitive or curious nature of children - Three teachers suggested that children are naturally curious. So it is easy to encourage creative thinking in science. It was suggested by one of the teachers that starting a topic with children's wondering questions can make learning more meaningful and exciting. This finding agrees with the study conducted by Cremin, Burnard & Craft (2006), which identified posing questions as one of the seven core elements for fostering possibility thinking.

Category2: Hands-on/ Do - Six teachers saw doing hands-on practical activities makes it easier. According to these teachers opinion, children are engaged in active learning when doing hands-on activities and so make it easier. Here they view being physically active as active learning. Children being physically active do not necessarily mean they are engaged in mind (thinking). This suggests there is some confusion among teachers regarding active learning and engaged.

Category3: Think & Do - Two respondents said it is easy to promote creative thought because activities are often investigative practical activity involving problem-solving (Early Years).

Category4: Think- Five teachers suggested it is easy to encourage thinking in children as they are naturally curious. Two sub-categories of thinking emerged:

4a: Creative - Here children are seen as naturally creative or imaginative (E.g. *"Children are naturally creative.")* and

4b: Questioning/ Problem Finding - E.g. *"Children are keen to explore and be creative so providing problems in which they can ask questions and create can be fun."* Three teachers had the view that children are naturally curious and explorative. Therefore giving children opportunities to ask questions can encourage creative thinking.

Category5: Teacher's Ability to Encourage Pupils - One teacher responded that pupils will be interested in science if a teacher encourages pupils.

Category6: Topic & Resources - One teacher answered that encouraging creative thinking depends on the topic which students are learning and the resources available. See the two tables (see appendix 3c) summarising the responses to question 4a. Encouraging creative thinking in science is easy or hard. Why do you think so?

Encouraging creative thought in science is hard because........

Category 1: Topic Constraints - Two teachers suggested that not all topics can encourage creative thought in science. *E.g. "Not every topic in science involves experiments, data collection or practical activities."* This teacher seems to have a hands-on/ do view of creativity, i.e. lessons with practical activities where children are physically active are seen as promoting scientific creative thought.

Category 2: Subject Constraints - Two teachers suggested that only some subjects provide opportunities for creative thinking. Science may not be seen as offering much creative thinking opportunities. This may be due to teachers' confusion between artistic creativity and scientific creativity.

Category 3: Resource Constraints - Two teachers suggested this view. Lack of resources has been seen as a barrier for encouraging creative thinking in science.

Category 4: Pressure on teachers to meet targets - Four respondents suggested that the limited time and the pressure on teachers to meet targets are considered as a barrier to promote creative thinking in science. e.g. *"Because there is so much to learn and, sometimes only 35 minute a week for science." "It can be done but teachers are more controlled, have to make sure certain targets/ objectives are covered in 6/7 lessons."*

Category 5: Difficult for children to think independently - Three teachers said children found it hard to think on their own. This suggests the need for teacher guidance to direct children's thought.

Category 6: Difficult for children to ask questions - A teacher noted children's difficulty to ask questions on their own and the need for teacher prompting or scaffolding .e.g. *"Sometimes the children find it difficult to ask questions and look for answers - they sometimes need prompts."*

Category 7: Need for Teacher Prompting - A teacher noted children's difficulty to ask questions and the need for teacher scaffolding .e.g. *"Sometimes the children find it difficult to ask questions and look for answers- they sometimes need prompts."* The table below summarise these responses.

- **Q 5a: Do you see problem-solving as related to creativity? See Table 6.3 given below.**

Table 6.3 summarise the responses to question 5a

Q 5a	Yes	No
Do you see problem-solving as related to creativity?	27 (93%)	2 (7%)

- **Q 5b: If yes in what way?**

Yes, problem-solving is related to creativity...

Category 1: Think Creatively - Eighteen teachers out the total 29 (one gave very short ambiguous responses) suggested thinking creatively/ divergent thinking/ thinking outside the box ... is needed to solve problems. Creating an experiment, developing a test for an effect were examples of solutions of a problem appeared in the responses. Majority of respondents saw thinking as the connection between problem-solving and creativity. e.g. *"to be creative you have to sometimes think outside the box and this is what good problem solvers have to do."*

Category2: Hands-on/ Do - Five respondents came up with hands-on/ doing activities like investigations as the link between problem-solving and creativity. *e.g." When children investigate certain aspects they are solving problems."*

Category3: Think & Hands-on/ Do - One teacher came up with a response -*"Again due to the link between assessing basic skills via application."* This seems to be application of skills, looks to fit in 'think & hands -on' category.

Q6: Please give me an example of a problem which children might solve in science?

An example of a problem which children might solve in science is...

Category 1: Think - Ten teachers' responses appear to be thinking or thought provoking. They seemed to be in a question form, encouraging children to think and problem solve. The same responses if slightly modified could be presented as problems eliciting think & hands-on/ do (investigative tasks).e.g. *"Which materials would be best to build a boat?"*

Category2: Hands-on/ Do - Three teachers gave responses which belonged to Hands-on/ Do category. Those initiated some physical activity from children. e.g. *"Mr Mole needs to provide some light in his house for when badger visits him."How can you make the light adjustable so that it doesn't hurt their eyes?"*

Category 3: Think & Do - Eight teachers suggested problems belonging to this category. They encouraged children to think and do some practical problem-solving activities. e.g. *"during a materials topic, the children were given a scenario in which a number of items had been mixed up. they then had to find out a way of separating the materials using a range of apparatus."*

Category 4: Finding Answers to Questions - Five teachers gave responses similar to questions seeking factual information. e.g. *"How can we eat a healthy, balanced diet?"* This is in the form a question. Some problems were ambiguous and therefore not categorised.

The table (6.4) below summarise the responses to question 6. Give an example of a problem which children might solve in science.

- **Q7: Do you encourage problem-solving in science?**

Table 6.4 summarise the responses to question 7a

Q 7a	Yes	No
Do you encourage problem-solving in science?	28 (97%)	1 (3%)

- **Q 7b: If yes, in what way?**

Encourage problem-solving through...

Category 1: Teacher provides problems - Teacher provides problems in the form of investigations (experiments/ tests), projects and discussions. Twelve respondents suggested this category. Here it was said that teacher provides problem to the children to investigate. One respondent suggested asking children to lead the enquiry themselves asking their own questions. Another respondent said that he/she will give a problem but not the equipment or any help. Children need to decide how they are going to solve it and choose the right equipment. e.g.*" I try to make the science concept relevant to real life and present problems for the children to solve when possible. I used to try to present them with a problem or a challenge. "*

Category 2: By posing questions

Sub-categories: 2a. Teacher posing questions - Five teachers responded that they pose questions in the classroom for children to solve. e.g. *"by posing questions and giving children the resources but not the solution."* One teacher teaching in the Reception year group said problem-solving happens during the taught sessions linked to a topic/ story and children also get a chance to ask questions during the challenge time, when resources were provided. Another teacher reported having a 'wonder wall' in the classroom where students wrote down their wonderings and used their free time to find answers. e.g.*" I encourage my students to seek ways to answer their own questions and not rely on the teacher for everything. We have a "wonder wall" where students write down their "wonderings" and we use our free time to research and find answers."*

Category 3: Think - (Encouraging pupils to think)- Two teachers reported that children are encouraged to think about how to test hypothesis and challenge their prior knowledge,

Category 4: Hands-on/ Do tasks - One teacher encouraged problem-solving by encouraging pupils to work independently on hands-on tasks.

Category 5: Guiding Teachers - One head teacher tried to encourage problem-solving by giving guidance to teachers regarding their contextual science topic.

- **Q 8. Who is finding the problem to solve?.**

Table 6.5 summarise the responses to question 8

	Pupil	Teacher
Who is finding the problem?	15 (54%)	13 (46%)

- **Q 9. Do children find their own problems to solve in science?**

Table 6.6 summarise the responses to question 9

	Yes	No
Do children find their own problems to solve in science?	20 (69%)	9 (31%)

- **Q10a. Do you encourage problem finding in science lesson?**

Table 6.7 summarise the responses to question 10a

	Yes	No
Do you encourage problem finding in science lesson?	23	6

- **Q10b.** If yes, please give an example of a problem, which children might find in science?

Four teachers suggested category 1 (Think) problems. Four teachers came up with problems encouraging thinking and hands -on/ doing tasks. One teacher came up with think and observation task. Two teachers gave examples of problems regarding the procedure (fair testing). They are more procedural and not science topic oriented. Example, given in the table below. Two teachers came up with the idea that they gave problems to students but students themselves had to choose the equipment needed to solve them. So selecting the right equipment was the problem part exactly. Two teachers suggested when their pupils faced some real life problems (not science), they approached teachers and they helped them to solve them. This is considered as a misinterpretation of the idea of problem finding. Some responses obtained were ambiguous. The table (6.8) summarise these responses.

Table 6.8 summarise the responses to question 10b

• **Do you encourage problem finding in science lesson? If yes, give me an example of a problem which children might find in science**	
Categories & Sub-categories	**Characteristic Responses**
1. Think	• "Why are some objects magnetic?"
2. Think & Hands-on/ Do	• "how can I make a spinner/aeroplane spin or fly the longest"
3. Think & Observe	• "why can you only see the stars at night?"
4.Procedural, not from a Science topic	• "How to ensure an investigation is fair." • "Why do the results not match our predictions?"
5. Choosing the right equipment	• "Best equipment to use when using a balloon rocket"

- **Q 10b: If no, why do you think this is so?**

Reasons for not encouraging problem finding in the lessons: Three teachers suggested that time is a factor. They are under pressure to finish certain areas of the curriculum and attain targets in a very limited time and so there is no time to teach for creativity. One teacher pointed out that as there is no assessment for this area in the present system he /she feels it is important to teach children about those topics that are assessed than looking up areas that aren't assessed. Obviously, teachers have to be choosy about the topics they have to cover within the limited time, than teach for creative thinking. Two teachers reported large class size

(31 pupils) as a constraint and pointed that it would be hard for the teacher to monitor and resource all the 31 problems effectively. One respondent noted that some lessons are hard for the children to find problems. In other words, it is contextual, which is another limitation. One teacher said that she hasn't come across with the idea of problem finding before and she will try to do it from now on.

Q 11a: Do you see problem finding as being related to creativity?
Table 6.9 summarise the responses to question 11a

	Yes	No
Do you see problem finding as being related to creativity?	26 (90%)	3 (10%)

Q11b: If yes, in what way?

Reasons for seeing problem finding as related to creativity: Out of the total 29 respondents, 26 said yes, saying problem finding is being related to creativity. Out of the 26 teachers, 15 commented on the relation between problem finding and creativity, while 7 just mentioned about problem-solving and creativity. One respondent noted that learning would be dull without problems. Put in the teacher's own words, *"Without problems, learning would be a dull and boring task."*The main category generated was 'Think'. Under thinking, several sub-categories of responses evolved.

Category1: Think

Sub-categories:1a: Thinking for both creativity and problem finding (3)-Three respondents said one has think for both problem finding and creativity.

1b: Thinking creatively for problem finding (5)-Five respondents suggested for problem finding, one has to use creativity or think creatively.

1c: Thinking from diff angles (4)-Four respondents noted that one has to think from different angles for finding problems (i.e. creative or divergent thinking).

1d: Thinking outside the box (3)-Three respondents said one has to think outside the box for finding problems (i.e. using creativity).

1e: Children engaged & interested (4)-Four respondents noted that children are engaged or actively involved when finding problems and also interested.

All these responses suggests while finding problems children think creatively and are mentally active and interested. They have to really 'think' to find problems, which is a challenging task. One respondent didn't say anything about problem finding and creativity but stated that learning would be dull without problems. Another respondent mentioned problem-solving needs creativity but said nothing about problem finding and creativity and so, not included in the table.

Q11c If no, why do you think so?

Three teachers out of the total 29 said they don't see any relationship between problem finding and creativity. One didn't give any reason for that. One noted that problem-solving is a logical process, while creativity is more artistic. This respondent may have a narrow artist view of creativity, which agrees with the findings of Newton (Newton, 2012). One teacher had the opinion that one has to think creatively to solve problems but he/ she couldn't see any connection between problem finding and creative thinking.

Q 12a: Do you think encouraging problem finding in science, is easy or hard? (b)Why do you think this?

Table 6.10 summarise the responses to question 12a

	Easy	Hard
Problem Finding is easy or hard?	9(31%)	20(69%)

Out of the 29 respondents, nine said problem finding was easy. Six categories of responses evolved from the data. They are given in the table below. One respondent suggested that problem finding is easy through open-ended activities. Another respondent stated that as science encourages active and independent learning, problem finding is easy. Another response was *"Most of the problems occur related to their life experiences."*This states that most of the problems in science are related to every day life and this makes problem finding in science easier for children. This agrees with the literature on problem finding, i.e. problems from real life. Two respondents reported that the availability of resources in science makes problem finding easier. This is very true with regard to the real life problems and accessing resources from our day to day life. Three respondents suggested that problem finding in science is easy because it is easy to encourage children to do further research, investigate, experiment etc.

Twenty respondents responded that it is hard to encourage problem finding. The reasons have been grouped into eight categories. They are given in the table above. One respondent said it is hard to set the stage for children to problem find. Seven respondents came up with different factors related to the child, which makes problem finding a hard task. They are ability to think independently, perseverance, observation skill, prior knowledge and understanding to notice a problem, reasoning and logical thinking. Some noted that some children may not have the knowledge and understanding to find a problem. As questioning is a challenging task, some children may give up easily. All the seven respondents agreed that questioning is a challenging task for children. Five teachers said time is a constraint for problem finding. Teachers are under pressure to cover the curriculum and attain targets within a limited time and it's hard for them to find time for problem finding. Also, the bigger class size adds to this problem. Two teachers said finding the resources for problem finding can be difficult. Having the equipments and facilities can be a problem according to them. (Tendency for some teachers to see science is all about working with lab equipments. In reality, at primary school level several other easily available resources from everyday life can be used to encourage children to problem find.) One teacher responded that large class size with no support makes it hard for teachers to find time and space for creative thinking. One respondent noted that some, more advanced children, may be able to find problems but others might need guidance and help from the teacher. This agrees with the idea of teacher scaffolding. Two teachers said problem finding is hard because it is contextual or dependent on the topic.

Q 13: Is there anything you want to add about problem finding in science?

Four teachers responded to the above question. Two teachers noted that to encourage children to find problems in reality, is a time consuming process. One added that, in reality teachers have no time to do this. Another teacher pointed that there is a lack of funding in primary schools nowadays. One teacher suggested that children can be made more self reliant when they learn to identify and solve problems.

- **Q 14a: Here is a list of aspects of science. Which 3 of them do you see as offering the best opportunities for problem finding? (b)What makes them the best?**

Teachers were asked to choose three topics from the national curriculum (DfE, 2013), which they think offers most opportunities for problem finding. The three topics which got the maximum ranking were Properties and Changes of Materials, Electricity and Plants. The presence of these topics in everyday life, availability of resources, more opportunities for hands-on investigations (practical work), visual cues (experience), opportunities for problem-solving, opportunities for open-ended investigations and presence of more quality questions and real life problems were suggested as the main reasons for their selection. The following two tables (6.10 and 6.11) summarise the responses to question 14a and 14b. The figure 6.1 summarise the responses obtained for question 14b.

Table 6.10 Topics and Reasons for Most Opportunities for Problem Finding

Ranking	**National Curriculum Areas**	**Science 2 Physics**	**Science 3 Chemistry**	**Science 4 Biology**	**Number of Opportunities**
1	Properties and Changes of Materials		X		14
2	Electricity	X			11
3	Plants			x	9
4	Magnetism	X			8
4	Forces	X			8
5	Sound	X			7
5	States of Matter		X		7
6	Light	X			5
6	Living Things and Their Habitats			x	5
6	Ourselves and Other Animals			x	5
7	Earth and Space				2
8	Evolution and Inheritance			x	1

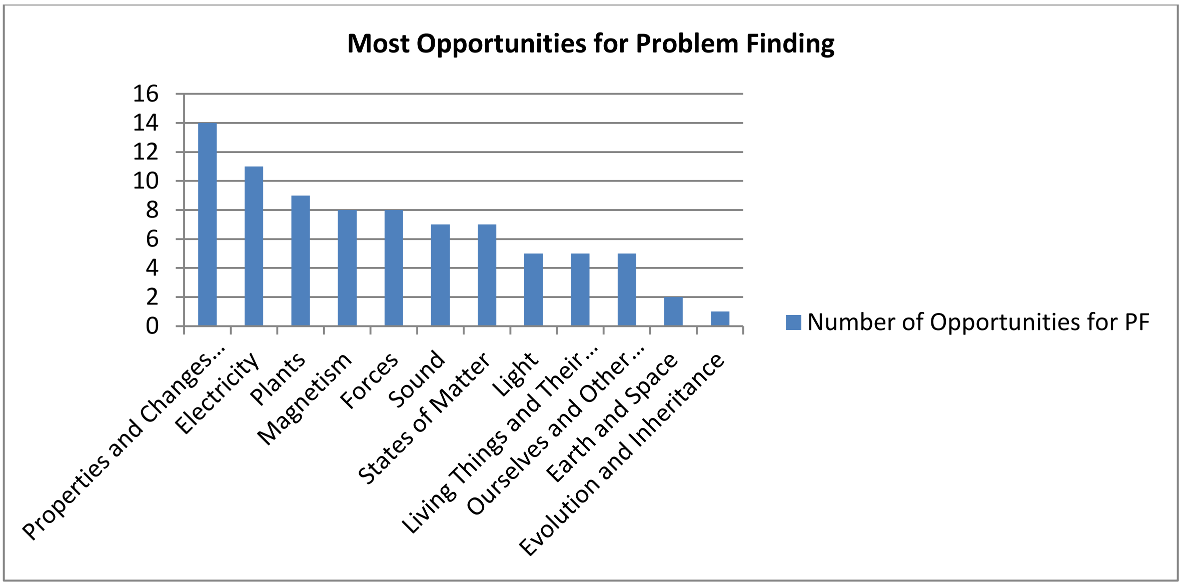


Figure 6.1 National Curriculum Areas and Most Opportunities for Problem Finding

- **Q 14b: What makes the selected items the best?**

  The table below summarises the responses to question 14b.

Table 6.11 Topics and Reasons for Most Opportunities for Problem Finding

Ranking	National Curriculum Areas	Reasons Suggested
1	Properties and Changes of Materials	Availability of resources Hands-on investigations Opportunities for open-ended exploration More good questions Appear in every day real life Opportunities for problem-solving Creative opportunities Problems from real life
2	Electricity	Availability of resources Hands-on investigations Opportunities for open-ended exploration Opportunities for problem-solving Visual questions More good questions Problems from real life Curriculum accessibility
3	Plants	More good questions Creative opportunities Visual questions Availability of resources Prior knowledge Appear in every day real life Curriculum accessibility

		Hands-on investigations

- **Q 15a: Here is a list of aspects of science. Which 3 of them do you see as offering the fewest opportunities for problem finding?**

When asked to name three topics that offered the least problem finding opportunities, teachers came up with Evolution, Earth and Space and Rocks. Lack of connection to everyday life, lack of resources, lack of opportunities for hands-on experiments or investigations, more abstract and difficult concepts, lack of opportunities to encourage children's interests and lack of visual cues or experience made them hard for problem finding. The following two tables (6.12 and 6.13) summarise the responses to question 15a and 15b. The figure 6.2 summarises the responses obtained for question 15b.

Table 6.12 National curriculum areas with fewest opportunities for problem finding

Ranking	**National Curriculum Areas**	**Science 2 Physics**	**Science 3 Chemistry**	**Science 4 Biology**	**Number of Opportunities**
1	Evolution			x	17
2	Earth and Space		X		16
3	Rocks		X		13
4	Ourselves and Other Animals			x	10
5	Living Things and Habitats			x	9
6	Plants			x	6
7	Sound	x			5
8	States of Matter		X		3
9	Force	x			2
10	Electricity	x			1

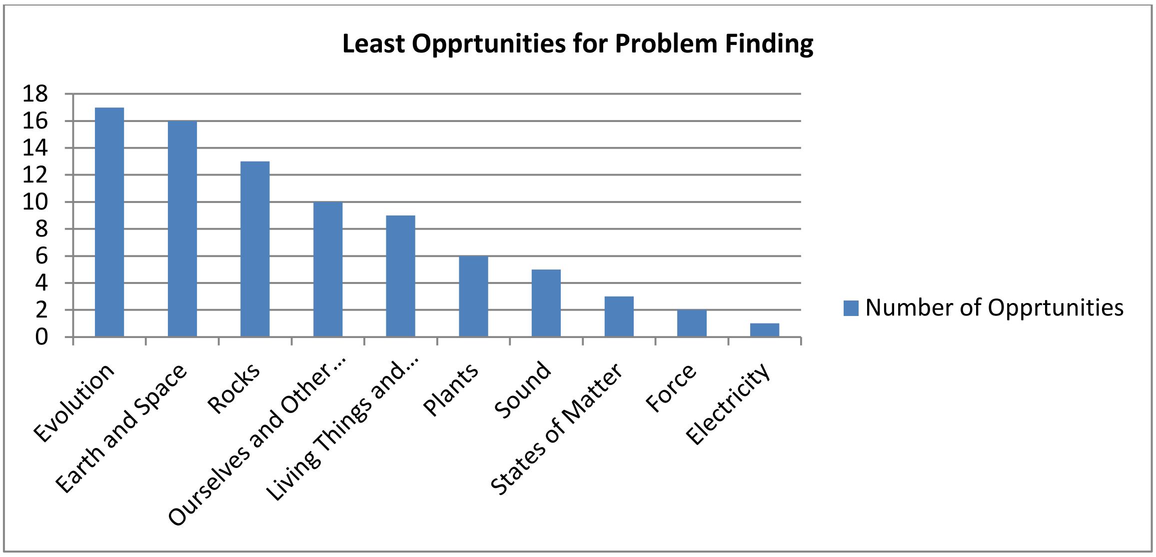


Figure 6.2 National curriculum areas with fewest opportunities for problem finding

- **Q 15b: What makes the selected items the worst?**

  The table below summarise the responses to question 15b.

Table 6.13 National Curriculum Areas and suggested reasons for fewer opportunities for problem finding

Ranking	National Curriculum Areas	Reasons Suggested for fewer opportunities for Problem Finding
1	Evolution	Fewer links to curriculum Less practical More theory based Not common in everyday life Less opportunities for problem finding Not visual Abstract Least interesting Lack of resources
2	Earth and Space	More theory based Less practical Less opportunities for problem finding Less opportunities for hands-on experiments More abstract Hard concepts to find problems Lack of resources
3	Rocks	Fewer links to curriculum Less practical Hard concepts to find problems Less opportunities for problem finding Least interesting Lack of resources Abstract

6.3 **Summary**

The findings revealed that these teachers who participated in the survey tended to be of the 7 types. First category of teachers saw science lessons involving practical tasks where children have to think and problem solve, as stimulating scientific creative thinking. Other two groups of teachers saw practical investigative problem solving (generating a conclusion) and application of scientific ideas to create a working model as evidence of scientific creativity. Observing natural phenomenon and hypothesising how the world works, and thinking of solutions to problems without practical task were also suggested as examples of scientific creative thinking.. Science lessons involving reproductive making tasks (e.g. making models using junk) and creative teaching using drama or role play, reciting, writing etc as incidents of scientific creativity. See figure 6.3 below illustrating categories of science lessons involving creativity emerged from teachers' questionnaire survey responses.

Though half of the teachers viewed encouraging scientific creativity as an easy task, the rest of them suggested it was hard due to several constraints. Most teachers encourage problem-solving by providing ready-made problems to solve. Though, some teachers said they encourage children's scientific questioning/ problem finding, most of them felt it was a difficult task due to constraints like lack of time, pressure to meet teaching targets and large class size. Topics like Properties and Changes of Materials, Electricity and Plants were seen as offering most opportunities for problem finding. Topics like Evolution, Earth and Space and Rocks were suggested as offering fewest opportunities for problem finding.

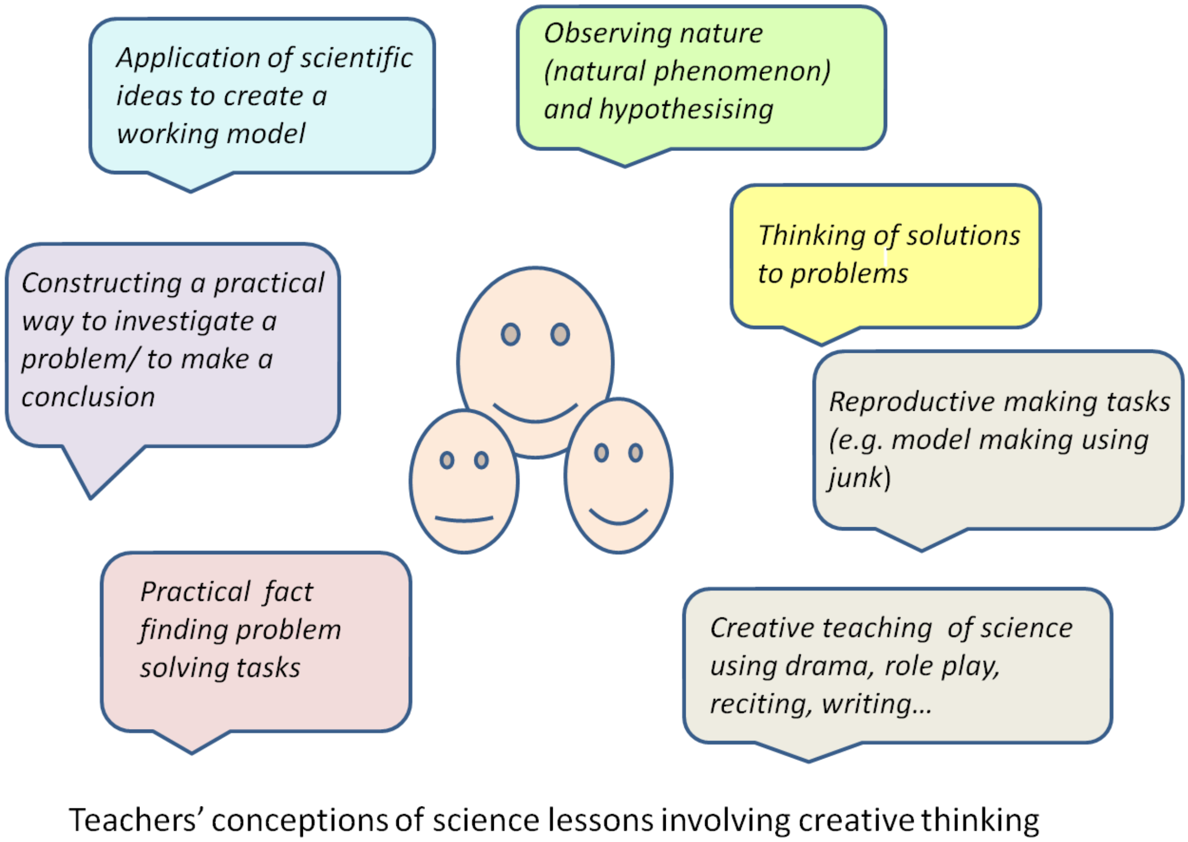


Figure 6.3 Categories of science lessons involving creative thinking emerged from the teachers' questionnaire survey responses

7 Chapter 7: Results from Student Teachers' Questionnaire Survey

7.1 Introduction

This chapter presents the findings related to the second component student teachers' conceptions, which includes the questionnaire survey results from 58 student teachers and relates to **Research Question 2.** What are student teachers' conceptions of creative thinking, problem-solving and problem finding in science?

7.2 Some Student Teachers' Conceptions

Given below are the questions provided in the questionnaire and the responses obtained. The following two tables 7.1 and 7.2 summarise the responses to questions 1 and 2 in the questionnaire.

- **Q1: Do you think science as a creative subject?**

Table 7.1 summarising the responses to question 10 in the questionnaire

	Yes	Sometimes	No
Do you think science as a creative subject?	35	23	0

- **Q2: Do you encourage scientific creative thinking in your classroom?**

Table 7.2 summarising the responses to question 11 in the questionnaire

	Yes	I will	Don't know	No
Do you encourage scientific creative thinking in your classroom?	31	2	13	1

- **Q3a: Give me an example of a science lesson which involves scientific creativity. (Topic and a brief discussion.)**

Student teachers were asked to give an example of a science lesson which involves scientific creativity. This was to get an idea of what they perceive as a science lesson which encourages creative thinking. Four clusters of responses were generated, two of which had sub-clusters. From the analysis of student teachers' survey responses three main categories evolved that focussed on the children's scientific creative thinking. The last category, creative teaching or teacher's creativity focuses on teacher's ability to plan a lesson creatively, which is actually creativity in arts and not scientific creativity.

Category 1: Hands-on/ Do Task- In this category, a science lesson which involves scientific creativity was perceived as a lesson involving 'Hands-on/ Do' task. There were eight responses identified under this category. Children were perceived to be physically active. Three sub-categories were identified under this category.

Sub-categories: 1a*.* Reproductive Practical Activity Student teachers perceived model making (junk modelling, working model) as an activity encouraging scientific creativity. Six respondents suggested this. Reproductive practical activities, where children recreated models using junk or other materials were seen as examples of scientific creativity which in reality aligns with creativity in arts.

1b. Practical Activity (Experiment) - Teachers perceived a science lesson involving hands-on practical activities like demonstration of an experiment, as an evidence of scientific creativity. One respondent supported this view.

1C. Observation & Data Representation- One respondent suggested this as an example of creativity in science. Put in the words of the respondent it is *"Teaching 'Life Cycles', one lesson idea would be to bring in various types of fruits, fleshy and non-fleshy, and encourage the children to make observations about the fruit inside and looking at the seeds specifically. They must collate their data using a table provided."*

Category 2: 'Think & Hands-on/ Do' task - In this category, a science lesson, which involves scientific creativity, was perceived as a lesson involving 'Think & Do' task. Nine responses were identified under this category. Three sub-categories of responses were identified.

Sub-categories: 2a. Practical Problem-solving Five respondents came up with practical problem-solving and all from the same topic 'Materials and their Properties'. Problems were given by teachers. For example, put in the words of a teacher *"Investigating a range of materials to identify which ones float".*

2b. Conducting experiments Three respondents saw conducting experiments as an example of creativity in science. For example, in a student teacher's own words *"Have the children conduct experiments to either confirm or disprove their ideas about the world."*

2c. Applying ideas in real life One student teacher suggested application of science ideas in real life as an evidence of creativity in science. In his / her words *"Flowers (parts, seeds, pollination, germination etc) - It helps students to have a beautiful garden in their home."*

Category 3: Think (Mental Problem-solving) - Five respondents supported thinking. Three sub-categories of responses evolved under this namely: mental problem-solving (For example Description: *"Mars mission - what would you bring and why?"* demonstration of experiments to elicit thinking (For e.g. *"Surface Tension-Floating of blade on the water surface, sinks when soap* *solution is added to it."*) and asking thought provoking questions (for e.g. *"Cell Clusters - Creative teaching beginning with asking some provoking questions"*).

Category 4: Creative teaching - Three respondents considered teacher's creative thinking/ creative teaching as scientific creativity. Actually, our focus is creative learning or learner's creativity and not teacher's creativity. In the words of a respondent, it says *"Using a story book such as hungry caterpillar to introduce life cycles and asking children to write our life cycle."*

Q3a: Which was the creative part?

Student teachers were asked to identify the creative part of the lesson. This was again an attempt to dig deep into teachers' conceptions of creativity in science and to extract their ideas by asking questions from different angles. Under this question, four main categories of responses evolved. The table given below shows the four clusters. Out of the four clusters, three of them have sub-clusters. Below is the table that identifies these and gives examples. Out of the four categories that evolved, three are focussed on learner's creative thinking and one on teachers' creativity. All are discussed below.

Category 1: Do/ Hands-on - Hands-on activities were considered as the creative part of the lesson by seven teachers. Out of the seven teachers, six of them saw model making as the creative part of the lesson. For example, *"preparation of model of digestive system"*. One respondent considered observation and data representation as the creative part, example *"to make observations about the fruit inside and looking at the seeds specifically".* Finding suitable material for the model, using junk material etc were seen as the creative part. This shows that some student teachers do hold a narrow artistic view of creativity in science.

Category 2: Think Five teachers saw the thinking part as the creative part of the lesson. Two teachers responded by saying *"thinking about properties of materials and the most suitable material"* as the creative part of the lesson. Two respondents reported *"demonstration of experiments encouraging children to think"* as the creative part. One respondent reported *"thinking about problems from every day life"* as the creative part.

Category 3: Think & Do- Three respondents thought opportunities for children to think and do practical work together forms the creative part of the lesson. *"Testing, thinking and finding out suitable material"* was considered as the creative part by one. Applying scientific ideas in real life was considered as the creative part by two teachers; for example, *"To create a beautiful garden by knowing the nature of each plant including their flowering seasons."*

Category 4: Teacher's Creativity/ Creative Teaching - Two respondents saw teacher's creativity in planning the lesson as a creative part.

3c: What was creative about it?

In order to tease out their thinking, the student teachers were asked what was creative about the lesson. From the phenomenographic analysis, four clusters were generated, two of which had sub-clusters. Below table identifies these and gives examples of each. Four categories emerged for the responses received for the question 'What was creative about it?'

Category1: Hands-on/ Do Nine respondents, responded suggesting hands-on/ do activities like using different materials, testing different materials and finding the suitable one, experiment demonstrations, preparatory activities etc as creative.

Category2: Think Six respondents saw thinking as creative. **Three sub- categories** evolved under thinking and examples of responses belonging to those categories were given below: think to come up with own ideas *("Designing outfits for them.")* decision making about materials to be used *("Children need to think of what will be effective (insulation).")* and understanding *("Students could easily understand the concept of surface tension through the experiment.")*

Category3: Think & Do Two student teachers suggested thinking & hands-on, doing tasks as creative. In his or her own words, *"The children are questioning the properties of materials and designing ideal clothing."*

Category4: Creative Lesson/ Creative Teaching - Two respondents saw lesson involving teacher's creativity as scientifically creative. For example, *"Science lessons can be made creative through the introduction of everyday objects, like fruits - different types."* In the words of a respondent *"By showing the diagrams of the concerned topic, students will remember its shape, colour etc than by simply lecturing."* This showed that there still exist a tendency among teachers to get confused between scientific creativity and artistic creativity.

Q4a: Do you think encouraging creative thought in science is easy or hard?

Student teachers were asked if encouraging creative thinking is easy or hard and why they think so. Around 70% of the respondents said it was hard to encourage creative thinking in science. See table 7.3 below.

Table 7.3 summarising the responses to question 4a

	Easy	Hard	Both
Do you think encouraging creative thought in science is easy or hard?	10	26	2

- **Q4b: Why do you think this?**

From the analysis, three main categories of responses evolved from the ten responses under the idea encouraging creative thinking is **easy**. They are discussed below.

Category 1: Curiosity Four respondents responded this way. For example put in the words of a student teacher, *"Children will be curious."*

Category 2: Think Two student teachers had expressed this view. For example in one teacher's own words, *"By allowing students to think more about the theories and principles in connection with the practical life situations."*

Category 3: Think & Do One respondent suggested that encouraging creative thinking was easy with think & doing activities in science. Put it in the teacher's own words, *"Science exploration and investigation can lend itself to creativity".*

For those teachers who in response to the question no. 13, and 13a said it was hard to encourage creative thought and gave the reasons, their responses fell into ten categories, described below. Twenty six respondents said it was **hard**.

Category 1: Topic Restraints Out of the 26 respondents who said it was hard to encourage creative thought, two gave topic restraints as the reason. Put it in one's own words, *"Depends on content, plan and most importantly the children."* Also, *"I think it is difficult to convey tricky concepts in a creative way without missing out important bits of information."*

Category 2: Factual Nature Four respondents expressed the factual nature of science makes it hard to encourage creativity. Example, *"Because it's such a set subject, hard facts etc."*

Category 3: Curriculum and target constraints Two student teachers expressed curriculum and target pressures force teachers to teach for attaining targets than to spend time for encouraging creative thought. Put in the student teacher’s own words, *"Teachers are very focussed on ticking off knowledge in the national curriculum. Sometimes it can be easier * to tell children facts and give instructions for an experiment rather than letting them design an experiment themselves (*in terms of organisation, logistics, classroom management etc)."*

Category 4: Independent thinking Four respondents suggested engaging children in independent thinking for creativity as a great challenge for teachers. For example, *"Engaging pupils in all science topics, requires pupils to engage in a deeper level of thinking so must be engaged."*

Category 5: Lesson Planning and Implementation Difficulty to plan lessons for creative thinking was seen as a reason by four student teachers. *(e.g."It is difficult to plan into lessons.")*

Category 6: Teacher's Subject Knowledge One respondent responded that teacher's lack of adequate subject knowledge may make it hard to encourage creative thinking in science. Put it in the teacher's own words *"It may be difficulty to think both creatively and scientifically if knowledge on topic is not strong."*

Category 7: Pupils' varied interests Five respondents suggested each pupil's interest would be varied and may not be interested, which makes encouraging creative thinking, hard. For example *"Each individual is unique. Every student may not be interested towards, this method."*

Category 8: Lack of books One respondent suggested that lack of books in some areas of science as a reason. In own words of the respondent, *"Children require a book to gain their enthusiasm for a topic, however this can be difficult to find for some subject areas without losing sight of the goals."*

Category 9: Big C view One student teacher had reported that creative thinking may not come from every one and few individuals may be creative and others may not, as another reason making it harder. In teacher's own words, *"Creative thinking may not come from every one and every time. Few peoples may have excellence in it, others may not."*

- **Q5a: Do you see problem-solving as related to creativity?**

Student teachers were asked if they see problem-solving as related to creativity. Forty four responses were received and all of them were positive. The table 7.4 below summarises the responses to question 5a.

Table 7.4 summarising the responses to question 5a

	Yes	No
Do you see problem-solving as related to creativity?	44 (100%)	0

- **Q5b: If yes, in what way?**

For those twenty seven teachers who responded yes for the above question, their responses fell into four categories. Out of the four categories, one of them i.e. category one has sub-clusters.

Category 1: Think - Thirty two responses belonged to this category. Twenty nine out of the 32 were under the sub cluster 1a. Thinking creatively to solve problems, thus shows one has to think creatively to solve problems (CT for PS). In their own words, for example, *"You can come up with creative ways to solve a problem."* One student teacher's response belonged to the sub-category 2a. Think creatively to design experiments to solve problems. Put in his/ her own words, *"Designing novel experiments to find the answers."* Two respondents suggested that solving problems would be a good way to encourage understanding in children. They belong to the third sub-category 3a. Generate understanding. For example, *"A concept in science the children will have lots of questions on. A good way to guide understanding would be to solve a problem in lesson."*

Category 2: Think & Do - Ten student teachers came up with responses belonging to think and do category supporting the relationship between problem-solving and creative thinking. For example, one respondent suggested, *"Can creatively test to prove/ disprove conceptions to solve a problem."* Another respondent came up with, *"Finding answers through experiment and investigation."*

Category 3: Do/ Hands-on - One student teacher's response fell into this category. Put in own words of the teacher, *"Practical activities can be creative."*

Category 4: Teacher as motivator - One respondent's response, *"Teacher should motivate to develop the creativity among them in the particular subject,"* threw light on the role of teacher in motivating pupils for problem-solving in science.

- **Q6: Please give me an example of a problem which children might solve in science?**

Student teachers were asked to given an example of a problem, which children might solve in science. Their responses were grouped into three clusters as in the table 7.5 given below. Analysis of the responses generated problems children might solve under three main categories.

Category 1: Think - (question form) Put it in words of a respondent, *"How to keep the snowman cold?"* a problem that promotes thinking. Eight respondents suggested problems grouped under this category.

Category 2: Hands-on/ Do - One respondent suggested a problem, which promotes doing. In the words of the respondent, *"Wrapping a snowman in a coat will keep it from freezing. This is hard to know, not the class could do in but using an ice cube rather than a snow man."*

Category 3: Think & Do - Six student teachers' responses were grouped under this category. For example, *"Present children with a withering plant. Challenge them to think about why the plant might be withering and to prove this."*

Table 7.5 summarising the responses to question 6

An example of a problem which children might solve in science	
Categories & Sub-categories	**Characteristic Responses**
1. Think (Question form) (8)	• How to keep the snowman cold? • Snowmen- do they melt faster if dressed in warm clothes? • Gravity and if objects fall at the same speed and if not, why? • Constructing a biological pyramid of a pond eco-system: students will think about the pond and the factors in it. Also about producers, consumers & decomposers by realising their size and specialities.
2.Hands-on/ Do (1)	• Wrapping a snowman in a coat will keep it from freezing. This is hard to know, not the class could do in but using an ice cube rather than a snow man.
3.Think & Hands-on/ Do (6)	• Do objects that are heavier land/ fall at the same pace as lighter objects? Dropping same sized objects that have diff weights drop from a controlled height. • Does putting a coat/ scarf on a snowman keep the heat in and melt the snow? Keep the heat out & keep the snowman cold? Make no difference? • Present children with a withering plant. Challenge them to think about why the plant might be withering and to prove this.

Q7a: Do you encourage problem-solving in science?

Student teachers were asked if they encourage problem-solving in science, 97% of them gave positive response. The table 7.6 below summarises the responses to question 7a.

Table 7.6 summarising the responses to question 7a

	Yes	No
Do you encourage problem-solving in science?	37 (97%)	1 (3%)

Q7b: If yes, in what way?

Those teachers, who answered yes to the question, if they encourage problem-solving, were asked to specify in what way. Their responses were analysed and categorised as in the given table. Phenomenographic analysis of the above responses grouped them into following four categories given below.

Category 1: Providing problems - Providing problems in the form of investigations. Two respondents suggested this. For example, *"Planning their own investigations."*

Category 2: By posing questions/ problems - Ten student teachers suggested this. Put in the words of the respondent, *"Through questioning and problem based learning."* In the words of another respondent, *"Posing a problem/ question and encouraging the children to develop a method for experimentation."* Another respondent suggested, *"Give them various questions related to the problem and ask them to collect information related to the topic."* From the three responses, different ways of encouraging problem-solving was understood.

Category 3: Supporting solution generation - Five respondents suggested they support children to come up with solutions. For example, *"Using their prior knowledge and trying to apply it."* Another teacher's response was *"When I teach various concepts in the classroom, I try to relate the daily life examples of the particular concept. By analysing that, pupils could try to find various solutions from day to day observing of problems."* Another response was, *"Understanding of the lesson helps students to solve related problems."*

Category 4: Identifying best possible solution - Two respondents reported they support problem-solving by supporting pupils to identify the best possible solution. Put in own words of the teacher, *"Identifying the best solution."*

Q8: Who is finding the problem to solve?

When the student teachers were asked to write who was finding the problem, around 20% answered it was the teacher while around 30% said pupils were finding the problems to solve. Nearly 50% of the respondents said both teachers and pupils find the problems to solve. The table 7.7 below summarises the responses to question 8.

Table 7.7 summarising the responses to question 8

	Pupil	Teacher	Both
Who is finding the problem?	11(33%)	7 (21%)	15 (46%)

Q9: Do children find their own problems to solve in science?

When student teachers were asked if children find problems to solve, majority of them (86%) answered yes. The table 7.8 below summarises the responses to question 9.

Table 7.8 summarising the responses to question 9

	Yes	No
Do children find their own problems to solve in science?	32 (86%)	5 (14%)

Q10a: Do you encourage problem finding in science lesson?

When asked if they encourage problem finding in science 97% of them answered they will try to do it in the future. The table 7.9 below summarises the responses to question 10.

Table 7.9 summarising the responses to question 10

	Yes	No
Do you encourage problem finding in science lesson?	32 (97%)	1(3%)

Q10b: If yes, please give me an example of a problem which children might find in science?

For those teachers who in response to question 10a, said yes, were asked to give an example of a problem, children might find in science. Their responses were analysed and categorised as in the given table. Most of them seemed similar to the teacher or textbook given problems.

Analysis of the above responses generated two clusters.

Category 1: Think - Four responses were included under this category. For example, *"Why does a coat keep a snowman warm?", "Students may ask the question how the nutrients become a part of our body."*

Category 2: Think & Do - Five respondents suggested problems under this category. Put in the words of one of the respondents, *"Children might be surprised to discover that a tennis ball and bowling ball fall at the same speed."* Another example, *"Children might ask why a balloon doesn't float."*

- **10b: If no, why do you think this is so?**

Those teachers who in response to question 10b, said No, were asked to answer why they think so. Only one respondent answered no, but didn't give any reason.

Q11a: Do you see problem finding as being related to creativity?

Table 7.10 summarising the responses to question 11a

	Yes	No
Do you see problem finding as being related to creativity?	33 (85%)	6 (15%)

Those teachers who responded to question 19 were asked to describe in what way they see problem finding as related to creativity. Their responses were analysed and categorised as given in the table below.

- **Q11b: If yes, in what way?**

Categories of responses obtained for respondents who answered yes for question no. 19.

Category 1: Think - Twenty five responses were grouped under this category. Eight sub-clusters were identified under the think category. They are given below with an example of response obtained for each sub-category.

1a. Thinking creatively for problem finding - Nine responses were included under this sub-category. For example, *"Because creative thinking helps to identify problems."*

1b. Problem Finding leading to creative thinking - Three responses came under this category. For example, *"Problem finding encourages students to think in a wider area and develops their creativity."*

1c. Thinking for deeper understanding - One response was included under this category. For example, *"Children are attempting to understand; finding problems helps to find a deeper knowledge."*

1d.Student Engagement - One respondent suggested this category. For example, *"The children must be engaging to develop their own questions in a subject."*

1e. Scientific attitude - One response came under this category. Put it in the words of the respondent, *"Problem finding will help the students to think creatively and critically. It helps them to develop a scientific attitude."*

1f. Seeking new information - One respondent suggested this category. Put in the words of the respondent, *"Pupils try to collect new information and apply that."*

1g. Solving problems creatively - Seven respondents suggested this sub- cluster. For example, *"We can find creative ways to solve the problem."* Another response was, *"Can use creative tests to prove/ disprove problems and find solutions."*

1h. Imaginative (art based view) - One response came under this sub-category. Put in the words of the respondent, *"You are required to be imaginative to some extent."*

Category 2: Think & Do - One response came under this category. In the words of the respondent, *"Practical tasks to demonstrate."*

- **Q11b: If no, why do you think so?**

Categories of responses obtained for respondents who answered No for question no. 19.

Category 1: Observation & Curiosity - One respondent suggested a response belonging to this category. In his/ her words, *"Finding problems is about being observant and inquisitive."*

Category 2: Problem-solving and creativity (not problem finding and creativity) - Three responses were included under this category. For example, *"They do not need to be creative to find a problem."* Another response was, *"Children use creativity to solve problems."*

- **Q12a: Do you think encouraging problem finding in science is easy/ hard?**

When student teachers were asked to answer whether encouraging problem finding is easy or hard around 60% of them said it is hard to problem find. The table 7.11 below summarises the responses to question 12a.

Table 7.11 summarising the responses to question 12a

	Easy	Hard	Both	Don't Know
Problem Finding is easy or hard?	12 (32%)	21 (57%)	1 (3%)	3 (8%)

- **Q12b: Why do you think this? Responses and categories are explained in the table below.**

Categories for 'encouraging problem finding is easy because...' responses

Category 1: Curious and inquisitive nature of children - Six responses came under this category. For example, *"Children naturally ask questions."*

Category 2: Nature of science - Four respondents gave responses coming under this category. For example, *"Because there are lots of topics to explore and lots of possible outcomes and conclusions."* Another respondent suggested, *"Science is full of enthusiastic interrelated facts."*

Category 3: Lesson starter - One respondent suggested this category. For example, *"Problems could be posed as a lesson starter."*

Category 4: Thinking creatively - One response came under this category. For example, *"Because when we start thinking creatively, problems will be identified easily."*

Categories of responses supporting the idea 'encouraging problem finding is hard, because...'

Category 1: Child factors - This category has **two sub- categories. 1a. Independent thinking and understanding and, 1b. Interest**

1a. Independent thinking and understanding - Three responses came under this category. For example, *"Requires a deeper level of thinking."* Another response was, *"It takes lot of time for students to understand certain topics in depth. Problem finding starts only when they try to find answers for questions, why, how etc."* **1b. Interest**- Two respondents suggested this category. For example, *"Every individual may not be interested."*

Category 2: Teacher factors - This category has one sub-cluster, 2a. Subject knowledge. Three responses came under this category. For example, *"Both finding out the problem and finding out the solution to the problem are difficult tasks for a teacher. A teacher should possess good subject knowledge."*

Category 3: Factual nature of science - Two respondents suggested this category. For example, *"It is often taught in schools in a more factual way (how something happens) as questioning and discussion (often seems more reserved for subjects like English)."*

Category 4: Curriculum targets and Pressure - One respondent suggested this category. Put it in the words of the respondent, *"Directing the learning to meet objectives."*

Category 5: Hard to encourage - Five respondents suggested this category. Put in the words of the respondent, *"It can appear daunting but does make science real."* Another response was, *"Because the teacher can't try to and know each person to solve problems."*

Categories for 'encouraging problem finding is 'both easy and hard, because....'

Category 1: Curious and inquisitive nature - One respondent came up with the curiosity and inquisitiveness of children. In the words of the respondent, *"Some children naturally ask lots of questions and try to pick apart theories, whereas others simply take in the info."*

- **Q13: Is there anything you want to add about problem finding in science?**

Category 1: Teacher support - One respondent suggested this category. In the words of the respondent, "If the students are provided with opportunities to get clarifications for their questions by the teacher, they will be interested to find more problems."

Category 2: Real life problems - One response came under this category. For example, *"It should go in hand with the practical life."*

Category 3: Discovery learning - One respondent suggested this category. Put in the words of the respondent, *"Problem finding will be the first step of discovery learning and discovering skills."*

- **Q14a: Here is a list of aspects of science. Which 3 of them do you see as offering the best opportunities for problem finding?**

When student teachers were asked to choose three best topics for problem finding from the national curriculum (DfE, 2013) they came up with the topics Forces, Earth, Space and Electricity. The reasons suggested for the popularity of the topics Forces and Electricity were their presence in everyday life, availability of resources, easy to access of required equipments, more opportunities for hands-on investigations (practical work), easy to encourage children's interests, presence of real life problems and the occurrence of misconceptions around these areas and opportunities to tackle them. The topic Earth and Space was chosen as they were seen as broad areas with plenty of unanswered questions requiring good thinking and simple resources. When student teachers were asked to name three topics that offered the least problem finding opportunities, they came up with the topics, Rocks, Evolution and Inheritance and Plants. Slower changes that take too long make these topics less investigative. Also, the abstract nature of the concepts, less prior knowledge and availability of lots of research and evidence make them the worst for generating problems. The table 7.12 and 7.13 below summarises the responses to question 14a and table 7.14 and 7.15 summarises the responses to question 14b. Figure 7.1 shows the National Curriculum areas with most opportunities for problem finding. Figure 7.2 shows the National Curriculum Areas with fewest opportunities for problem finding.

Table 7.12 Topics Offering Most Opportunities for Problem Finding

Rank	NC Areas with Most Opportunities	Science 2 Physics	Science 3 Chemistry	Science 4 Biology	Number of Opportunities
1	Forces	x			24
2	Earth and Space				15
3	Electricity	x			13
4	Properties and Changes of Materials		X		12
5	Light	x			10
6	States of Matter			X	8
6	Evolution and Inheritance			X	8
6	Plants			X	8
7	Living Things and Their Habitats			X	7
7	Sound	x			7
8	Magnetism	x			6
9	Ourselves and Other Animals			X	2

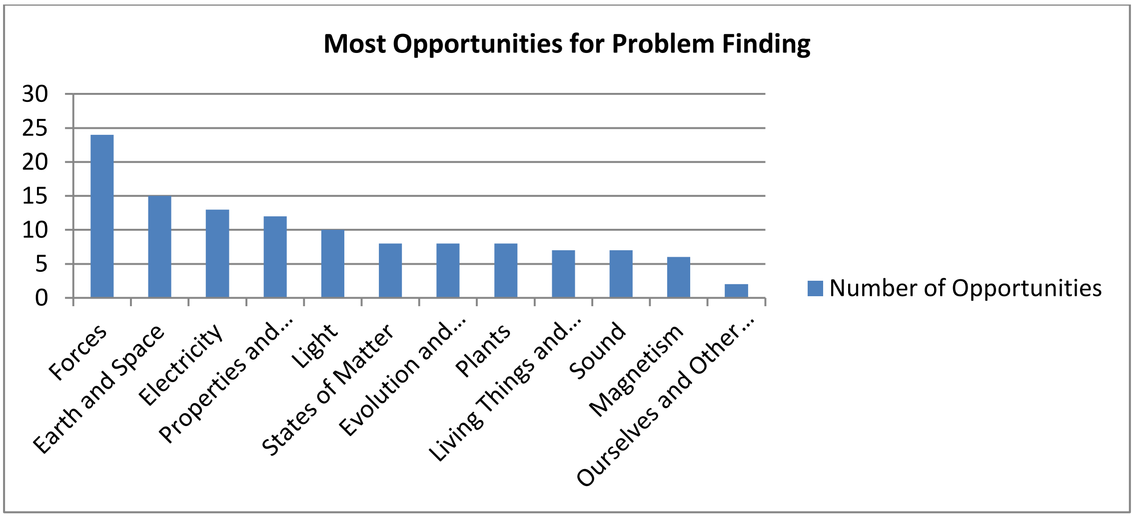


Figure 7.1 National Curriculum Areas and Most Opportunities for Problem Finding

- **Q14b: What makes the selected items the best?**

Table 7.13 Topics and Reasons for Most Opportunities for Problem Finding

Ranking	NC Areas with Most Opportunities	Reasons Suggested
1	Forces	Physical Problems from everyday life Opportunities for hands-on investigation (ideas can be tested) Creative opportunities Can encourage interest Real problems to explore Availability of resources Measurable Equipments easier to bring to the classroom More application level Easy to find problems More misconceptions and opportunity to tackle them
2	Earth and Space	Best for problem finding with simple resources Have unanswered questions Broad areas with more unanswered questions Requires good thinking Differences between two atmospheres
3	Electricity	Physical Creative opportunities Can encourage interest Opportunities for hands-on investigation (ideas can be tested) Availability of resources More misconceptions and opportunity to tackle them Test theories Problem-solving opportunities Equipments easier to bring to the classroom Requires good thinking

- **Q15a: Here is a list of aspects of science. Which 3 of them do you see as offering the fewest opportunities for problem finding?**

Table 7.14 National curriculum areas with fewest opportunities for problem finding

Rank	NC Areas with Least Opportunities	Science 2 Physics	Science 3 Chemistry	Science 4 Biology	Number of Opportunities
1	Rocks		x		24
2	Evolution and Inheritance			X	17
3	Plants			X	13
4	Sound	x			10
5	Living Things and Their Habitats			X	9
6	Earth and Space		x		8
7	Ourselves and Other Animals			X	7
7	Magnetism	x			7
8	Properties and Changes of Materials			X	6
8	Light	x			6
9	Forces	x			4
9	States of Matter				4

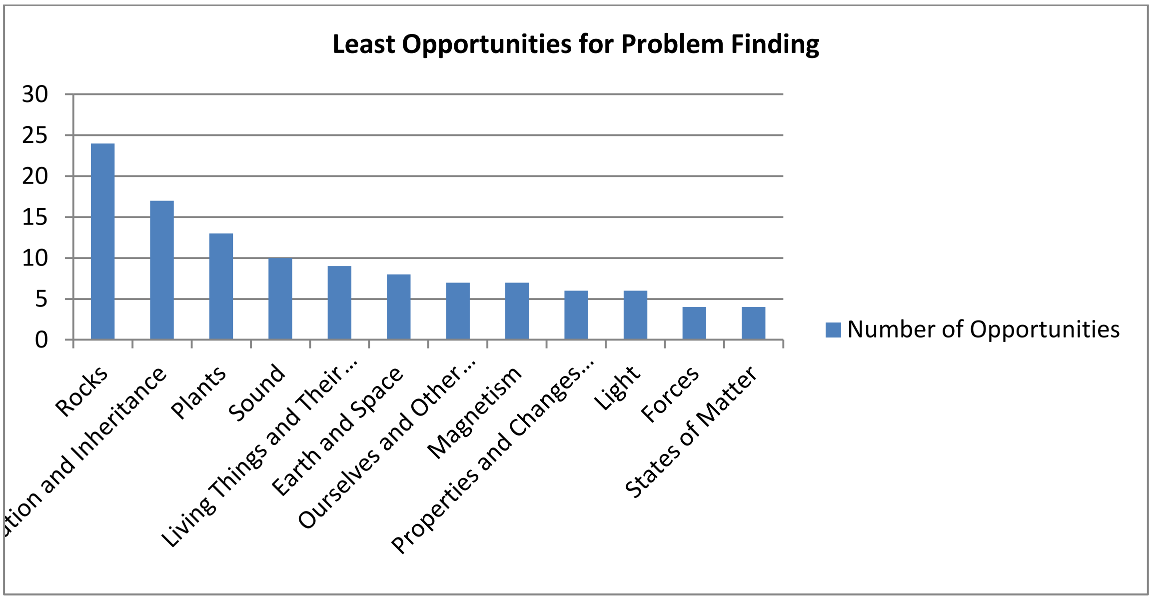


Figure 7.2 National curriculum areas with fewest opportunities for problem finding

- **Q15b: What makes the selected items the worst?**

Table 7.15 Topics and Reasons for Least Opportunities for Problem Finding

Rank	NC Areas with Least Opportunities	Reasons Suggested
1	Rocks	Slower changes (take more time to change) which are harder to make interactive Lots of research and evidence available Harder to investigate Less opportunities to change variables or test at More factual Harder to derive a problem as 'fixed' concepts More abstract Less knowledge Cannot be easily explained
2	Evolution and Inheritance	Less hands-on experiments Takes too long Outside of child's world Harder to investigate May have misconceptions Unavailability of positive situations to show
3	Plants	Slower changes (take more time to change)which are harder to make interactive Less knowledge Biology is difficult to use in the classroom Hard to conduct experiments Lots of research and evidence available

7.3 **Summary**

The findings revealed that these student teachers who participated in the survey tended to be of the 7 types. The first category believed that, science lessons involving practical tasks (fact-finding) where children had to think and problem solve as stimulating scientific creative thinking. Constructing a practical way to investigate a problem or conducting experiments or tests to make a conclusion was seen as promoting scientific creativity by some. Application of scientific knowledge in real life (e.g. constructing a garden at home) or to create something which works was reported as evidence of scientific creativity by the third category of teachers. Thinking of solutions to problems without practical task and, demonstration of experiments to elicit thinking and understanding were the other two types responses emerged as examples scientific creative thinking. A small proportion of student teachers viewed lessons involving reproductive making tasks like model making and creative teaching using activities like writing a story or a poem as encouraging scientific creativity. See the figure 7.3 below illustrating categories of science lessons involving creativity emerged from student teachers' questionnaire survey responses.

Most student teachers believed it was difficult to encourage scientific creative thinking due to several constraints. Most student teachers encourage problem-solving by providing ready-made problems to solve. Student teachers reported that they do not encourage children's scientific problem finding or question asking. They said they will try to promote it in the future as some felt that problem finding encourages deep learning. Majority felt it was a difficult to encourage problem finding as it depends on factors including children's ability for independent thinking, their prior knowledge and interests and, pressure to meet curriculum targets. Topics like Forces, Earth and Space and, Electricity were seen as offering most opportunities for problem finding. On the other hand, topics like Rocks, Evolution, Inheritance and Plants were commented as offering fewest opportunities.

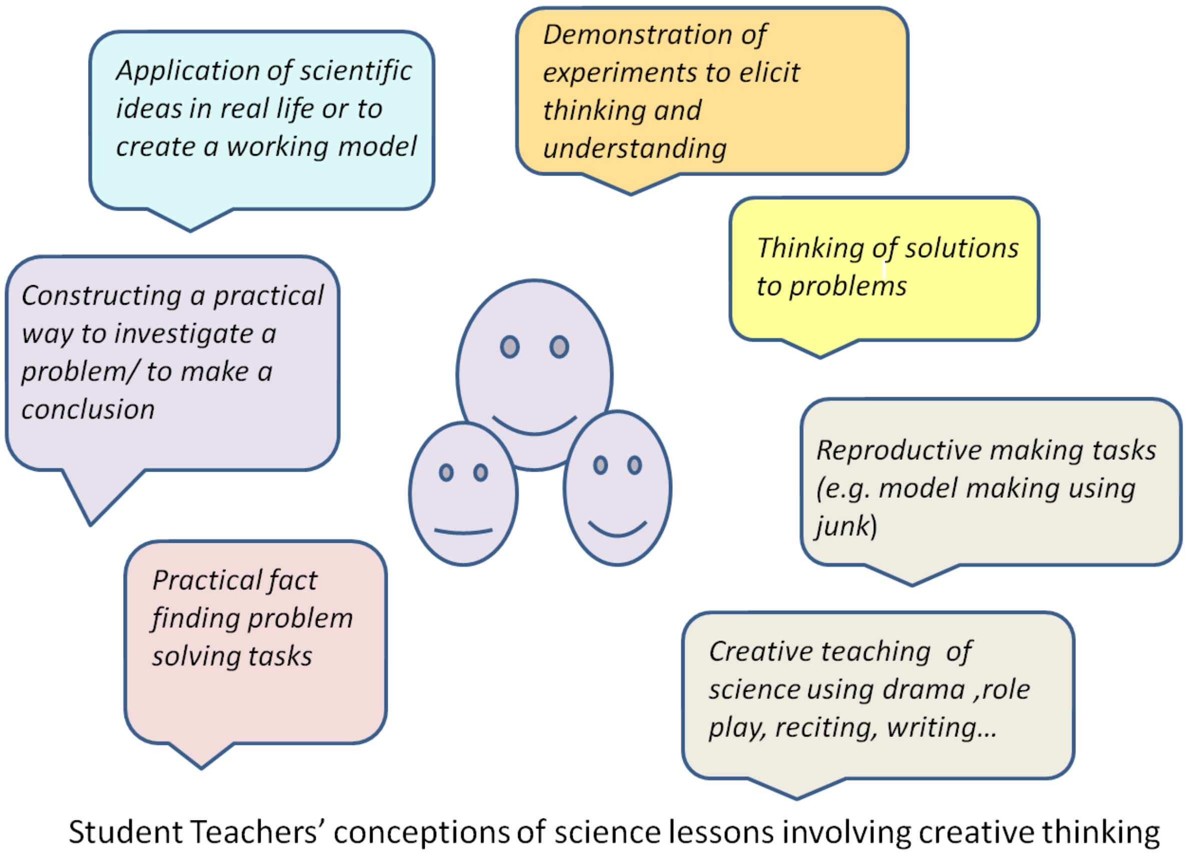


Figure 7.3 Categories of science lessons involving creative thinking emerged from the student teachers' questionnaire survey response

8 Chapter 8: Results from Lesson Observations and Brief Discussions with Teachers, and Analysis of Textual Resources

8.1 Introduction

This chapter presents the findings related to the observations of teachers' teaching science and brief discussions with them on textual resources they use for planning the lesson. The chapter also presents the findings from the content analysis of textual resources. Lesson observations relate to the **Research Questions 3.** What are the strategies primary teachers use to promote creative thinking, problem-solving and problem finding in science? Short discussions with teachers inform the **Research Question 4.** Are textual materials available in the school or online for teachers to support creative thinking, problem-solving and problem finding in science? Textual analysis answers the **Research Question 5.**Do textual resources (text books, schemes of work, online resource) support creative thinking, problem-solving and problem finding in science? The purpose of this part was to gain further insights into teachers' strategies to promote creative thinking, problem-solving and problem finding in science.

8.2 Lesson Observations

- **Observation 1: Year 5, School 1** (Pilot Observation)

Topic: Unit Title: Physics - Electricity (Based on the lesson plan. Lesson plan attached in the appendix) **Lesson**: Circuits- Does thickness of a wire affects the brightness of a bulb? Does a longer wire make the bulb brighter? **Lesson Objective**: Plan scientific enquiries to answer questions, including recognising and controlling variables. Record results using scientific diagrams. Report findings (taken from the lesson plan).

Outcomes: Children will have planned and carried out a fair test to answer a question. Children will have made predictions, recorded results and used them to draw their own conclusions.

Differentiation (activities for Low Ability/ Medium Ability pupils): LA- Equipment will be provided. Children will be provided with three different thicknesses of wire to test. MA-To explore how the length of the wire affects the brightness of the bulb. HA- To explore how different wires affect the brightness of a bulb- supervised by TA. **Resources**: Cells, wires, bulbs. Wires of different thickness and length.

Observation report: (Think & Do lesson)

Lesson-Teacher started the lesson by asking pupils to recall what they have done in the last lesson, including the meanings of some scientific terms they had learned last week like conductor, insulator and current. Teacher then introduced the investigation they are going to do through a concept cartoon in which the question/ problem of enquiry was given (Does the length/ thickness of a wire affects the brightness of the bulb?). Three characters in the cartoon suggested three different predictions. Teacher asked the pupils to think whether they are correct or wrong? He gave a few minutes to discuss in pairs what they think about the predictions given by the three characters. Teacher then asked some pupils to share which prediction they think is right and the reason behind it.

P1- Thinner wire will be brighter.

P2- Having more wires makes bulb dimmer. So having thicker wires, the electricity might escape and dimmer the bulb would be.

P3- If there is less wires, more quicker for the electricity to reach the bulb.

P4- If it is thicker wire, can fit in more voltage and faster the electricity will reach the bulb

P5- If thicker or thinner the wire same amount of electricity flows.

P6- Long, thick wire, lots of electricity will flow (longer & plump wires, more electricity) and brighter, while thinner wire, less electric flow and dimmer.

Teacher asked a pupil to read aloud the problem of investigation.

Problem- Eric the electrician has been asked by his boss to investigate which kind of wire would be the best to make bulbs shine as brightly as possible. All children were asked to make a prediction and write it in the worksheet provided. They were then asked to test their predictions and record their results in the worksheet.

Teacher asked pupils that under normal circumstances one should not touch an electric wire but the wires they use in the classroom are safe to touch, why? Teacher asked them to discuss it in pairs and share their ideas/ reasons.

P7 said, the bulbs they use allow only a certain amount of electricity to pass through. Teacher added that they use low voltage bulbs and wires. Teacher also asked to check the voltage of a cell they use and also to find the voltage of a car battery.

Problem given to investigate: Eric's problem- which kind of thickness of the wire would make the bulb shines as bright as possible?

(Teacher said you can investigate your own question or Eric's- Problem is given- but children can frame it in their own words. (Problem given)

Children need to decide what equipments you would use- limited equipments- tissue paper (did last week).Teacher asked the children what should always go in a prediction and a pupil replied (P8)a prediction should contain one's point of view. Teacher asked how one can make the prediction "the thinner the wire, the brighter the bulb" a better prediction and tried to elicit

from pupils. A pupil answered (P9) to add because... in the prediction and teacher stressed that by adding reason to a prediction can make it a brilliant prediction. Although the teacher gave children the problem to investigate, he told them that they could investigate their own question connected to the same topic. Teacher moved around the class and discussed with each group the procedure they are going adopt, as they have done more or less similar investigation during the last lesson (like measuring the brightness of the bulb using more wires/ more bulbs etc). Children were quite sure about what they were supposed to do. Wires of different thickness, tissue paper, bulbs, etc were provided. Teacher asked about the variable they are going to change and a pupil (P10) replied it is the thickness of the wire (Teacher added that the wires given roughly were the same length.)When teacher asked pupils to share their predictions, some pupils gave their predictions and reasons for them. Given below,
P11 (pupil no. 11) - I think the thickness of the wire doesn't change, same volts

P12- I think the thicker the wire, the brighter the bulb because there is more current, more volt can pass through. Teacher also praised children as they used scientific vocabulary like volt, current etc. Teacher also discussed how they are going to keep the test fair by recalling from their last investigation. Teacher stressed that variables that were kept same are the number of batteries, size, the colour of tissue paper, thickness of tissue paper, the back ground light of the class room etc. Pupils were asked to make a list in the worksheet supplied. Teacher explained how they are going to measure the brightness of the bulb using tissue paper. Children may decide if they are going to fold the tissue paper into layers or if they are going to tear it into pieces and pile one above the other to measure the brightness. Wires of different thickness and length, cells, bulbs, tissue paper etc were provided. Children worked in their own groups. Teacher supervised by moving around in the class and checking on the progress of each group. Teacher discussed about repeating the test to see if they get the same results. He also elicited from the pupils what to add in the conclusion and asked them to write a conclusion during the last 10 minutes of the lesson. Pupils shared their conclusions which included their prediction and what they observed. Also shared some issues they felt not fair (problem with folding the tissue paper, lack of an instrument (ammeter) to measure the brightness,). Finally they concluded what they would like to tell Eric about the test - teacher took all pupils to the corridor and demonstrated the flow of current by asking pupils to walk through the door at the end of the corridor, when one half of the door was closed and also when both halves of the doors were open and asked them to observe when was more flow of pupils happened. Teacher encouraged them to think and elicited their response and they concluded that the thicker the wire more current will flow (this activity will help them to memorise the concept as they compared the flow of pupils with the flow of the current).

Summary of Observation 1

Behavioural cues and events related to creative thinking and problem-solving and the time when they occurred were recorded in the observation schedule by the observer. No behaviours regarding problem finding was noticed. The number and the description of each event recorded are given below. Although the teacher allowed children limited freedom to choose their own questions to investigate, he/ she did not seem to push or prompt them and follow up any (if any) questions by the pupils and their investigations. Limited time, pressure to meet lesson targets, large class size with one teacher etc may limit teacher's freedom to encourage children to follow up their own questions, if they had any. Children felt comfortable and confident in repeating the same procedure given by the teacher, which they might have done in the previous lessons. Table 8.1 below explains the observed behavioural cues associated with creative thinking, problem-solving and problem finding.

Table 8.1 Behavioural Cues Associated with Creative Thinking, Problem-solving and Problem Finding

	Behaviour cues	**No. of events**	**Description of events**
CT	1c. Pupils (P1, P2, P3, P4) giving tentative explanations, reasons, causes and hypothesis (make predictions) 1e. Pupil constructing a test/ procedure to collect descriptive information.	1	1. Pupils gave predictions and tentative reasons When teacher asked, some pupils (6 to 7) pupils (P1, P2, P3, and P4 ...P6) gave predictions (chose one among the three predictions from the concept cartoon). All pupils were asked to choose a prediction and write it in the space given on the worksheet. Teacher asked pupils that under normal circumstances one should not touch an electric wire but the wires they use in the classroom are safe to touch, why? Teacher asked them to discuss it in pairs and share their ideas/ reasons. P7 said, the bulbs they use only allow a certain amount of electricity to pass through. Teacher added that they use low voltage bulbs and wires. When teacher asked pupils to share their predictions, two pupils (P11, P12) gave their predictions and reasons for them. P12- *"I think the thicker the wire, the brighter the bulb because there is more current, more volts can pass through."* 2. Teacher explained how to conduct the test but pupils had opportunity for decision making regarding how they are going to use the tissue paper, whether they are folding it in layers or tearing and piling pieces of paper to measure the brightness of the bulb.

	(Here, the teacher gave pupils the procedure but they could make slight changes in the procedure especially on how they were using the tissue paper during the investigation. They had limited freedom.)		
PS	2a. Teacher finding problems to solve 2b. Teacher defining problems to solve 2c. Teacher clarifying the problem	1 1 1	1. Teacher gave the problem of enquiry, i.e. 'does the length or thickness of a wire affects the brightness of the bulb?' through a concept cartoon.
PF			

(CT/ Creative Thinking, PS/ Problem-solving, PF/ Problem Finding)

- **Observation 2:Year 5, School 1**

Topic: Unit Title- Living Things and their Habitats (Biology) **Lesson-** Habitats and Adaptations (Adaptations of Plants and Animals)

Learning Objective- To understand what a habitat is. To understand that animals and plants adapt to their environment.

Outcomes- Label a selection of habitats. Say how an animal adapt to its environment.

Differentiation activities for LA/ MA pupils- Copy out the information on habitats into their books. Think of three animals that live in different habitats and show how they suit their environment. Children to give examples.

Resources- Habitats power point and worksheet

Observation Report: (Think Lesson, No hands-on activity)

The lesson began with teacher explaining about a writing task to be completed after the lesson. Teacher asked pupils on each table (A, B, C) to go through the worksheet kept on each table. Worksheet had the picture of a plant or an animal. Pupils had to think, discuss and write- where the animal or the plant lives and why it lives in that particular environment. The animals were penguin, fish, frog, polar bear, cactus, camel and squirrel. Teacher with the help of a power point discussed about each animal/ plant and their adaptations which make them live in their particular environment. Pupils in each group, suggested their own ideas of animal/ plant adaptations to the teacher. Teacher discussed about different habitats and about habitat destruction by natural as well as human factors. Pupils gave example for different natural causes as well as human actions causing of habitat destruction. Discussed the meaning of the term vandalism. In the end children were asked to do the writing task (problem-solving) about different animals, their habitats and adaptations (Power point, discussion, work sheets).

Behavioural cues and events related to creative thinking, problem-solving and problem finding recorded in the observation schedule by the observer are summarised below. It was noticed that the teacher gave children opportunity to ask questions and clarify their doubts. Questions asked were mostly non-science or factual questions. The number and the description of each event recorded are given below. Table 8.2 below explains the observed behavioural cues associated with creative thinking, problem-solving and problem finding.

Table 8.2 Behavioural Cues Associated with Creative Thinking, Problem-solving and Problem Finding

	Behaviour cues	**No. of events**	**Description of events**
CT	1b. Pupil finding and describing about analogies 1c. Pupil giving tentative explanations, reasons, causes and hypothesis	1 2	Analogy between balanced habitat and balanced diet. 1. Pupil when asked suggested why camels have wide feet like polar bear (to prevent their feet from sinking in the soil). 1. Pupil, when probed by the teacher suggested why camels have really long eye lashes (to prevent sand from getting into the eyes).
PS	2a. Teacher finding problem for pupils to solve.	1	1. Teacher gave worksheet with a plant / an animal and pupils were asked to write about the habitat which it belongs and the adaptations it has to survive in that environment.
PF	3g.Teacher giving pupils opportunity to ask questions	1	Pupils asked questions about habitats (e.g. Can a lizard found in the mountains in Iran be seen on floors in the UK?)

(CT/ Creative Thinking, PS/ Problem-solving, PF/ Problem Finding)

- **Observation3: Year 5 School 1** (Continuation of observation 2 in Y5)

Topic: Unit Title- Living Things and their Habitats (Biology)

Lesson- Food chains and Webs

Learning Objective- To understand what a food chain is. To understand that it always starts with a green plant.

Learning Outcomes- Use all the vocabulary associated with a food chain. Write a food chain.

Differentiation activities for LA/ MA pupils- Write a selection of food chains.

Observation Report: (Think Lesson)

With the help of a power point, the teacher explained Food chain and associated terms like producers, consumers, herbivore, carnivore, omnivore.... etc and built food chains. Children gave examples of each group. Also discussed which group a lady bird belongs. Teacher wrote food chains, while discussing with pupils, encouraging them to suggest each unit in the food chain. A written activity was provided at the end of the lesson. Pupils were asked to draw a selection of food chains. Write an example of a producer and a consumer? What a herbivore is? What a carnivore is? What an omnivore is?

The observer looked for behavioural cues and events related to creative thinking, problem-solving and problem finding. Events related to problem-solving and problem finding observed were recorded. One pupil raised a factual question in the end of the lesson. The number and the description of each event recorded are given below. Table 8.3 below explains the observed behavioural cues associated with creative thinking, problem-solving and problem finding.

Table 8.3 Behavioural Cues Associated with Creative Thinking, Problem-solving and Problem Finding

	Behaviour cues	No. of events	Description of events
CT			
PS	2a. Teacher finding problems to solve	1	Pupils were asked to draw a selection of food chains. Write an example of a producer and a consumer?
PF	3g. Teacher giving pupils opportunity to ask questions (one pupil asked a factual question)	1	One pupil raised a factual question during the lesson. (Is Venus fly trap a producer or a consumer?)

(CT/ Creative Thinking, PS/ Problem-solving, PF/ Problem Finding)

- **Observation4:Year 4, School 1**

Topic: Unit Title- Sounds (Physics)

Lesson- Introduction to Sound

Learning Objective- To recognise how sounds are made, associating some of them with something vibrating. To recognise that sounds get fainter as the distance from the sound source increases.

Learning Outcomes- Describe sounds I hear. Explain how some musical instruments make sounds.

Differentiation activities for LA/ MA pupils-

SEND- children to have word banks. Draw pictures instead of writing.

EAL- to use word banks and dictionary to translate. Draw pictures instead of writing.

Children will be working in ability groups. Teacher to provide support in 1 activity.

Resources- Tape of low, high, loud, quiet sounds and of sirens or train approaching and going away. Pictures of animals perking up their ears or with large ears.

Selection of musical instruments including at least one of each that makes sounds by shaking, banging, plucking or blowing.

Observation Report: (Think Lesson)

Teacher started the lesson with a problem-solving activity i.e. a sound quiz after recalling from the last lesson on pleasant and unpleasant sounds. The teacher started the lesson with a sound quiz. Teacher played a tape and children were asked to listen to twenty different household sounds, identify each one and note them down. Feedback given by the teacher in the end. Pupils were also asked to remain silent and listen to near by and far away sounds they hear and discussed about them (e.g. sound from an ice cream van).

Activity 1. (Teacher led)- Pupils were grouped into three groups. Group 1 with the teacher explored how different musical instruments produced sounds, focussing on vibration. Think how we can feel the sound?

Activity 2. (Teacher led)-Group 2 were shown pictures of animals perking their ears and asked to think and write the reason why some animals perk their ears and position their ears?

Activity 3. Group 3 were shown pictures of animals having ears with different shapes and discussion on why some animals have large ears and some have small ears. Children were asked to think and write reasons why some animals have large ears. Behavioural cues and events related to creative thinking and problem-solving were found and recorded in the observation schedule by the observer. Pupils received opportunities to observe, think and suggest reasons. The number and the description of each event recorded are given below. Table 8.4 below explains the observed behavioural cues associated with creative thinking, problem-solving and problem finding.

Table 8.4 Behavioural Cues Associated with Creative Thinking, Problem-solving and Problem Finding

	Behaviour cues	**No. of events**	**Description of events**
CT	1c. Pupil giving tentative explanations, reasons, causes and hypothesis	2	Pupils were given opportunity to think, discuss and give reasons for the question, why animals prick their ears. Pupils were asked to think, discuss and suggest reasons for the question, why some animals have large ears

	1a. Pupil giving tentative descriptions of situations, properties of substances and patterns or trends in a data.	1	Pupils were given opportunity to see, explore and reflect on how sound was produced from different musical instruments
PS	2a. Teacher finding problem to solve	1	Sound quiz- Teacher played a tape and children were asked to listen to twenty different household sounds, identify each one and note them down.
PF			

(CT/ Creative Thinking, PS/ Problem-solving, PF/ Problem Finding)

- **Observation 5: Year 4, School 1**

Topic: Unit Title- Sounds (Physics) **Lesson**- Vibrations

Learning Objective- To identify how sounds are made, associating some of them with something vibrating. To recognise that vibrations from sounds travel through a medium to the ear.

Learning Outcomes-Child can understand that sounds are made when objects vibrate

Child can explain that sounds travel through gases, liquids and solids.

(Children often think sound will only travel through air. Solids generally transmit sounds better than liquids. Sounds could be travelling through metal, air or water in a radiator pipe.)

Differentiation activities for LA/ MA pupils- SEND- children to have word banks. Draw pictures instead of writing. EAL- to use word banks and dictionary to translate. Draw pictures instead of writing. Children will be working in ability groups. Teacher to provide support in 1 activity. MAT- Link understanding to speed of sound in air.

Extension- Children could find out the relationship between pitch of note and length of wave, loudness of note and height of wave (session resources)

Resources- Drum, rice grains, elastic bands, tuning fork, beaker f water, ruler, cymbals, triangle and beaters, speaker for a stereo system, yoghurt pots/ paper cups and strings.

Observation Report: (Think & Do lesson)

Teacher started the lesson asking questions and recalling from last lesson on sound. She then demonstrated sound vibrations using a drum and rice scattered on it, a plucked rubber band, a vibrating tuning fork dipped in water and a ruler clamped to the table and tapped at one end. Teacher asked how these vibrations reach our ear. Can they travel through gas, liquid and solid? The class then watched a video on you tube showing vibrations and how they travel.

Activity- Try if they could feel vibrations with their fingers that they cannot see e.g. larynx as they talk. Try if sound travels through the table (solid) by putting your ear closer to it and tapping on it.

Children suggested their own ideas when teacher asked if one could hear in water. (1a)

When teacher asked pupils to share their thoughts on how a whale or a dolphin could hear and communicate under water, one pupil gave tentative suggestion on this. When teacher asked to compare sounds produced by a bottle nosed dolphin to other sounds, pupil got opportunity to find and describe about analogies between sounds. (1b)

Pupils experimented vibrations using tuning fork, rubber band, ruler, triangle etc.

Teacher demonstrated sound travelling through different medium by using a tuning fork hit on a table and listening, then repeating the tapping and putting ear to the table and listening and also tapping the tuning fork on the table and dipping it in water. Children were asked to repeat these in groups.

Activities: (Problem-solving activity for the whole class)(2a)

Children in small groups were asked to try five different activities as demonstrated by the teacher and draw a picture and write about what they have done and the effect it produced. (Activities: 1. Rice and drum, 2. Water and tuning fork, 3. Triangle and stick, 4. Elastic band, 5. Ruler clamped to the table.)The observer looked for behavioural cues and events related to creative thinking, problem-solving and problem finding. Any events related to creative thinking and problem-solving were observed and recorded. The number and the description of each event recorded are given below. Table 8.5 below explains the observed behavioural cues associated with creative thinking, problem-solving and problem finding.

Table 8.5 Behavioural Cues Associated with Creative Thinking, Problem-solving and Problem Finding

	Behaviour cues	No. of events	Description of events
CT	1b. Pupil finding and describing about analogies	1	When the teacher suggested an activity, (tapping on the table and listening to it by placing one's ear on the table) to see if sound travels through solids, pupils gave similar examples of activities. One pupil (P1) suggested tapping on the wall and listening to it. Another pupil (P2) suggested tapping on a cup and listening to it to.
	1a. Pupil giving tentative descriptions of situations, properties of substances and patterns or trends in a data.	2	When the teacher asked how they could see if the tuning fork is vibrating in the water, one pupil (P3) suggested that water might move or splash. Another pupil (P4) suggested that bubbles (or ripples as suggested by the teacher) might come from water when the tuning fork vibrates.

			When teacher asked children to express their ideas by showing a concept cartoon on hearing sound under water, a few pupils shared their thoughts either by supporting on of the views of the characters in the concept cartoon or by sharing own thoughts.
PS	2a. Teacher finding problems to solve 2c. Teacher clarifying the problem	1 1	1. Teacher arranged different activities (tests) on the table and children were asked to write about them. 1. Teacher clarified the problem by making it clear what the pupils are supposed to write. i.e. Write a question for each activity, test or try it, draw a diagram and write on what they did with each instrument and what effect it produced? Activities were: 1.Drum and rice sprinkled on the drum and a hammer to hit the drum 2. Water and tuning fork 3. Triangle and a stick 4. Elastic bands 5. Ruler attached on the table with a band
PF			

(CT/ Creative Thinking, PS/ Problem-solving, PF/ Problem Finding)

Observation 6: Year 6, School 2

Unit- Living Things, How animals adapt to their environments? (Autumn Term)

Learning Objectives: Identify how animals and plants are adapted to suit their environment in different ways and that adaptation may lead to evolution.

Outcomes: To be able to explain how animals are adapted to different habitats

Observation Report: (Think & Do lesson)

The observer looked for behavioural cues and events related to creative thinking, problem-solving and problem finding. Events related to creative thinking, problem-solving and problem finding observed were recorded. This lesson acts as a good model to show how outdoor investigation along with teacher's questions particularly 'why' questions can lead to productive discussion. Though a few pupils got the opportunity to ask questions or clarify their doubts about the 'Life in the Hedgerow', their questions were not used or developed as starting points for further scientific study. The number and the description of each event recorded are given below. Table 8.6 below explains the observed behavioural cues associated with creative thinking, problem-solving and problem finding.

Table 8.6 Behavioural Cues Associated with Creative Thinking, Problem-solving and Problem Finding

	Behaviour cues	No. of events	Description of events
CT	1c. Pupil giving tentative explanations or reasons, causes and hypothesis.	1	1. When teacher tried to elicit answers from pupils by asking why there are plants in the hedges, showing the 'Life in the hedgerow' worksheet, pupil generated reasons (like soil, a bit of sunlight, not too much ......). 2. When teacher asked the question why the berries have nasty thorns pupil generated tentative reasons like to stop animals from eating them.
PS	2a. Teacher finding problems to solve	2	1. School habitat research- Children set traps (empty disposable cups on the school field (under soil/ covered by leaves ...) to collect animals. They have to empty traps daily (for 3 days) and record the animals found in them. Use this information to explain why the animals are found in that habitat. 2. Teacher asked children to build a food chain from the list of animals found in the school garden (activity during the previous lesson). Pupils were reminded to start with a green plant or a producer.
PF	3g. Teacher giving pupils opportunity to ask questions	1	1. Teacher after discussing about the animals present in the 'Life in a hedgerow' worksheet asked if there is any of them who are not sure why those animals are there. One pupil asked why butterflies are there in the hedgerow. Another pupil asked why a bee is there? Another pupil asked, if snails eat grass and plants? (nothing in the hedgerow without a reason)

(CT/ Creative Thinking, PS/ Problem-solving, PF/ Problem Finding)

- **Observation7: Year 5, School 2**

Class- Year 5 **Lesson:** Pollination and Fertilization- Seed Dispersal (lesson)

Teacher used Hamilton trust online resource to plan the lesson. Table 8.7 below explains the observed behavioural cues associated with creative thinking, problem-solving and problem finding.

Table 8.7 Behavioural Cues Associated with Creative Thinking, Problem-solving and Problem Finding

	Behaviour cues	No. of events	Description of events
CT	1a. Pupil giving tentative descriptions of situations, properties of substances and patterns or trends in a data. 1c. Pupil giving tentative explanations or reasons, causes and hypothesis.	1 1	1. Pupils were asked to think and discuss in pairs about different methods of seed dispersal. Pupils suggested different agents of seed dispersal - wind, animals, when flower dies...etc were suggested by few students (3/4 pupils) whom teacher asked. 1. After showing the video the teacher asked a pupil why is it important for the seeds to move away from the mother plant? What would happen if there were lots of plants in one area? (teacher probing) When teacher asked, two pupils suggested their own reasons (e.g. there won't be enough water for all the plants). Teacher then probed what else and made them say nutrients.
PS	2a. Teacher finding problems to solve 2c. Teacher clarifying the problem	1 1	1. Teacher asked pupils to make a poster on seed dispersal. 1. Teacher clarified the problem by giving specific questions i.e. 1a. Methods of seed dispersal (pictures given for pupils to choose and paste) 2a. Write why is it important to scatter the seeds away from the mother plant? 3a. Give examples.

(CT/ Creative Thinking, PS/ Problem-solving, PF/ Problem Finding)

Observation Report- (Think Lesson)

The observer looked for behavioural cues and events related to creative thinking, problem-solving and problem finding. Events related to creative thinking and problem-solving were observed and recorded. No events related to problem finding were observed. The number and the description of each event recorded are given below.

- **Observation 8: Year 4, School 2**

Class- Year **4, Lesson**- Animals- Investigating Skeletons (sigmascience.co.uk).

Investigate- Are all the bones in taller people's bodies bigger than those in shorter people? Pupils are expected to set up simple practical enquiries, comparative and fair tests. They have to make systematic and careful observations and, where appropriate, taking accurate measurements using standard units, using a range of equipment. Record findings using simple scientific language, drawings, diagrams and tables.

Objective- Identify that humans and some other animals have skeletons and muscles for support, protection and movement.

Observation Report- (Think and Do Lesson with Fair testing)

This is an investigative lesson in which children are supposed to carry out a fair test independently (as given in the lesson plan). Worksheets were given to record information gathered (sigmascience.co.uk). Teacher gave the problem/ enquiry. Children were asked to make their own prediction if Dr. Fracture's statement is true or false and write it in the given space on the worksheet ("I think Dr. Fracture's statement is true" or "I think Dr. Fracture's statement is false"). When teacher asked a pupil what they are going to do first, the answer given was that they will start by measuring. Teacher then explained how they are going to do the investigation rather than discussing with children and eliciting their responses/ ideas and together coming up with a procedure/ fair test. Teacher gave clear instructions regarding how they are going to take the measurements, from where to where etc (all the details). It was noted that children didn't receive much opportunity to think (creatively) and make suggestions or ask questions regarding the lesson. One pupil asked a question regarding reporting the findings. A teaching assistant was there to assist the lesson. They then straight away started doing the investigation in groups. Maintaining discipline was a big challenge as there were a few children with behavioural issues and naturally the teacher has to prioritise on getting the learning task done by all children in the limited allotted time. After the enquiry, group 1 who had the tallest pupil and the smallest pupil in the class have been asked to share their results and they have found that all the bones of the tallest pupil were bigger than all the bones of the smallest pupil in the class.

Behavioural cues and events related to problem-solving were observed and recorded in the observation schedule by the observer. The number and the description of each event recorded are given in the table. Only one pupil asked a question in the end but it was not used as the basis of further study. It occurs to me that using problem finding might be more difficult with children who are difficult to control, just like any practical work. Table 8.8 below explains the observed behavioural cues associated with creative thinking, problem-solving and problem finding.

Table 8.8 Behavioural Cues Associated with Creative Thinking, Problem-solving and Problem Finding

	Behaviour cues	**No. of events**	**Description of events**
CT			
PS	2a. Teacher finding problems to solve 2c. Teacher clarifying the problem	1	1. Teacher gave the Dr. Fracture's problem to children. Dr. Fracture says that all the bones in a skeleton of a taller person are bigger than bones in a smaller person. How do we investigate? 1. Teacher clarified the problem- we will be investigating this by measuring how tall everyone is and by measuring diff bones - height, hand span and head span. (Here teacher explained how they are going to do the investigation to the children and they repeated it.)
PF	3g. Teacher giving pupils opportunity to ask questions	1	1. One pupil asked if age affects the height.

(CT/ Creative Thinking, PS/ Problem-solving, PF/ Problem Finding)

8.3 **Results of the Brief Discussions with Teachers on Textual Materials**

After observing the lessons the researcher had short purposeful discussions with the teachers regarding the textual resources available in school/ they use to plan their lessons. Teachers mostly use the Hamilton Trust linked resources to plan their lessons. They also found the resources available on the BBC school science website very useful for planning learning activities. Teachers at one of the schools used Rising Stars resources for assessment. It was noted that most teachers used online resources to plan lessons. Lessons based on the Hamilton Trust resources seemed to be of good standards. (e.g. www.bbc.co.uk/learningzone/clips/electromagnets/289.html, www.bbc.co.uk/bitesize/ks2/science/physical_processes/circuits_conductors/play/ or)

8.4 Summary and Preliminary Comments (Lesson Observations & Brief Discussions with Teachers)

Classroom observations of teachers' teaching science and short discussions were conducted to understand what teachers do or the strategies and resources teachers use to encourage children's creative thinking, problem-solving and problem finding. Teachers mostly said they rely on online resources like Hamilton Trust for their lesson planning. They also used the resources from www.bbc.co.uk/bitesize/ks2/science to support classroom learning. A few teachers used text books for planning assessments. It was observed that primary school children have plenty of problem-solving opportunities and teachers provide students problems to solve, some involves hands-on investigations *(e.g. 'Does the length or thickness of a wire affects the brightness of the bulb?')* while others are non-practical *(e.g. 'Make a poster on seed dispersal.)*. The creative thinking opportunities identified in the classroom were mostly those asking children to plan a fair test to find reliable descriptive information (experimental space) though teachers themselves tell children how to do it. Though teachers encouraged children to make predictions as a routine activity before testing only some of them took time to encourage children to come up with reasons to support their predictions. With lessons not feasible for investigations (e.g. food chain, habitats) teachers gave some children opportunity to generate tentative reasons through the asking of 'why' questions though not many (e.g. *'Why camels have really long eye lashes?'*). During an investigative lesson on bones, teacher gave clear instructions regarding how they are going to do the investigation and therefore, children didn't receive much opportunity to think, make suggestions or ask questions. Maintaining discipline was an issue as several children in the class had severe behavioural problems, a challenge when promoting children's productive thought. An outdoor investigative lesson focussing on 'the insect life in the hedgerow' combined with teacher's questions led to productive discussion. Though the teacher gave some children opportunity to ask questions, none of their questions were used or developed as starting points for further scientific study.

Although this is a very small sample of science lessons, it serves to suggest that:

- Teachers encourage children's problem-solving by providing readymade problems to solve which includes problems involving practical investigations as well as problems encouraging thinking about solutions without practical work.
- Though problems given by teachers provide opportunities for creative thinking, they may limit to opportunities involving practical fair testing to find reliable descriptive information thereby promoting creativity in the experimental space.
- Though teachers gave children opportunities to generate tentative reasons through the asking of 'why?' questions, they were more seen with non-investigative lessons like food

chain and habitats, thus rationing opportunities to promote creative thinking in the hypothesis space. This may in turn limit opportunities to test children's tentative explanations rationing creative thinking in the experimental space.

- Mostly, teachers gave some children opportunity to ask questions. At times when all children were allowed to ask questions, it was limited to one question per child. None of their questions were used or developed as starting points for further scientific study.
- Class management issues may make teachers reluctant to encourage children's question asking (if they were inclined to do so)
- Teachers may ration or limit questioning opportunities to a small number of children because of
    - time constraints
    - target pressure
    - teacher's lack of subject knowledge and confidence
    - lack of awareness of the importance of encouraging children's questioning etc

To what extent might textual resources support or promote creative thinking, problem-solving and problem finding in science, and hence, support the teacher in doing so? The next section offers some findings from an analysis of some such resources which includes text books, schemes of work and an online resource used by schools.

8.5 Results of the Content Analysis of Textual Resources

A sample of KS2 level (aged 7 to 11 years) text books, schemes of work and an online resource used by some of the schools where the data collection was conducted were analysed. The series of analysed texts (belonging to the KS2-year3, 4, 5, and 6) are listed below.

1. Collins Science Directions, Teaching File
2. Collins Science Directions, Pupils Book
3. Scholastic Hundred Science Lessons (Scottish NC)
4. Folens Science in Action,
5. Letts Teaching and Learning Science Activity Book,
6. Letts Teaching and Learning Science Teachers' Book,
7. Pearson Longman Exploring Science and
8. Hamilton Trust Online Resource.

Content analysis of textual resources was conducted in order to understand to what extent they support the teacher in promoting creative thinking, problem-solving and problem finding in science. The researcher looked for opportunities for stimulating scientific creative thinking, problem-solving and problem finding in these text materials and the guidance for teachers to promote these. Children have to think creatively to solve problems. Creative thinking and problem-solving overlap and therefore, it was difficult to differentiate between opportunities for creative thinking and problem-solving as such. The learning activities identified as encouraging creative thinking and problem-solving were counted and recorded under separate headings (quantitative part) however all the opportunities stimulating creative thought were in the form of problems requiring solutions. So, the quantitative measures are not accurate.

This section presents the findings from the content analysis of textual resources. Textual materials have been analysed qualitatively and the details are presented at length in Appendix 5a. Here, I will extract some illustrative observations and commonalities.

First, the textual materials tended to be similar in the following ways:

1. Textual resources offered several ready made problem situations for children to solve.
2. Most of the problem situations were those asking to plan a fair test to find some descriptive information. E.g. *'Investigating what happens to the size of a puppet's shadow when you change how far it is from a light source.'* Creative thinking is encouraged when a child constructs *a practical way* to find reliable descriptive information. Therefore, these were considered as incidents of scientific creativity, particularly in the experimental space (see Chapter 55, Methods for details). Though, most of the creative thinking opportunities identified were of this type, there was no information or directions for teachers on this. Some of these situations asked 'Why...?' questions which prompt children to generate tentative reasons, causes or explanations, thus encouraging creative thought in the hypothesis space though not many. *(E.g. 'Encourage pupils to explain why height of the puppet changed using the knowledge that light travels in straight lines.')*
3. Some problem situations were those encouraging thinking and hands-on activity but not fair testing type. E.g. '*Group the rock samples into 3 groups: sedimentary rocks with grains or layers, igneous rocks with crystals and metamorphic rocks which are glassy and have layers of crystals.'*
4. Other questions were those that may encourage children to think and research more about the topic particularly if the teacher is enthusiastic. For example, *'Maintain a food diary for a week. From your food diary choose a selection of foods to plan a healthy meal.'* Another example from a different textbook is *' Investigate how crops fail and what can be done to relive famine.'*

5. Problem finding opportunities were absent.

To illustrate these similarities, I point to two resources (Folens and Letts) and present the tables of results for them below. Although no directions were given to teachers in promoting creative thinking, they both share the above features in terms of promoting creative thinking and problem-solving. Little opportunities for problem finding were seen. Tables 8.9 and 8.10 below shows the opportunities for creative thinking, problem-solving and problem finding in the analysed textual material.

Table 8.9 Opportunities for creative thinking, problem-solving and problem finding in the areas of National Curriculum

Folens Science in Action -(507/FO) Y3 Jo Powell, Simon Smith, Anne Whitehead, Steve Sizmur, (Published by Folens, 2004)			
	Sc 2 Biology **Teeth and Eating**	**Sc 3 Chemistry** **Rocks and Soils**	**Sc 4 Physics** **Light and Shadows**
CT	1. Design a fair test to investigate the effect of cola , sugar and water on teeth (marble/ tooth/ egg) Think & Do	1. Investigation to find which sample of the soil holds more water. Predict. Investigate. Record. (Soil with bigger particles has bigger air spaces.) Think & Do	1. Investigating what happens to the size of a puppet's shadow when you change how far it is from a light source. How will you keep the test fair? Record, distance and height of the shadow. Encourage pupils to explain why height of the puppet changed using the knowledge that light travels in straight lines. Think & Do 2. Recording length of shadows depending on the position of the shadow in the play ground. Investigate what happens to the length of the shadow over the day. When is the shortest? Longest? Why the length changes? Think & Do
PS	1. Food diary: Maintain a food diary for a week, group foods into 4 groups (table, p10). From your food diary choose a selection of foods to **plan a healthy meal** (should contain food from each of the groups). Think & Do 2. Plan a meal for someone in the hospital (balanced and	1. Group the rock samples into 3 groups (sedimentary rocks (with grains or layers), igneous rocks (crystals), metamorphic rocks (glassy and layers of crystals). Think & Do 2. Riddle? (rock)	

	tasty). Think		
PF			

(CT/ Creative Thinking, PS/ Problem-solving, PF/ Problem Finding)

Table 8.10 1Opportunities for creative thinking, problem-solving and problem finding in the areas of National Curriculum

Letts - 1. Teaching and Learning Science Teacher's Book , KS2, Y3 Alan Jarvis, Ian Baldry, Wendy Hart, Diane Lowton, William Merrick, Joan O'Sullivan			
	Sc 2 Biology Unit: Helping plants to grow well	**Sc 3 Chemistry Unit: Materials and their Properties**	**Sc 4 Physics Unit: Magnets and Springs**
CT	1. Design a fair test to investigate if a plant would suffer if given too much water. Think & Do 2.Plan an investigation to see if plant growth is affected by sun light. Think & Do	1. Design a fair test to find out the best material to cover the floor. (hard enough) Compare hardness and order materials accordingly. Think & Do 2. Design a fair test to find out the best kitchen towel based on their absorbency. Think & Do 3. Plan an investigation that shows which pair of tights is the most stretchy. Think & Do 4. If a new fabric material had just been invented how you would test it to see if it would be suitable for clothing. (Is it waterproof? thermal insulator? stretch? hard-wearing? absorbent? easily wash?) Think & Do	1. Plan an investigation to find out whether all magnets are equally strong. Plot a bar chart. Think & Do
PS	1. Investigate how crops fail and what can be done to relive famine.(oxfam.org.uk) Think	1. Discuss the materials used to make drinking cups and the positive and negative features of each. Think	
PF			

(CT/ Creative Thinking, PS/ Problem-solving, PF/ Problem Finding)

Second, the textual resources did show differences. In particular

1. Opportunities for encouraging creative thought by generating a practical way to test a tentative explanation of an event were extremely rare in the analysed texts. One problem situation created a similar opportunity by asking children to design a method to prove a tentative explanation was wrong (e.g. *'Someone tells you the water on the outside of the drinks can come from the ice inside the can. Plan a test to prove it hasn't.').*
2. Questions like *' What might happen if farmers put too much water on a field? Explain.' though do not promote hands-on activity but encourages children to* make tentative descriptions or predictions using scientific knowledge. This is an example of weaker constructive thinking (pre-hypothesis space) a starting point leading to the generation of causes, reasons, explanations and hypothesis based on one's scientific knowledgebase promoting creative thinking in the hypothesis space.
3. Very rarely, some problem situations gave children opportunity to generate questions though under the same theme. For example, *'Ben has grown some bean plants in the dark and they are yellow and thin. Ben wants to know if they will go green if he puts them in the light. Write a question for Ben to investigate. Make a prediction.'* This problem acts as a very good example for a bridging activity between a teacher given problem-solving situation to child driven problem finding situation through question asking.

To illustrate these differences, I include here the table of two of the resources (Folens and Pearson Longman and contrast them. It will be seen that the differences are with regard to opportunities for promoting creative thinking and problem-solving. One or two problems gave children the opportunity to raise a similar question to investigate. Tables 8.11 and 8.12 below shows the opportunities for creative thinking, problem-solving and problem finding in the analysed textual material.

Table 8.11 Opportunities for creative thinking, problem-solving and problem finding in the areas of National Curriculum

Folens Science in Action -(507/FO) Y5 Petheram, L. , Szczesniak, P., Anne Whitehead, Steve Sizmur, (Published by Folens, 2004)			
	Sc 2 Biology Unit B:Life Cycles	**Sc 3 Chemistry Unit D:Changing State**	**Sc 4 Physics Unit F:Changing Sounds**
CT	1. Seed germination (investigation): a) Do seeds need water to germinate? b)light c)temperature/ warmth (Decide on what each group is going to find out, how to make it a fair test? how	1. Factors affecting evaporation: Choose a question and plan a fair test. Keep changing one factor while keeping others constant.(How spread out or folded a towel, how warm it is, windy or still	1. Design a fair test to find how the length of an elastic band affects the sound it produce. (Putting a pencil under an elastic band around a match box changes the length of the band that can vibrate)P71.

	many seeds will you use? why?) Think & Do	days...factors to vary) Think & Do	Think & Do 2. Plan a fair test to find out the factors that affects the sound produced by a wind instrument. (change? same? observe?...)p74 Think & Do
PS	1. How could plants living in small ponds spread their seeds to new ponds? (seed dispersal in water- find out) Think	1. Someone tells you the water on the outside of the drinks can come from the ice inside the can. Plan an experiment to prove that it hasn't. Think & Do	
PF			

(CT/ Creative Thinking, PS/ Problem-solving, PF/ Problem Finding)

Table 8.12 Opportunities for creative thinking, problem-solving and problem finding in the areas of National Curriculum

Pearson Longman - Exploring Science, KS 2, Y3 Penny Johnson and Mark Levesley (507/EX)			
	Sc 2 Biology Unit :3B Helping plants to grow well	**Sc 3 Chemistry Unit: 3D Rocks and Soils**	**Sc 4 Physics Unit: 3Ea Magnets and Springs**
CT	1. What might happen if farmers put too much water on a field? Explain. Think	1. Plan a fair test to see which kind of soil lets water flow through easily. Think & Do	1. Plan a fair test to find which material a magnet will attract. Predict. Think & Do 2. Fair test to find out which magnet is the strongest. (paper clips, paper) Think & Do 3. Fair test to investigate what makes Mike's toy car move by stretching the elastic band. Think & Do
PS	1. Ben has grown some bean plants in the dark and they are yellow and thin. Ben wants to know if they will go green if he puts them in the light. ***Write a question for Ben to investigate.*** Make a prediction. (copy- P30) Think		
PF			

(CT/ Creative Thinking, PS/ Problem-solving, PF/ Problem Finding)

8.5.1 Quantitative Analysis

Table 8.13 given below shows a rough number of opportunities for creative thinking, problem-solving and problem finding in the analysed textual material. This is not accurate because it is difficult to differentiate between creative thinking and problem solving opportunities as they both overlap each other.

Table 8.13 Summary of the Quantitative Analysis of Textual Resource

No.	Name of the Text Series	Primary (KS2)Year Groups	Creative Thinking	Problem-solving	Problem Finding
1.	Collins Science Directions (Series 1) Teaching File	Year 3, 4, 5, 6	11	24	0
2.	Collins Science Directions Pupils Book	Year 4, 5, 6	5	4	0
3.	Scholastic 100 Science Lessons	Year 3, 4, 5, 6	22	12	0
4.	Folens Science in Action	Year 3, 4, 5, 6	16	10	0
5.	Letts Teaching and Learning Science Activity Book	Year 3 & 4 Year 5 & 6	6	12	0
6.	Letts Teaching and Learning Science Teachers' Book	Year 3, 4, 5, 6	17	8	0
7.	Pearson Longman Exploring Science	Year 3, 4, 5, 6	19	6	0
8.	Hamilton Trust Online Text Resource	Year 3, 4, 5, 6	18	6	0

8.6 Summary and Some Interim Comments (Analysis of Textual Resources)

Content analysis of textual resources was conducted in order to understand to what extent they support the teacher in promoting creative thinking, problem-solving and problem finding in science. The textual resources analysed includes text books, schemes of work and an online textual resource used by some of the schools where the data collection was conducted. The researcher looked for opportunities for scientific creative thinking, problem-solving and problem finding in these text materials and hence, the support or guidance for teachers to promote these. Children have to think creatively to solve problems. Creative thinking and problem-solving overlap each other and therefore, it was difficult to differentiate between opportunities for creative thinking and problem-solving as such. The learning activities identified as encouraging creative thinking and problem-solving were counted and recorded under separate headings (quantitative part) however all the opportunities stimulating creative thought were in the form of problems needing solutions. So, the accuracy of the quantitative measures was compromised.

Textual resources offered plenty of problems to solve. Nevertheless, these resources offered little which could support teachers should they wish to promote creative thinking and problem finding. Though textual resources offered little guidance on ways of promoting scientific creative thinking, they offered some opportunities for creative thinking (experimental space) mostly by asking children to plan fair tests to find factual information. Most of the resources offered opportunities for fair testing. A few problems offered children opportunities to generate tentative reasons or explanations through the asking of 'Why..?' questions, thus encouraging creative thought in the hypothesis space.Opportunities for encouraging creative thought (in the experimental space) by generating a practical way to test a tentative explanation of an event were extremely rare in the analysed texts. Only Folens Science in Action appeared to offer such support only to the extent that it created a similar opportunity by asking children to design a method to prove a tentative explanation was wrong (e.g. *'Someone tells you the water on the outside of the drinks can come from the ice inside the can. Plan a test to prove it hasn't.').* Some science problems stimulated children to make tentative descriptions or predictions using their scientific knowledge an example of weaker constructive thinking, a starting point for creative thinking. However, these resources offered little that could support teachers to promote problem finding, only two resources (Pearson Longman, Letts) offered such support only to the extent that children had the opportunity to come up with a question to investigate under a given problem scenario (e.g. *'Ben has grown some bean plants in the dark and they are yellow and thin. Ben wants to know if they will go green if he puts them in the light. Write a question for Ben to investigate. Make a prediction.')*.These types of problems were very rare, only offered by two resources (Pearson Longman and Letts Science Teacher's Book).

Though this content analysis has included a very small sample of text materials and online resource used by teachers, it serves to suggest that:

- Textual resources offered little information on what counts as creative thinking in science and ways of promoting children's creative thinking and problem finding.
- Though problems given in the text books provide opportunities for creative thinking, they may limit to opportunities involving practical fair testing to find reliable factual information. In other words they may limit to encouraging creativity in the experiment space through planning and conducting fair tests to collect descriptive information.
- Text materials may ration providing opportunities to generate tentative explanations, reasons etc and to think creatively in the hypothesis space. This may in turn limit

opportunities to test children's tentative explanations rationing creative thinking in the experimental space.

- Textual resources provide plenty of readymade problems or questions for children to solve and thus encourage problem-solving. Practical problems as well as problems encouraging thinking about solutions without practical work are there in the textual resources.
- Two problems from two resources seemed to provide children opportunity to generate testable questions connected to that particular concept. These may act as bridging activity between teacher given problem-solving and children's problem finding, a good model to try out.
- Generally, text materials do not provide children opportunities for problem finding.
- Teachers could not expect to find direction or support on encouraging children's scientific creative thinking and problem finding from textual resources examined here.

8.7 General Summary

Teachers and textual resources promote problem solving by providing children problems to solve. Generally, textual resources do not provide children opportunities for problem finding. Teachers sometimes give children opportunity to ask questions but none of their questions were used for further scientific investigation or study in the classroom. As textual resources examined here offer little information on ways of promoting scientific creative thinking and associated behaviours like problem finding, teachers could not expect to find direction or guidance from them.

9 Chapter 9: Results from Strategy Trials with Children

9.1 Introduction

The study began by asking questions like 'Can primary school children ask questions, find problems in science? Can teachers support children to ask scientific questions or problems to investigate in science?'Given that there is little evidence that these teachers consider problem finding in their teaching, or that their textual resources point them in that direction, or generally support them in this respect, are there strategies which can encourage children to find problems, ask questions particularly causal or explanatory questions? This chapter presents the results of tests of strategies constructed for this purpose. In short, this chapter answers the Research Question Q6. What strategies can be used to engage children in question asking to raise scientific questions that can serve as problems to solve in the classroom? It will be recalled that the strategies are set out in Figure 9.1. given below.Children's questions generated by these five strategies were:

1. Categorised as factual or explanatory questions, and
2. Sorted into questions that can be answered through research, observation, demonstration, investigation or none of these, using the mnemonic RODIN.

The analysis of the pattern of science questions, factual and explanatory questions were carried out and the results are presented in this chapter under two main sections in all the strategies described in this chapter. They are:

1. Analysis of the number and pattern of factual and explanatory questions:
   a) under whole KS2, upper KS2 and lower KS2,
   b) based on the topic content by which questions were generated under the whole KS2, upper KS2 and lower KS2
2. RODIN analysis of questions (Research, Observation, Demonstration, Investigation, None of these):
   a) under the whole KS2,
   b) based on the topic content (for e.g. separate RODIN analysis for Elephant in the wild, captivity, and embryo). For RODIN analysis tables, see Appendix 6b.

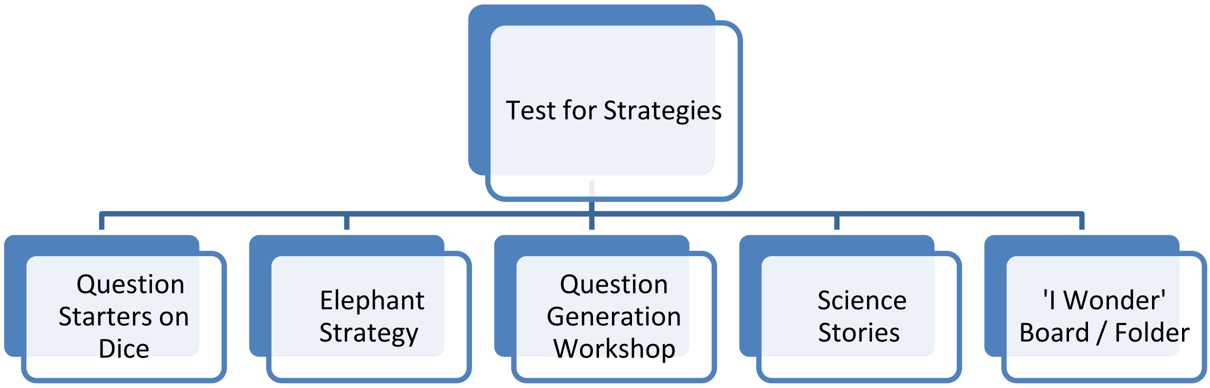


Figure 9.1 Strategies to Encourage Children's Question Asking

9.2 Strategy1: 'Question Starters' on the Giant Dice

It will be recalled that children were given worksheets with Question starters or stems like 'What would happen if...?.', 'What happens when....?', 'How would you...?' 'Which.....is/ does....?' 'Which is best for.....?' and 'Will it.....if we....?' The researcher had a big dice with each question starter written on its face. The researcher rolled the dice in the above order of the question starters and children were asked to complete each question starter to make a question. The questions were later categorised into factual or explanatory questions and RODIN questions and the pattern analysed.

9.2.1 Analysis of the number and pattern of factual and explanatory questions a) under whole KS2, upper KS2 and lower KS2

- ***Whole KS2***

The Q1 in the graph represents all the first questions produced by children, Q2 all the second questions, Q3, third questions, repectively. In the whole KS2, a high percentage of explanatory questions appeared at Q1 because the first question starter given (What happens if...) was the one which encourage children to generate science questions about new situations thereby generating higher order questions which are explanatory in nature. Therefore, factual questions were suppressed at Q1 and more explanatory questions were generated. The Figure 9.2 given below illustrates this. Separate analyses for males and females have been done and similar pattern of questions were observed (suppression of factual questions and generation of more explanatory questions at Question 1 or Q1).The figures 9.3 and 9.4 displayed below illustrate these findings. Also, separate analyses of upper and lower KS2 primary year groups (older and younger) have been done and similar question patterns were observed. This applies for females and males in all the three groups. Therefore, the data was merged. It was noticed that the girls ask more questions than boys in all the groups.

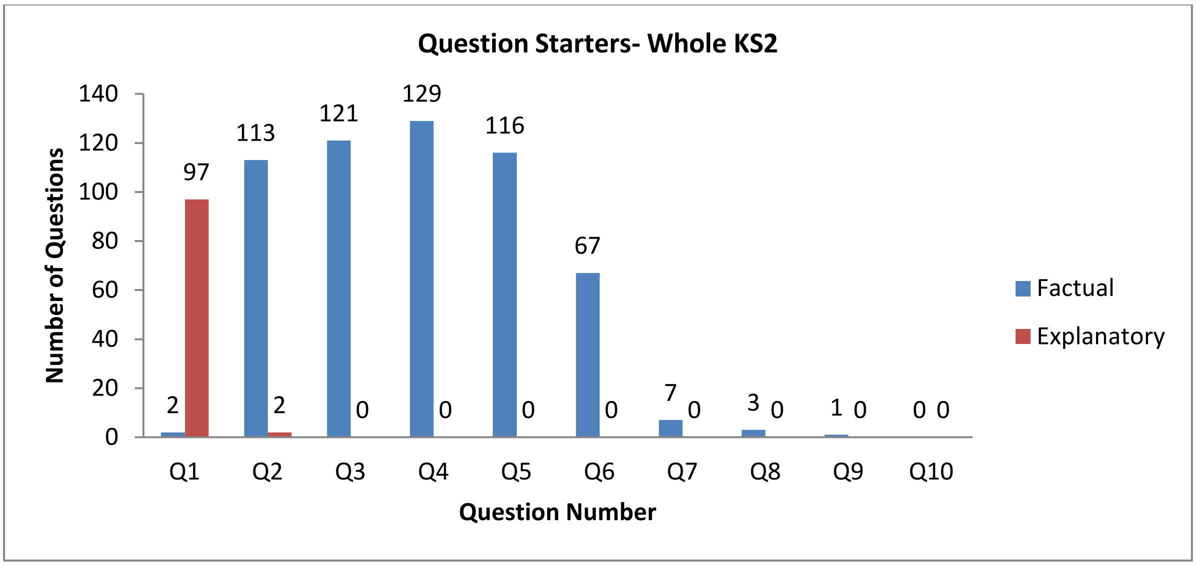


Figure 9.2 Whole KS2: Pattern of Factual and Explanatory Questions

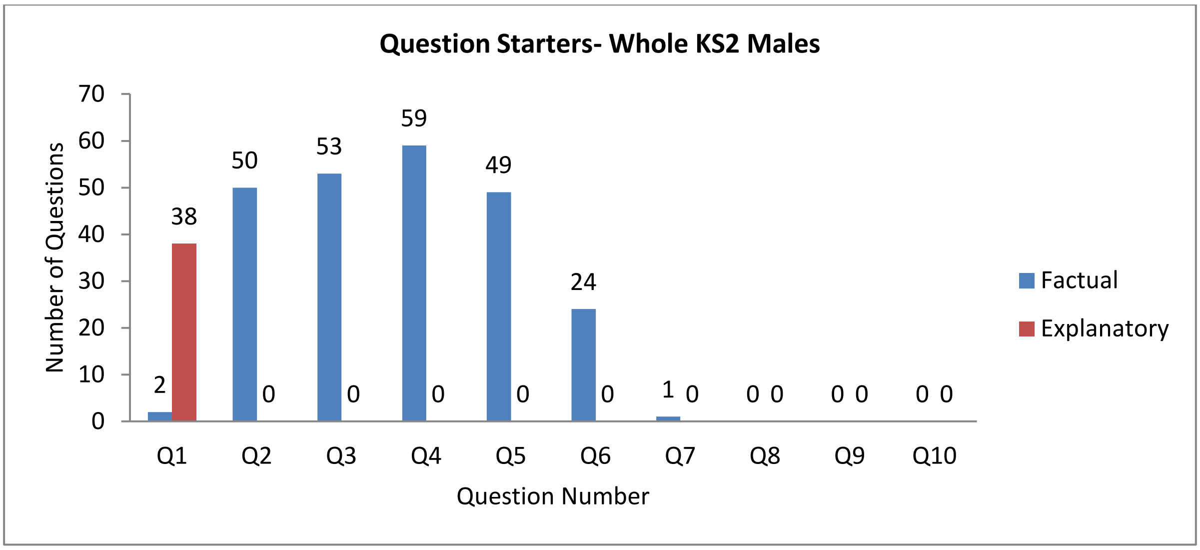


Figure 9.3 Whole KS2Males: Pattern of Factual and Explanatory Questions

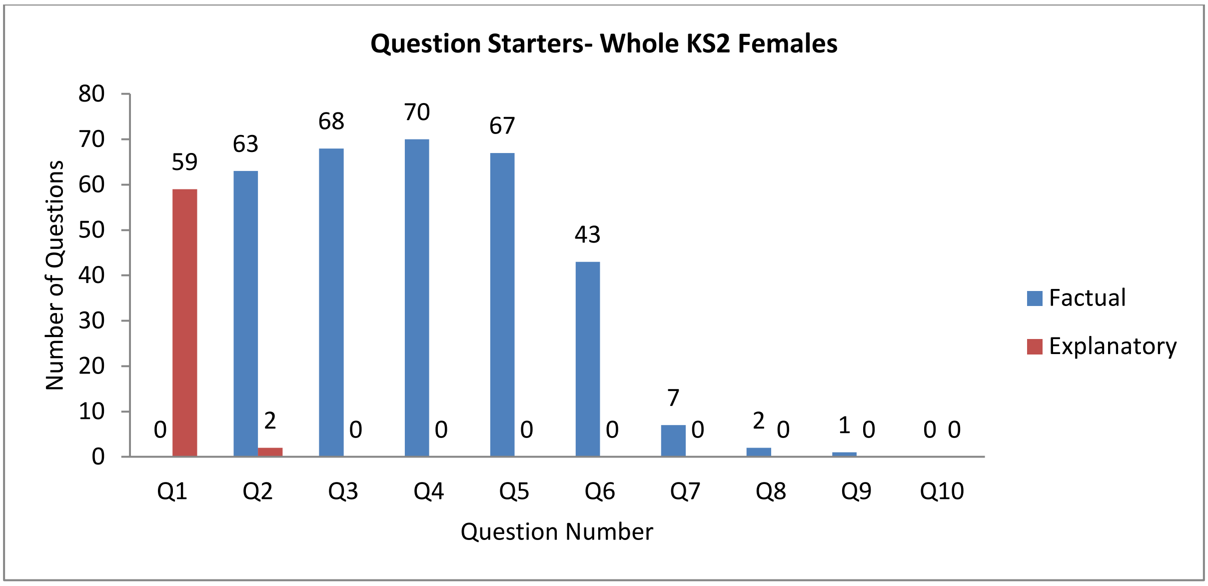


Figure 9.4 Whole KS2 Females: Pattern of Factual and Explanatory Questions

- ***Upper KS2***

A high proportion of explanatory questions are seen at Q1 when upper KS2 data was considered separately (see figure 9.5). In other words factual questions are suppressed at Q1 and more explanatory questions are generated. Same results were seen with males and females in upper KS2 when analysis was done separately. Figures given in appendix 6b illustrate this.

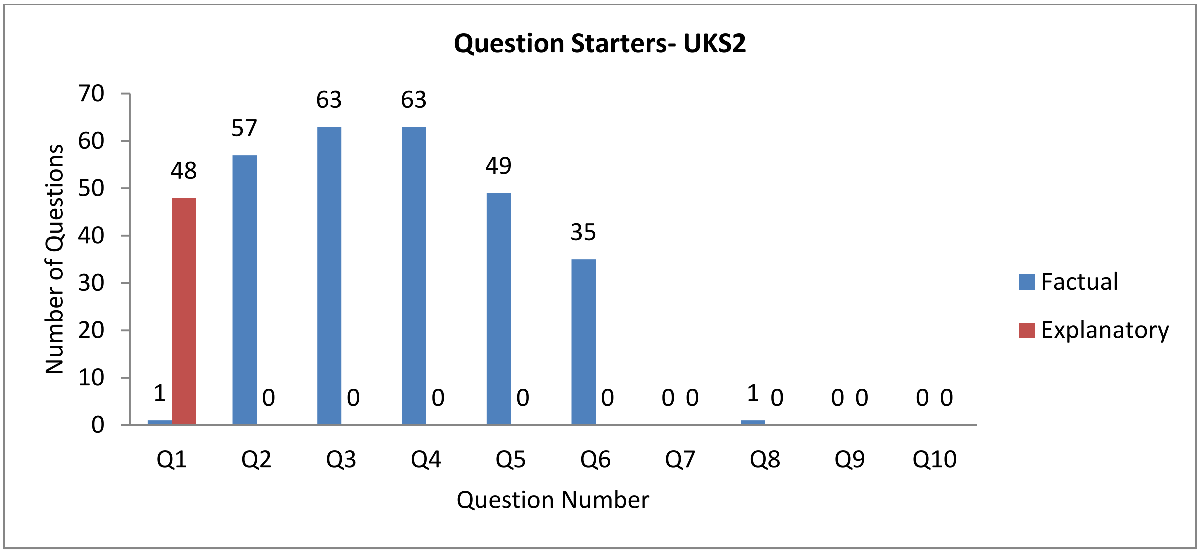


Figure 9.5 Upper KS2: Pattern of Factual and Explanatory Questions

- ***Lower KS2***

A similar high proportion of explanatory questions are seen at Q1 when lower KS2 data was analysed separately (see figure 9.6). The same pattern of suppression factual questions and generation of more explanatory questions were noticed at Q1 when males and females were analysed separately. See figures given in appendix 6b.

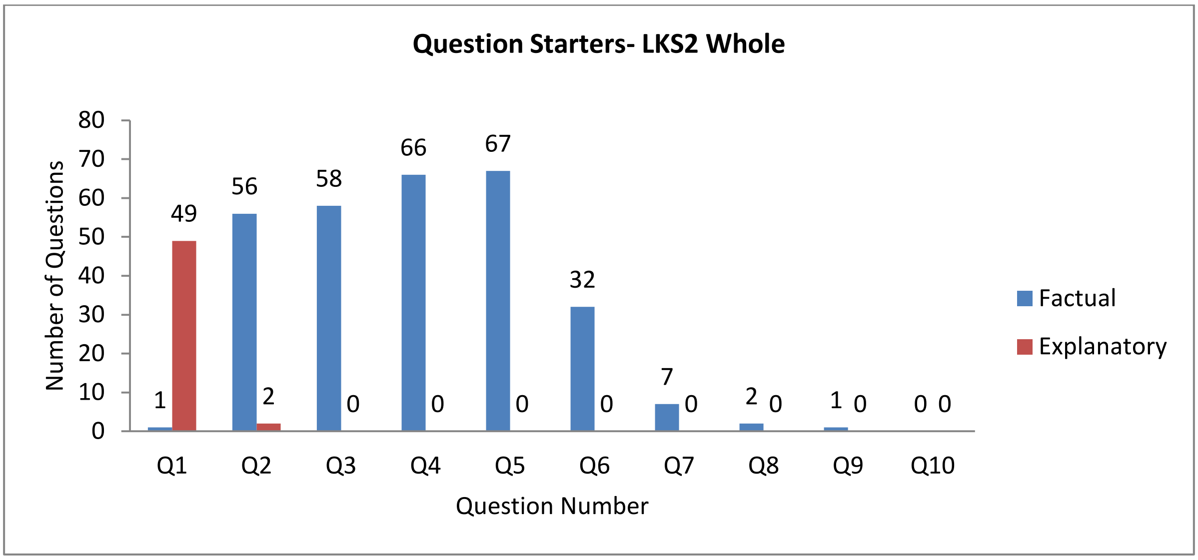


Figure 9.6 Lower KS2: Pattern of Factual and Explanatory Questions

The responses of children are summarised in the tables below. Separate tables for lower and upper KS2 have been provided. The data has been combined as the patterns of questions were similar. Tables 9.1 and 9.2 summarise the lower and upper KS2 responses. Table 9.3 summarise the combined whole KS2 responses.

Table 9.1 Lower KS2: Summary of Science Questions Produced

Gender	**Factual Questions**	**Explanatory Questions**	**Total Science Questions**
Males	134 (46%)	21 (41%)	155 (45%)
Females	156 (54%)	30 (59%)	186 (55%)
LKS2	290	51	341

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

Table 9.2 Upper KS2: Summary of Science Questions Produced

Gender	**Factual Questions**	**Explanatory Questions**	**Total Science Questions**
Males	104 (39%)	17 (35%)	121 (38%)
Females	165 (62%)	31 (65%)	196 (62%)
UKS2	269	48	317

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

Table 9.3 Whole KS2: Summary of Science Questions Produced

Gender	Factual Questions	Explanatory Questions	Total Science Questions
Males	238 (43%)	38 (38%)	276 (42%)
Females	321 (57%)	61 (62%)	382 (58%)
Whole KS2	559	99	658

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

9.2.2 Analysis of the number and pattern of factual and explanatory questions based on the topic: comparison between 'Eggs' and 'Bags'

When the whole KS2, upper KS2 and lower KS2 data were analysed separately based on their topics i.e. Eggs (topic Birds' eggs) and Bags (topic Bags made from different materials), similar pattern of high prevalence of explanatory questions at Q1 were noticed with the 'Eggs' topic. With the topic 'Bags' the explanatory questions were fewer at Q1. In other words, when the pattern of questions were analysed based on the topic (Eggs/ Bags) it was observed that the Eggs topic generated a higher percentage of explanatory questions at question one (Q1) in the whole KS2, upper and lower KS2. See figures 9.7 and 9.8 for whole KS2 separate topic wise analysis results. Figures 9.9 and 9.10 shows Upper KS2 and figures 9.11 and 9.12 shows Lower KS2 separate topic wise analysis results.

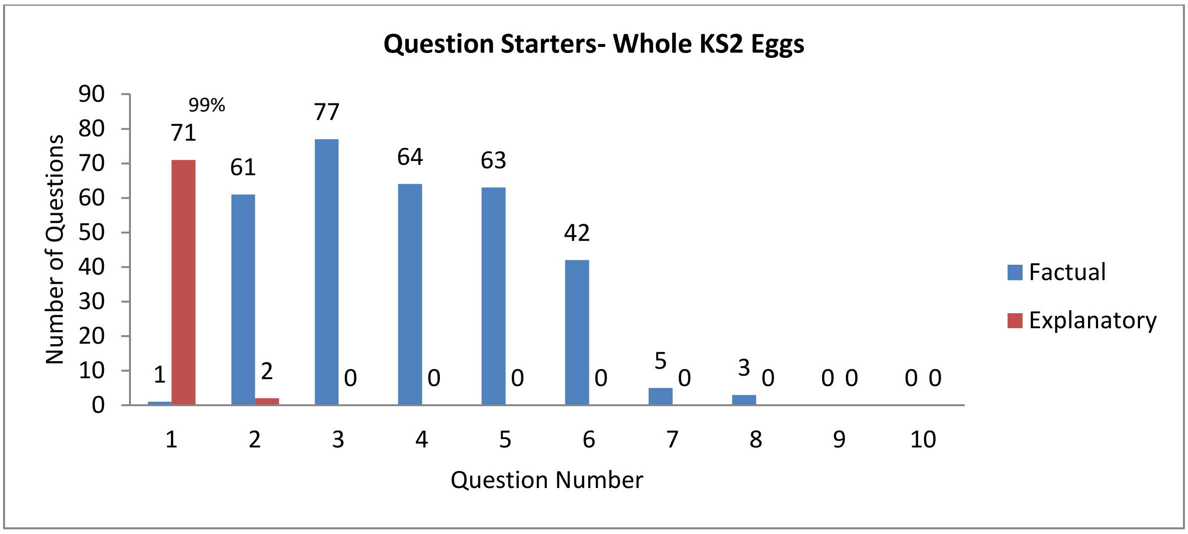


Figure 9.7 Whole KS2 'Eggs' Topic: Pattern of Factual and Explanatory Questions

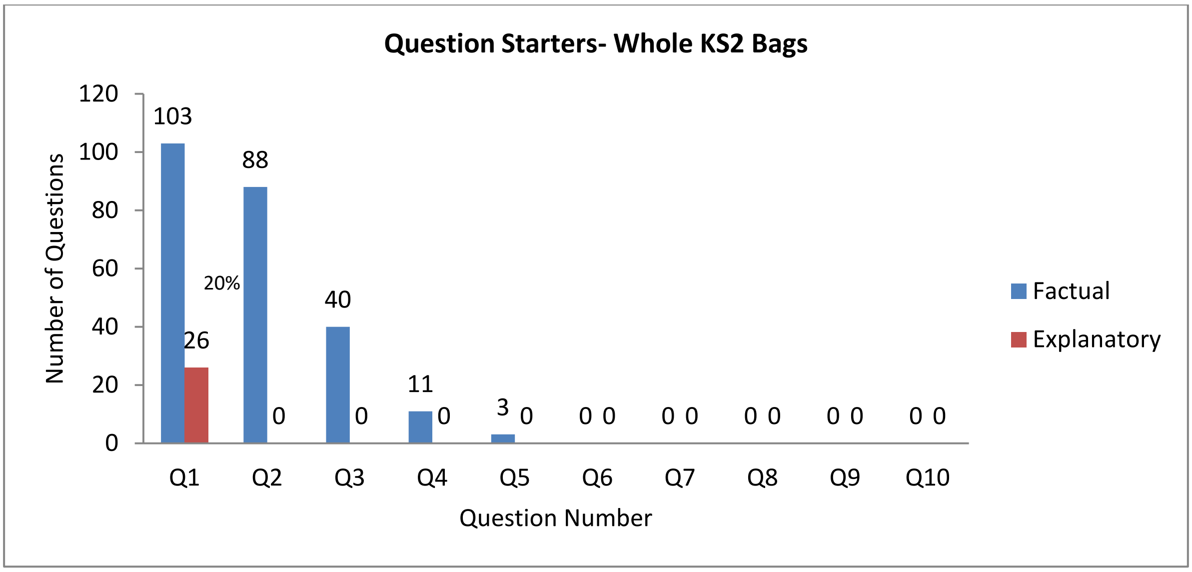


Figure 9.8 Whole KS2 'Bags' Topic: Pattern of Factual and Explanatory Questions

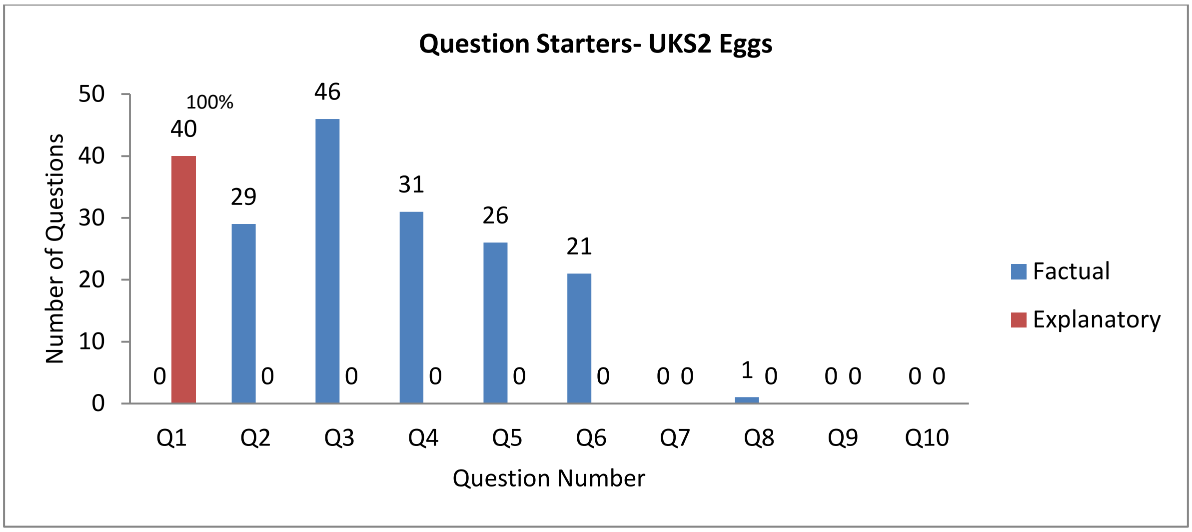


Figure 9.9 Upper KS2 'Eggs': Pattern of Factual and Explanatory Questions

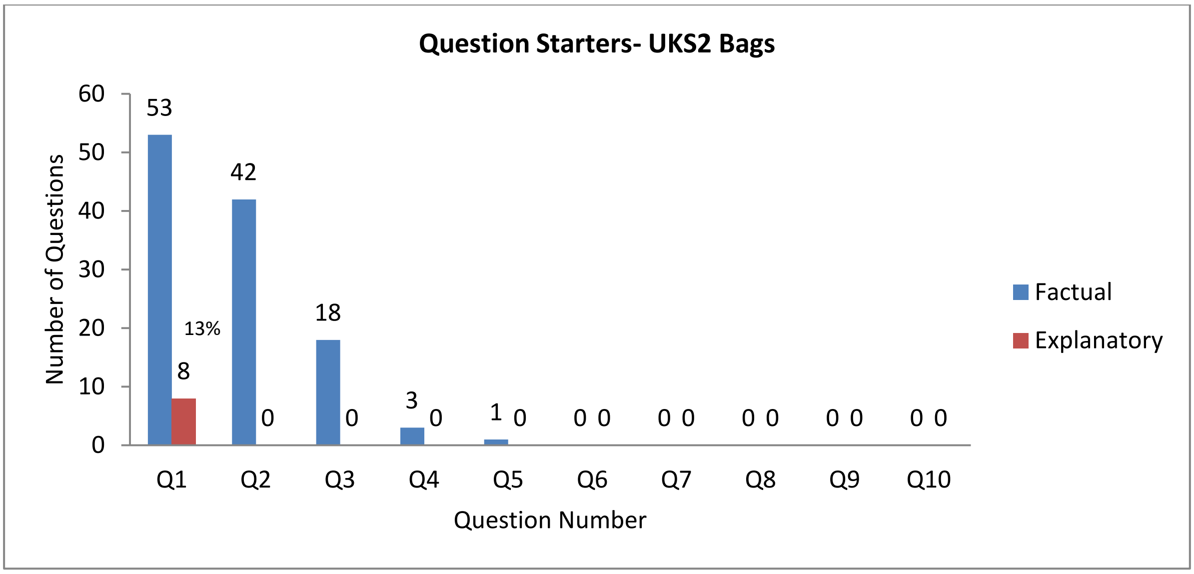


Figure 9.10 Upper KS2 'Bags': Pattern of Factual and Explanatory Questions

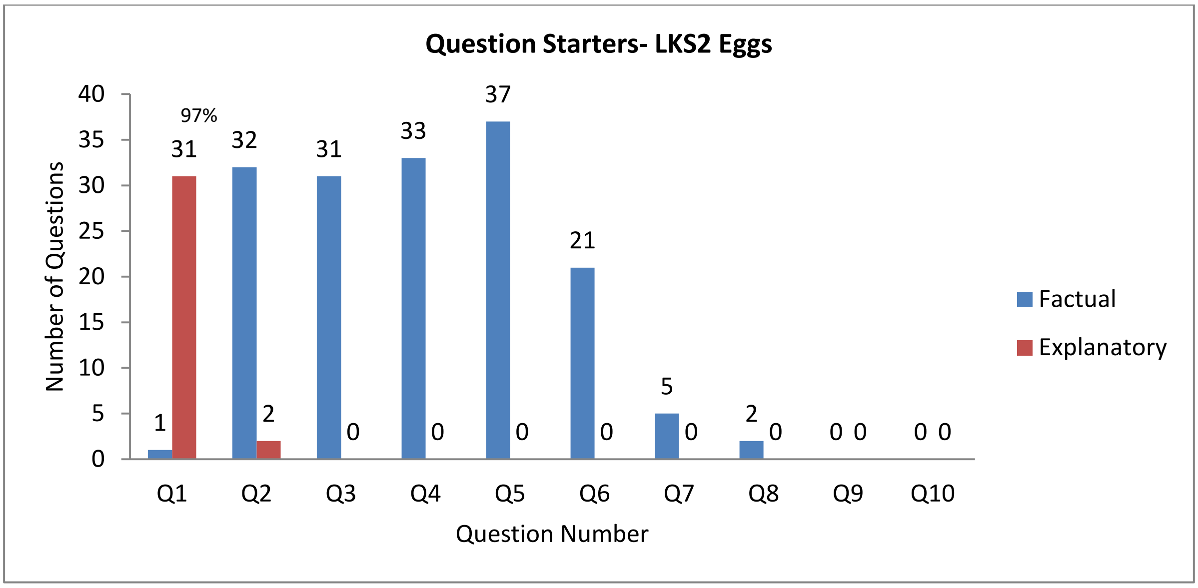


Figure 9.11 Lower KS2 'Eggs': Pattern of Factual and Explanatory Questions

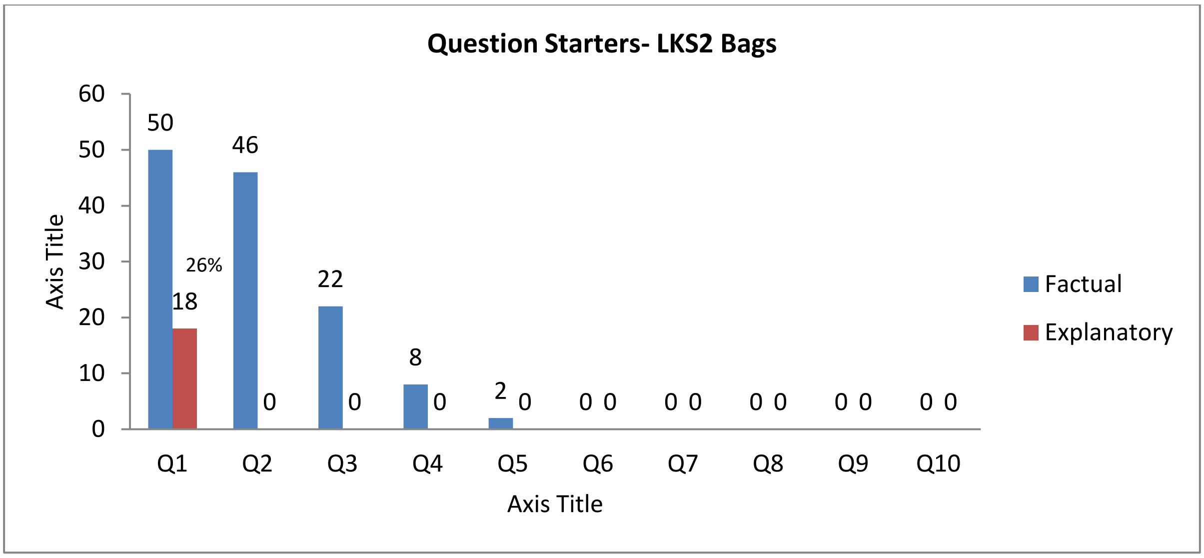


Figure 9.12 Lower KS2 'Bags': Pattern of Factual and Explanatory Questions

9.2.3 RODIN Analysis of Science Questions

Table 9.4 given below summarise the number of questions generated by the use of Question Starters on the giant dice strategy for each category on the RODIN scale (Research, Observation, Demonstration, Investigation and None). Here, most of the science questions generated were those that could be answered by conducting further Research (45%) as well as investigations (52%). When separate RODIN analysis was conducted for the whole KS2 topics 'Eggs' and 'Bags' they showed a similar pattern with majority of questions open to Investigation and Research. It was noticed that some questions which are not in an investigative form, can be re-phrased into an investigative question with the help from the teacher.

Table 9.4 Question Starter Strategy: Summary of RODIN Analysis for the Whole KS2

Topic	**R**	**O**	**D**	**I**	**N**	**Total Science Questions**
Eggs	231	15	0	137	6	389
Bags	65	1	0	203	2	271
Eggs & Bags	296	16	0	340	8	660

9.2.4 Summary

The question starter strategy generated six hundred and fifty eight (658) science questions. There were 159 participants. An average of four science questions, were produced. The six question starters provided were like 'What would happen if...?', 'What happens when....?', 'How would you...?', 'Which.....is/ does....?', 'Which is best for.....?', and 'Will it.....if we....?' Majority of the factual questions were those started with 'Which...?', 'How would you...?' and 'What happens when...?.' In the whole KS2, a high percentage of explanatory questions were generated while suppressing questions asking for facts. It is likely that at Q1 the first question starter used i.e. 'what happens if....'prompted children to think about new situations leading to the asking of higher order questions which are explanatory in nature. Therefore, it can be concluded that by giving specific question starters or stems (e.g. Why...? or What happens if...?) children can be encouraged to ask specific higher order questions like explanatory questions and investigative questions while suppressing factual questions.

Table 9.5 summarise the science questions generated from the whole KS2 using the question starters strategy.

Table 9.5 Question Starter Strategy: Summary of Science Questions Produced from Whole KS2

Schools	No. of Pupils	Males	Females	Factual Questions	Explanatory Questions	Science Questions
LKS2	83	42	41	290 (52%)	51 (52%)	341 (52%)
UKS2	76	30	46	269 (48%)	48 (48%)	317 (48%)
Whole KS2	159	72	87	559	99	658

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

RODIN analysis showed that most of the science questions generated were those that could be answered through conducting research (45%) and investigations (52%). It was noticed that some questions which are not in an investigative form, can be re-phrased into an investigative question with the help from the teacher.

9.2.5 **Preliminary Comments**

- The 'Question Starter' strategy generated 658 questions from 159 participants (an average of 4 questions per person).
- Providing specific question starters or stems forced children to respond to the question stem and complete it leading to the generation of different types of questions.
- The first question starter 'What happens if.....' prompted children to generate more explanatory questions suppressing lower order factual questions.
- RODIN analysis showed giving 'Question Starter' strategy was useful in generating different categories of questions particularly research and investigative questions.

9.3 Strategy 2: The 'Elephant Strategy'

It will be recalled that children were shown three pictures of elephant, one in the wild, in captivity and an elephant embryo and were asked to generate science questions. The questions were later classified as factual or explanatory questions and RODIN questions and the pattern analysed.

9.3.1 Analysis of the number and pattern of factual and explanatory questions a) under whole KS2, upper KS2 and lower KS2

- ***Whole KS2***

Figure 9.13 shows the pattern of factual and explanatory questions generated for the whole KS2. The Q1 in the graph represents all the first science question produced by children, Q2 all the second questions, Q3, third questions, repectively. Therefore for question 1, there were 112 science questions in total and out of them, 89 were factual and 23 were explanatory. As we move from Q1 to Q11, the number of factual questions decreases. Explanatory questions were less at the beginning. Though the number of explanatory questions are high at Q2, the percentage of explanatory questions to the total number of questions is highest at Q5 (31%).This shows that more explanatory questions started to emerge later after gaining some factual knowledge and understanding about the topic. Similar pattern was observed for males and females when analysed separately. Therefore, the data was combined. See figure 9.14 and 9.15 for the separate analysis of males and females. It was noticed that the girls ask more questions than boys in all the groups.

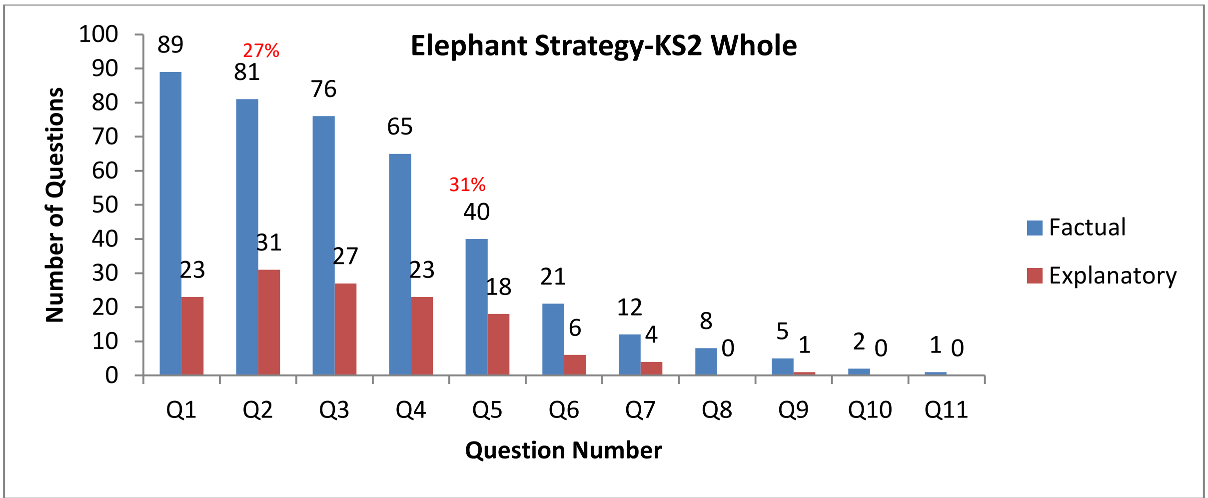


Figure 9.13 KS2 Whole Group: Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the number of science questions i.e. both factual and explanatory questions at each question.)

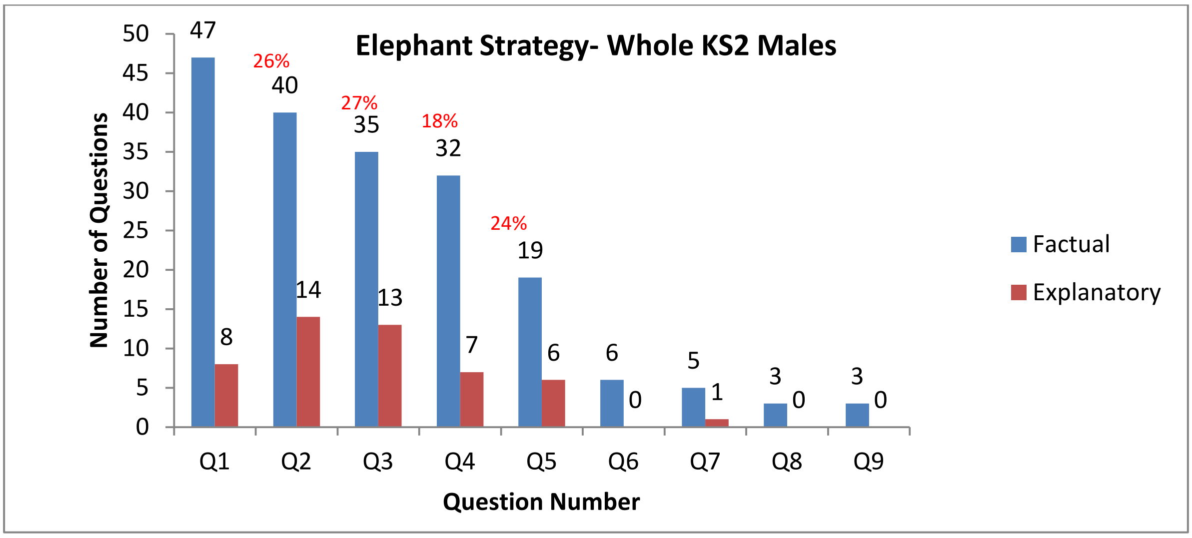


Figure 9.14 Whole KS2 Males: Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the number of science questions i.e. both factual and explanatory questions at each question.)

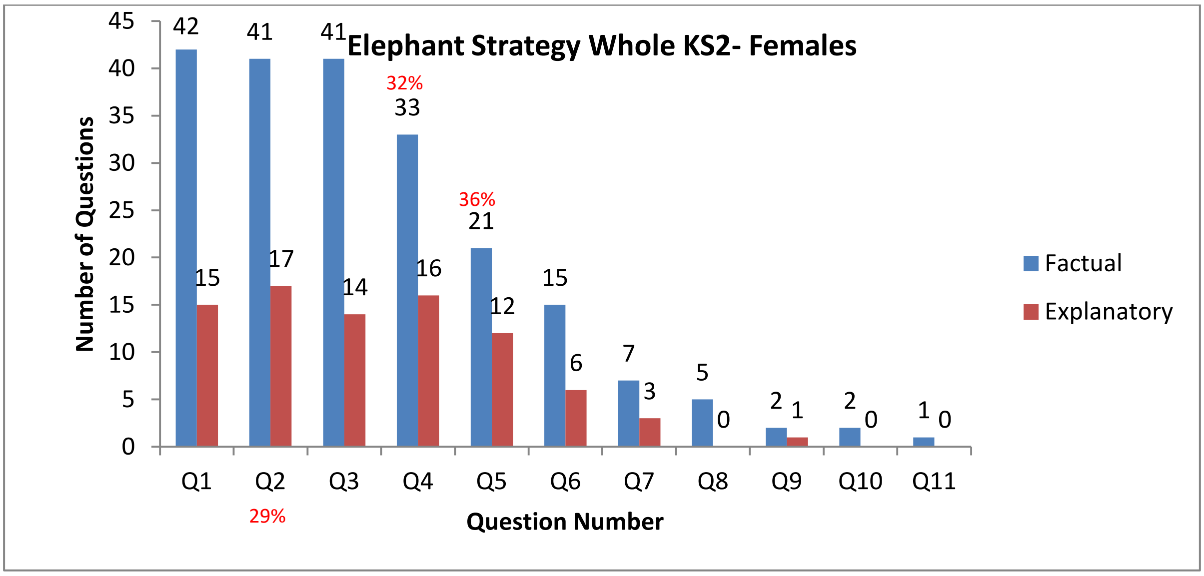


Figure 9.15 Whole KS2 Females: Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the number of science questions i.e. both factual and explanatory questions at each question.)

- ***Upper KS2***

When upper KS2 data was analysed separately factual questions were high in the beginning but they decreased gradually. Explanatory questions were found to be less in the beginning but they peaked at Q2 (44%) and then decreased gradually forming a curve. See figure 9.16. When males and females were analysed separately, a similar high proportion of factual questions were seen at the start. Explanatory questions were fewer initially but showed a sudden increase at Q2 (and then a gradual decline there after. See figures in appendix 6b.

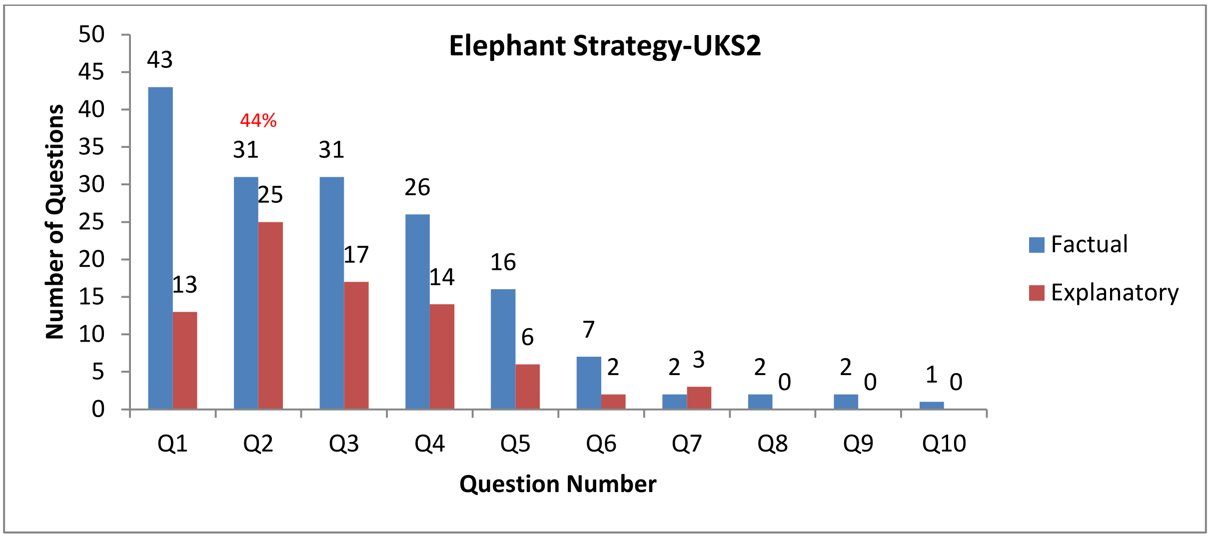


Figure 9.16 UKS2: Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the number of science questions i.e. both factual and explanatory questions at each question.)

- ***Lower KS2***

When lower KS2 data was analysed separately, the factual questions were high initially but they showed a gradual decline. Explanatory questions were lesser at the start but they increased, peaked and then declined. The highest percentage of explanatory questions to the total science questions (33%) were found to be at Q5. A delayed peak of explanatory questions at Q5 was observed with lower KS2 or younger children. See figure 9.17. When lower KS2 males and females were analysed separately, the factual questions were high initially but they showed a gradual decline. Explanatory questions were lesser at the start but they increased, peaked and then declined. See appendix 6b for more figures.

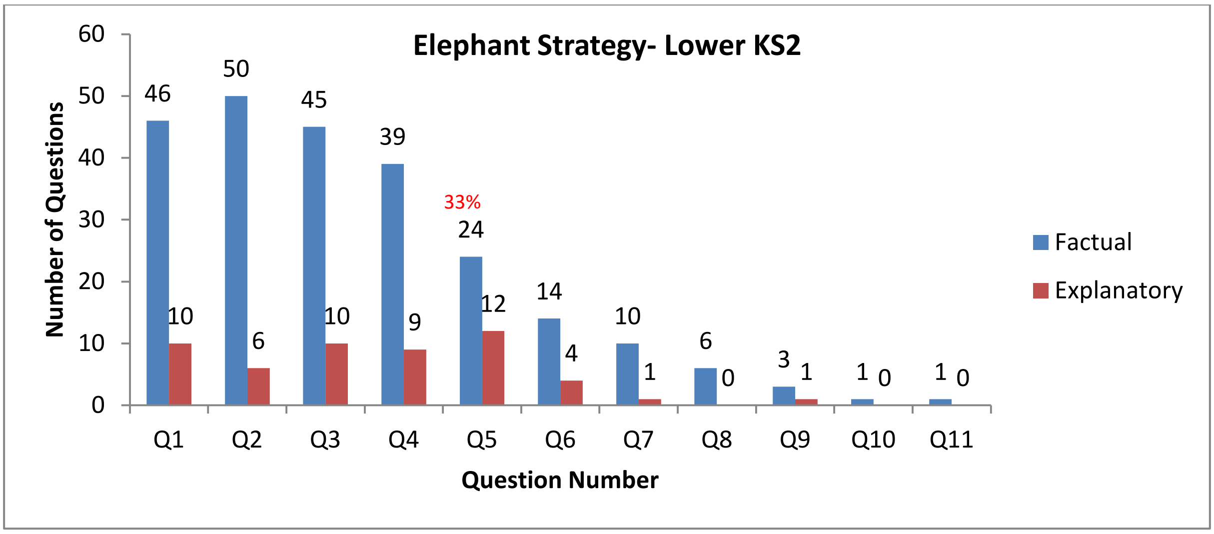


Figure 9.17 Lower KS2: Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the number of science questions i.e. both factual and explanatory questions at each question.)

The responses of children are summarised in the tables below. Separate tables for lower and upper KS2 have been provided. The data has been combined as the patterns of questions were similar. Tables 9.6 and 9.7 summarise the lower and upper KS2 responses. Table 9.8 summarise the combined whole KS2 responses.

Table 9.6 Lower KS2: Summary of Science Questions Based on Gender

Gender	**Factual**	**Explanatory**	**Total**
Males	119 or 49.7%	17 or 32%	136 or 46.5%
Females	120 or 50.2%	36 or 67.9%	156 or 53.4%
Total	239	53	292

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

Table 9.7 Upper KS2: Summary of Science Questions Based on Gender

Gender	**Factual Questions**	**Explanatory Questions**	**Science Questions**
Males	71 (44%)	32 (40%)	103 (43%)
Females	90 (56%)	48 (60%)	138 (57%)
Total	161	80	241

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

Table 9.8 Whole KS2: Summary of Science Questions Based on Gender

Gender	Factual	Explanatory	Total Science Questions
Males	190 or 47.5%	49 or 36.84%	239 or 44.8%
Females	210 or 52.5%	84 or 63.16%	294 or 55.16%
Total	400	133	533

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

9.3.2 Analysis of the number and pattern of factual and explanatory questions b) Based on the topic content: Comparison between Elephant in Captivity, Elephant in the Wild and Elephant Embryo in the Womb

Table 9.9 Whole KS2 Summary of Science Questions Based on Topic

Photo	Factual	Explanatory	Science Questions
Wild	125 or 31.2%	50 or 37.5%	175 or 32.8%
Captivity	135 or 33.7%	59 or 44.3%	194 or 36.3%
Embryo	140 or 35%	24 or 18%	164 or 30.7%
	400	133	533

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

When the whole KS2 was considered, all the three photographs: elephant in the wild, captivity and embryonic elephant, generated similar pattern of science questions. Separate data analysis was carried out for lower, upper and whole KS2 and similar pattern of factual and explanatory questions were observed.Since the three photographs produced similar patterns of questions, the data has been combined and the results are presented below as whole KS2. The elephant in the wild photograph when analysed separately, factual questions were more at the beginning and they declined gradually. Explanatory questions were less at the start but increased and peaked (at question 4 and 5 (40%) and declined. See figure 9.18. The elephant in the captivity photograph when analysed separately, factual questions were more at the beginning but they declined gradually.Explanatory questions were less at the start but peaked and declined. See figure 9.19 given below. Similarly, the elephant embryo photograph when analysed separately, factual questions were more at the beginning but they decreased slowly. Explanatory questions were less at the start but they peaked and declined. A delayed peaking of higher level explanatory questions were seen with all the three photographs.See figure 9.20 given below.

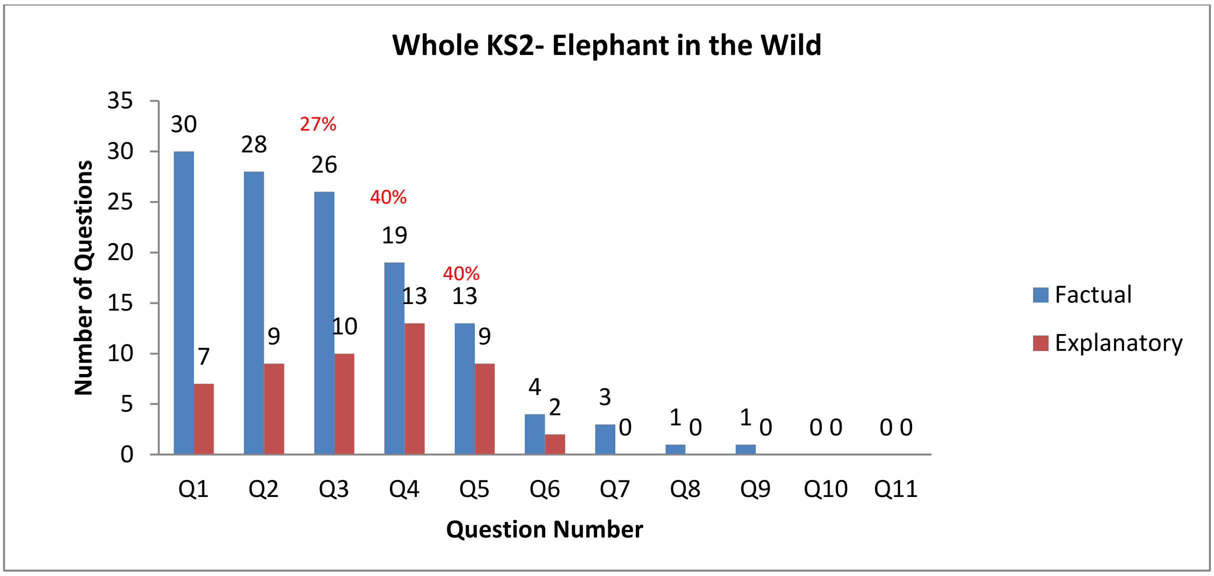


Figure 9.18 Whole KS2: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the number of science questions i.e. both factual and explanatory questions at each question.)

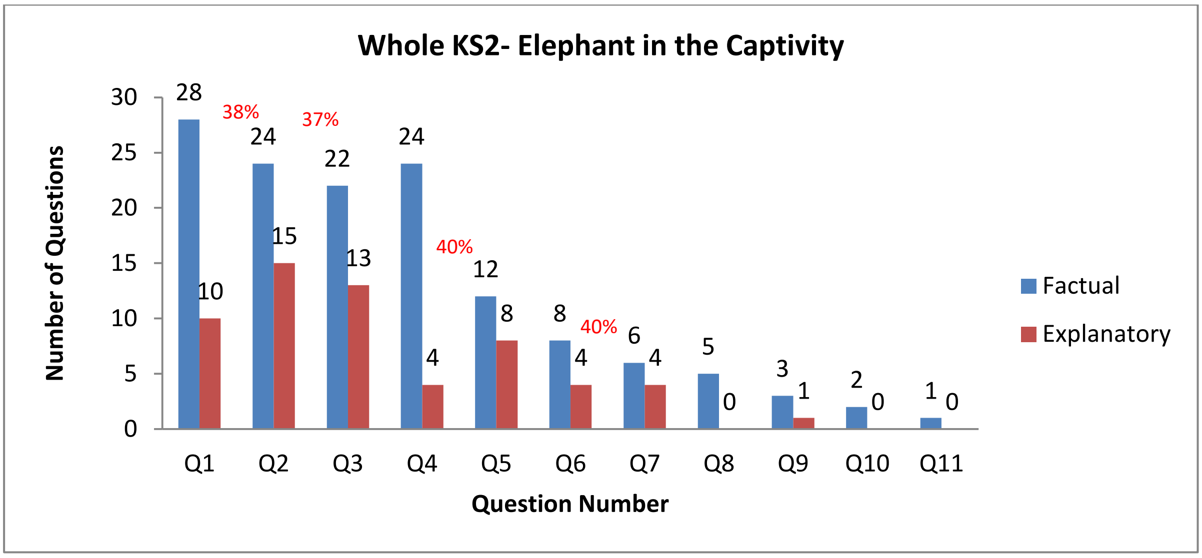


Figure 9.19 Whole KS2: Number and Pattern of Occurrence of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the number of science questions i.e. both factual and explanatory questions at each question.)

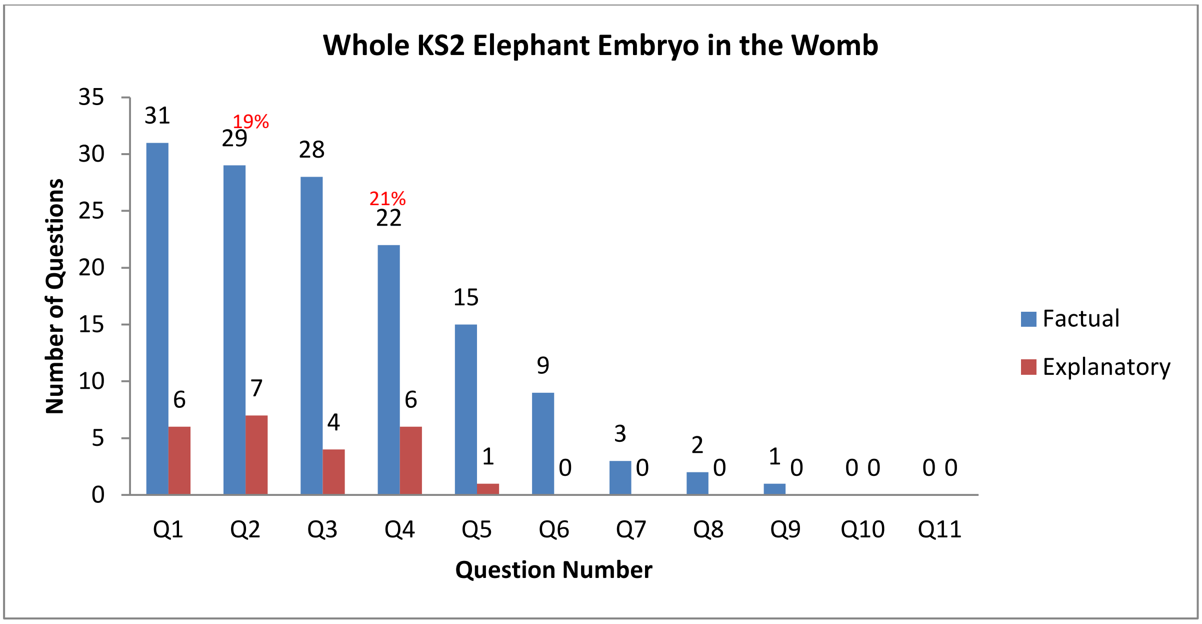


Figure 9.20 Whole KS2: Number and Pattern of Occurrence of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the number of science questions i.e. both factual and explanatory questions at each question.)

9.3.3 RODIN Analysis of Questions

As elephants are not common in the UK context, 97% of science questions generated were research questions that could be answered through research. Children can collect information from books, online searches, videos, photographs etc to answer their questions. When separate RODIN analysis was done all the three photographs generated similar percentages of science questions (elephant embryo photograph generated 31% of science questions, the elephant in the wild, 33% and, the elephant in the captivity produced 36%). Table 9.10 given below displays the RODIN analysis results. Here, several observation questions have been classified as Research questions as elephant is not common in the UK. Examples are, *I wonder how many times does elephant flap their ears? Do elephants use their trunks like snorkels to breathe under water? Where do elephants sleep?*

Table 9.10 Whole KS2: Summary of RODIN Questions

Topics	**R**	**O**	**D**	**I**	**N**	**Science Questions**
Wild	173	0	0	0	2	175
Captivity	194	0	0	0	0	194
Embryo	149	0	0	0	15	164
KS2 Whole	516	0	0	0	17	533

(RODIN: Research, Observation, Demonstration, Investigation and None of these)

9.3.4 **Summary**

The 'Elephant Strategy' generated 533 science questions from 116 children. An average of four science questions were generated per child. Out of the 553 science questions, 400 were factual questions and 133 were explanatory questions. Only 25% of the science questions generated were explanatory questions that push children to explain, predict or apply their knowledge in new contexts. The rest were factual questions requiring recall of facts. Around 90% of the explanatory questions comprised of 'Why..?' and 'I wonder why....?' questions. The rest were mainly 'What if...?' questions. Majority of the scientific questions generated were factual questions asking for descriptive, procedural or quantitative information (What...? Where...? When...? Which...? Who...? Are...? Is....? I wonder what...? How...? I wonder how....? Do...? Does...? Can...? Would...if...? *How long..? How far...?).* The table 9.11 below gives a summary of factual and explanatory questions generated.

Table 9.11 Summary of Science Questions from 'Elephant Strategy': Factual and Explanatory

Primary Stage	Factual Questions	Explanatory Questions	Science Questions
UKS2	161(40%)	80 (60%)	241 (45%)
LKS2	239 (60%)	53 (40%)	292 (55%)
KS2 whole	400	133	533

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

The RODIN analysis of questions concluded that majority (97%) of the science questions generated were Research questions that could be answered through research. Several Observation questions were classified as research questions as elephant is not common in the UK. It was observed that through out the whole KS2, all the three elephant photographs generated a similar high proportion of factual questions from the beginning which then declined slowly. Explanatory questions were fewer at the start but they grew in number, peaked and then declined. With younger children (lower KS2 or 8-9 years) a more delayed peak of explanatory questions was noticed compared to older children (upper KS2 or 10-11 years). As the Elephant topic being novel, children, particularly younger ones might take longer to generate explanatory questions as they have to build an understanding about the situation first by asking factual questions and then progress to explanatory questions to develop deeper causal understanding. Also, as younger children have less prior experience, they may take a little longer than older children to ask explanatory questions.

9.3.5 **Preliminary Comments**

- The strategy generated 533 questions from 116 participants (an average of 4.59 questions per person).
- Only 25% of the science questions generated were explanatory questions that push children to explain, predict or apply their knowledge in new contexts. The rest were were questions asking for recall of facts.
- Explanatory or causal questions were fewer at the start but they increased, peaked and then declined while factual questions predominated from the start.
- It is likely that the elephant topic being novel or unfamiliar, children particularly younger ones took longer to ask explanatory questions (Why...? or What if...?) as they need to build some understanding about the topic first by raising factual questions.
- Elephant photographs being interesting and novel particularly to children in the UK can generate curiosity and an increased desire for knowledge
- RODIN analysis showed majority of questions generated by the Elephant Strategy were Research questions as elephant is not common in the UK.

9.4 Strategy 3: Question Generation Workshop (Real Eggs and Bags)

During question generation workshop, different types of birds' eggs and bags made from different materials were used to elicit questions from children. The questions were later categorised into factual or explanatory questions and RODIN questions and their pattern analysed.

9.4.1 Analysis of the Pattern of Factual and Explanatory Questions a) under whole KS2, upper KS2 and lower KS2

- ***Whole KS2***

In the whole KS2, factual questions were high in the beginning but they declined gradually. Explanatory questions were also high in the beginning which then decreased gradually and disappeared. The highest percentage of explanatory questions was produced at question 3 (Q3, 34%). A similar high proportion of explanatory questions (32% - 34%) were generated between Q1 and Q4. See figure 9.21 given below. When whole KS2 males were considered separately factual questions were more in the beginning but they declined gradually. Though explanatory questions peaked at Q3 higher percentages of explanatory questions were generated particularly between Q1 and Q4, which then decreased and disappeared. See figure 9.22. When whole KS2 females were considered separately, a similar pattern of factual and explanatory questions were noticed. Higher percentages of explanatory questions were generated particularly between Q1 and Q4, which then decreased slowly and disappeared. See figure 9.23. In short, when males and females were analysed separately, similar patterns of factual and explanatory questions were noticed. Therefore, the data has been combined. It was noticed that the girls ask more questions than boys in all the groups.

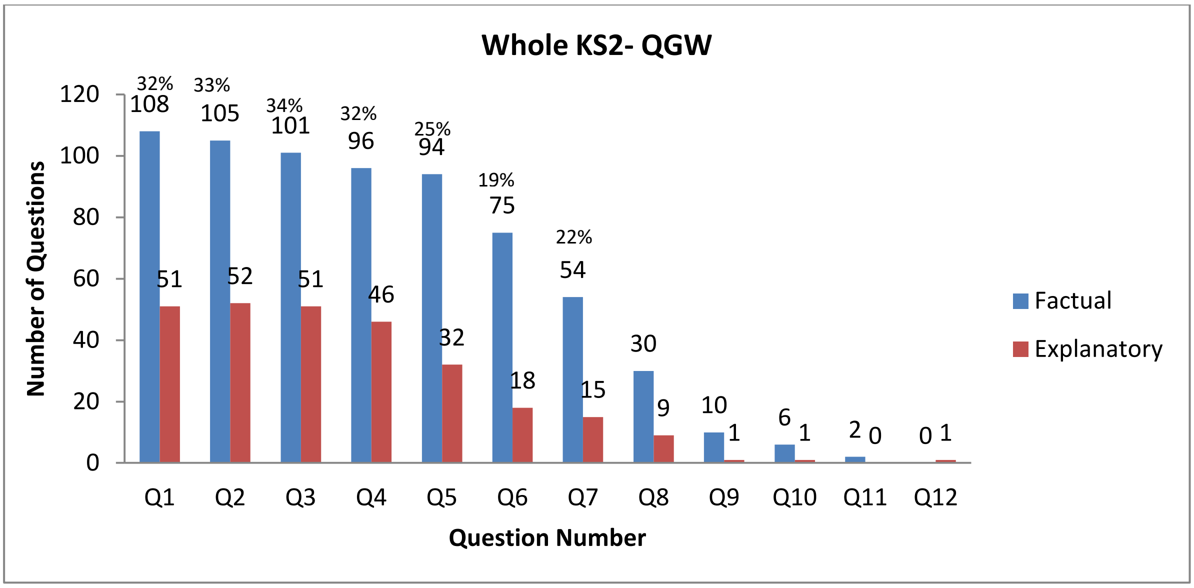


Figure 9.21 Whole KS2: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

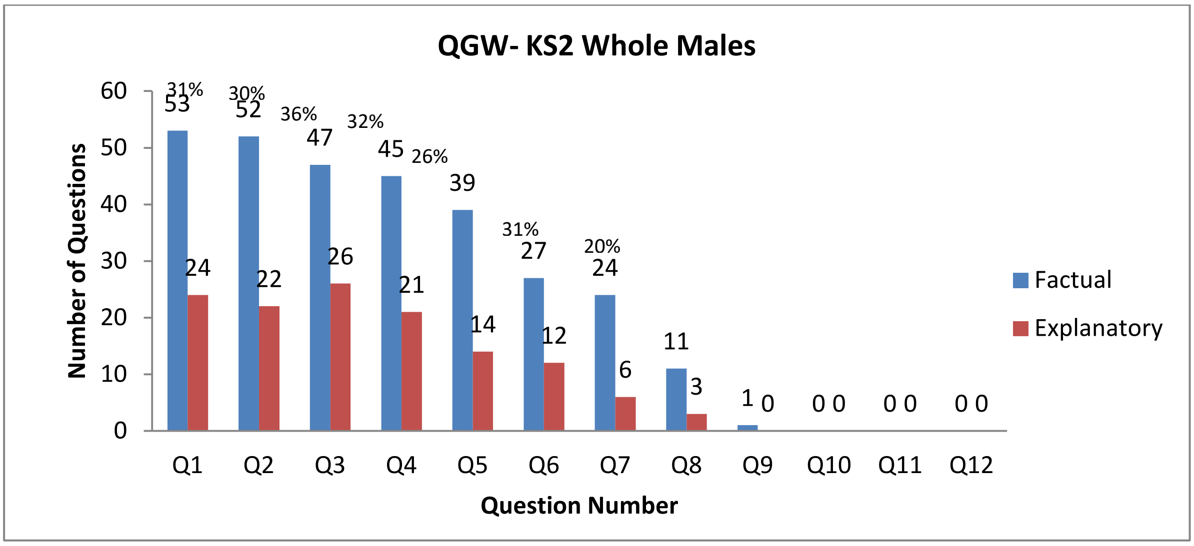


Figure 9.22 Whole KS2 Males: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

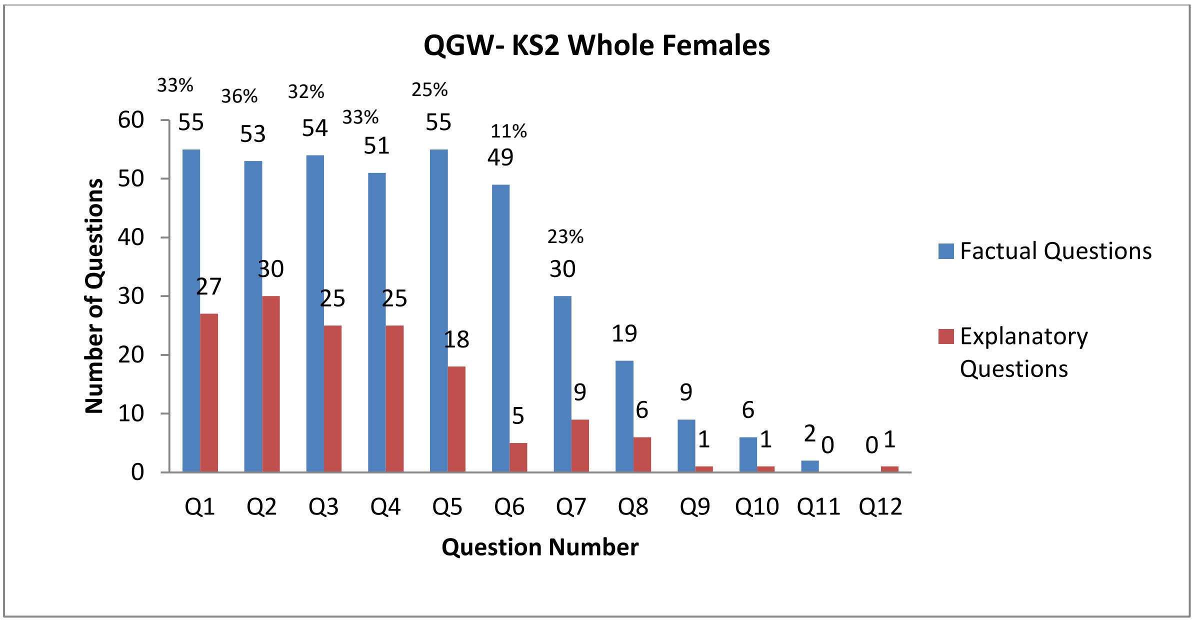


Figure 9.23 Whole KS2 Females: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

- ***Upper KS2***

When upper KS2 data was considered separately, higher proportion of factual questions were noticed at the start, after which they decreased gradually and disappeared. Explanatory questions were more from the start (peak at Q1) and they declined gradually. There were a relatively higher proportion of explanatory questions between Q1 and Q4. See figure 9.24. With upper KS2 males, factual questions were high from the start but they decreased gradually. Explanatory questions were less at Q1, peaked at Q2, and then decilned slowly thereafter. See figure in appendix 6b.With upper KS2 females, factual questions were high at the start but they decreased gradually. Explanatory questions were less at Q1, but they peaked at Q2, and Q4 and decilned slowly thereafter. More explanatory questions were generated from qestion1 or Q1 to Q4. See figure in appendix 6b.

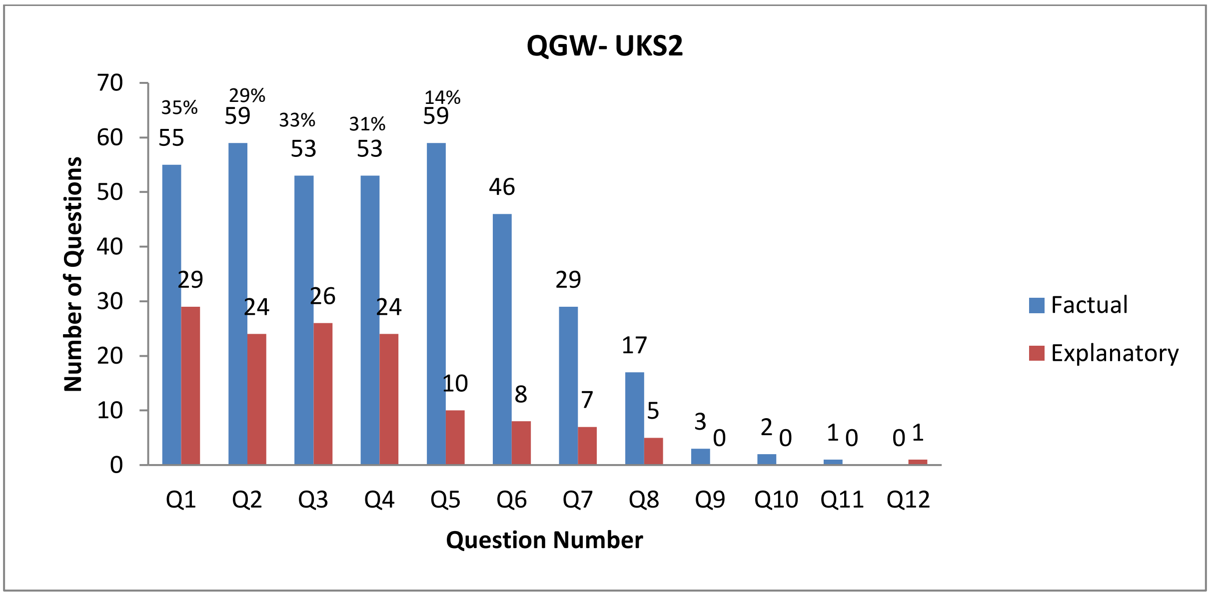


Figure 9.24 Upper KS2: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

- **Lower KS2**

When lower KS2 data was considered separately, factual questions were more in the beginning but they decreased slowly and disappeared. Explanatory questions were less at Q1 but they peaked at Q2 and Q5 and then decreased gradually. A higher percentage of explanatory questions were generated from Q2 to Q5 after which they decreased gradually. See figure 9.25. It is likely that younger children (lower KS2) took slightly longer than older children (upper KS2) to ask explanatory questions. Similar high proportion of factual questions were noticed when females and males were analysed separately. See figures in appendix 6b.

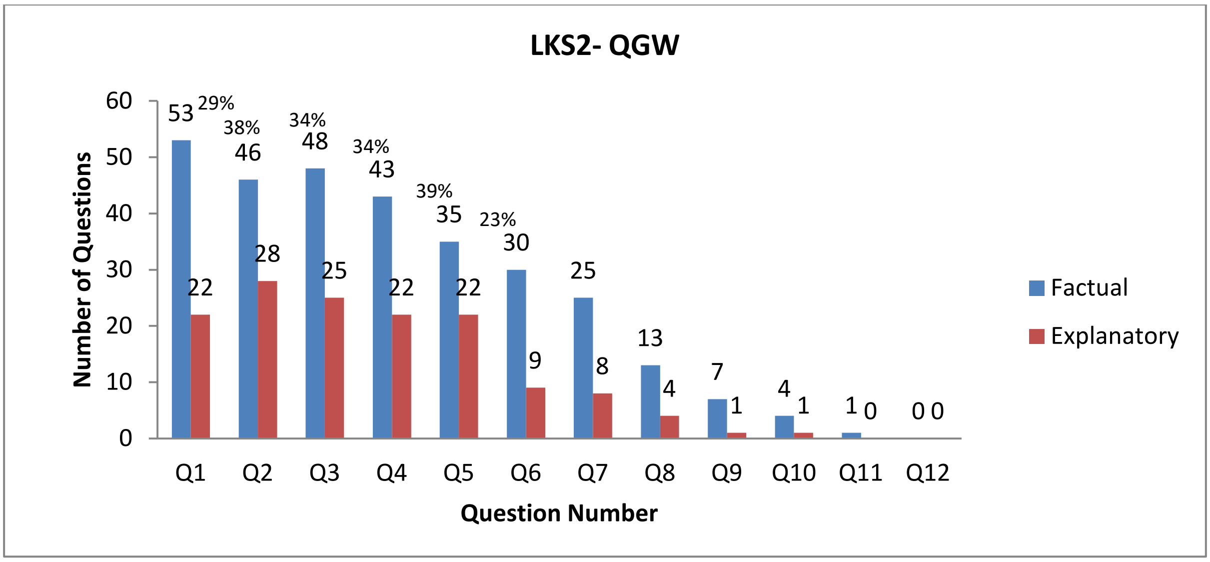


Figure 9.25 Lower KS2: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

The responses of children are summarised in the tables below. Separate tables for lower and upper KS2 have been provided. The data has been combined as the patterns of questions were similar. Tables 9.12 and 9.13 summarise the lower and upper KS2 responses. Table 9.14 summarise the combined whole KS2 responses.

Table 9.12 Whole KS2: Gender wise Summary of Science Questions

Gender	Factual Questions	Explanatory Questions	Science Questions
Males	299 (44%)	128 (46%)	427 (45%)
Females	383 (56%)	148(53%)	531 (55%)
Total	682	276	958

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

Table 9.13 Upper KS2: Gender wise Summary of Science Questions

Gender	Factual Questions	Explanatory Questions	Science Questions
Males	162(43%)	57(43%)	219 (43%)
Females	215 (57%)	77 (57%)	292 (57%)
UKS2	377	134	511

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

Table 9.14 Lower KS2: Gender wise Summary of Science Questions

Gender	Factual Questions	Explanatory Questions	Science Questions
Males	137 (45%)	71 (50%)	208 (47%)
Females	168 (55%)	71 (50%)	239 (53%)
LKS2	305	142	447

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

9.4.2 Analysis of the number and pattern of factual and explanatory questions b) Based on the Topics 'Eggs' and 'Bags'

- ***Whole KS***

When the whole KS2 'Eggs' data was considered separately factual and explanatory questions were more in the beginning but they decreased gradually and disappeared. See figure 9.26. When the whole KS2 'Bags' data was considered separately factual and explanatory questions were more in the beginning but they decreased gradually and disappeared. A high percentage of explanatory questions were produced from the start. See figure 9.27.

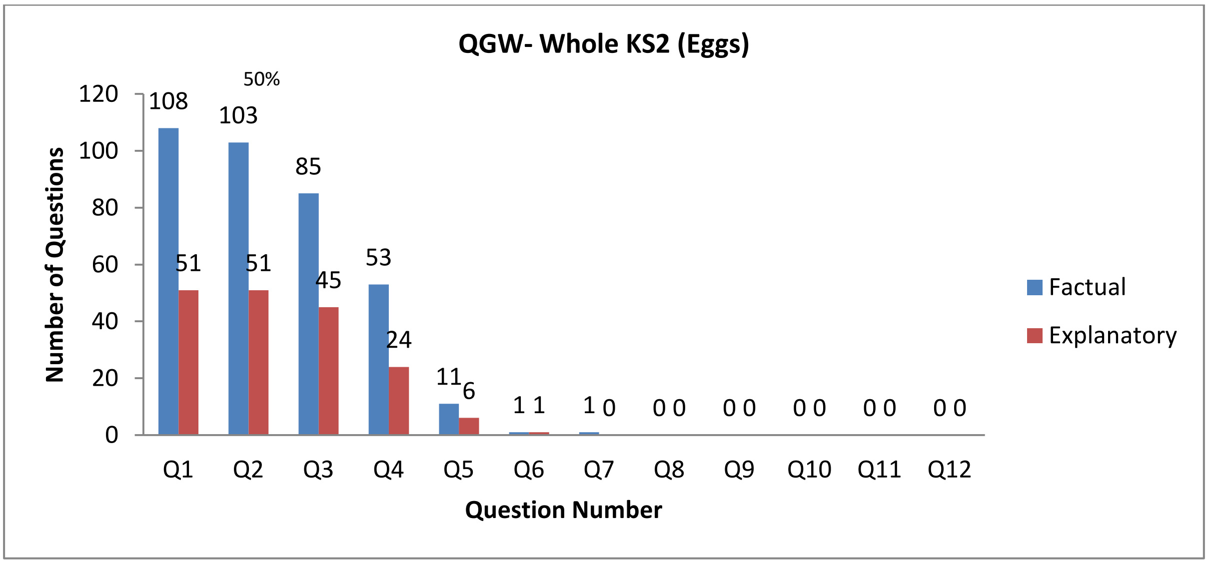


Figure 9.26 Whole KS2 Eggs: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

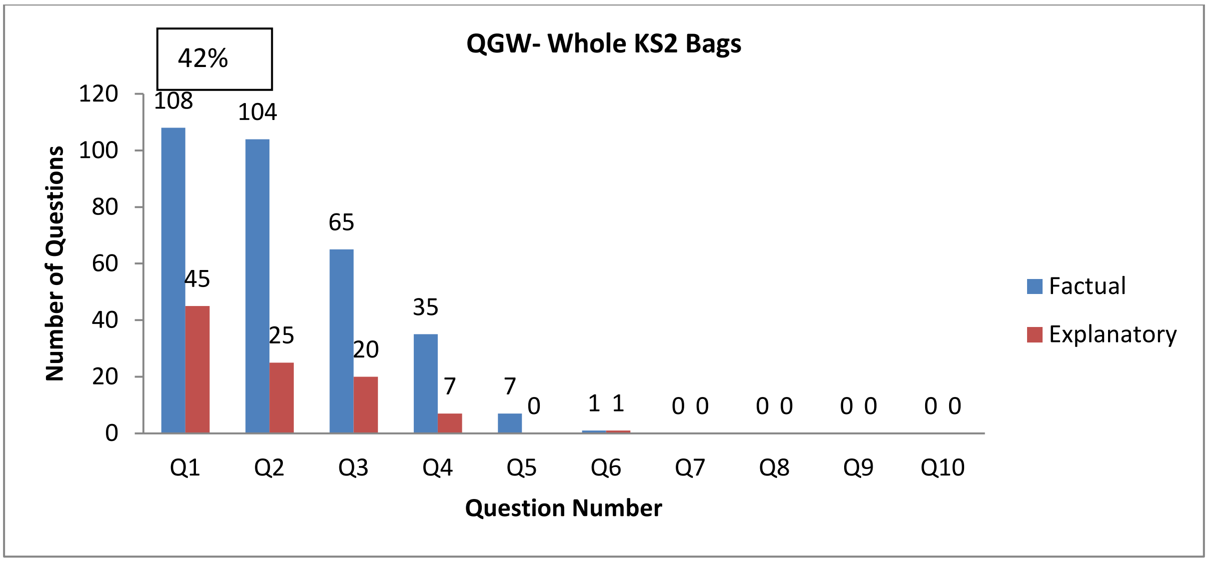


Figure 9.27 Whole KS2 Bags: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

- ***Upper KS2***

When upper KS2 'Eggs' data was considered separately, factual and explanatory questions were more in the beginning but they decreased gradually and disappeared. A high percentage of explanatory questions were produced from the start with older children. See figure 9.28. When the upper KS2 'Bags' data was considered separately factual and explanatory questions were more in the beginning but they decreased gradually and disappeared. A high percentage of explanatory questions were produced from the start with older children with 'Bags' topic. See figure 9.29.

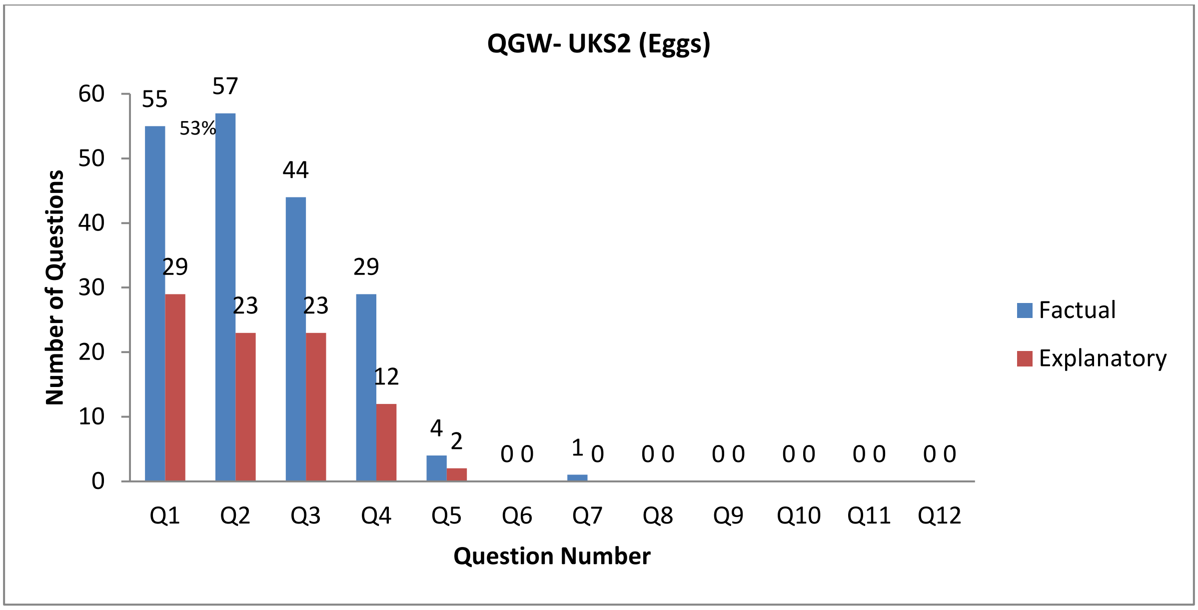


Figure 9.28 Upper KS2 Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

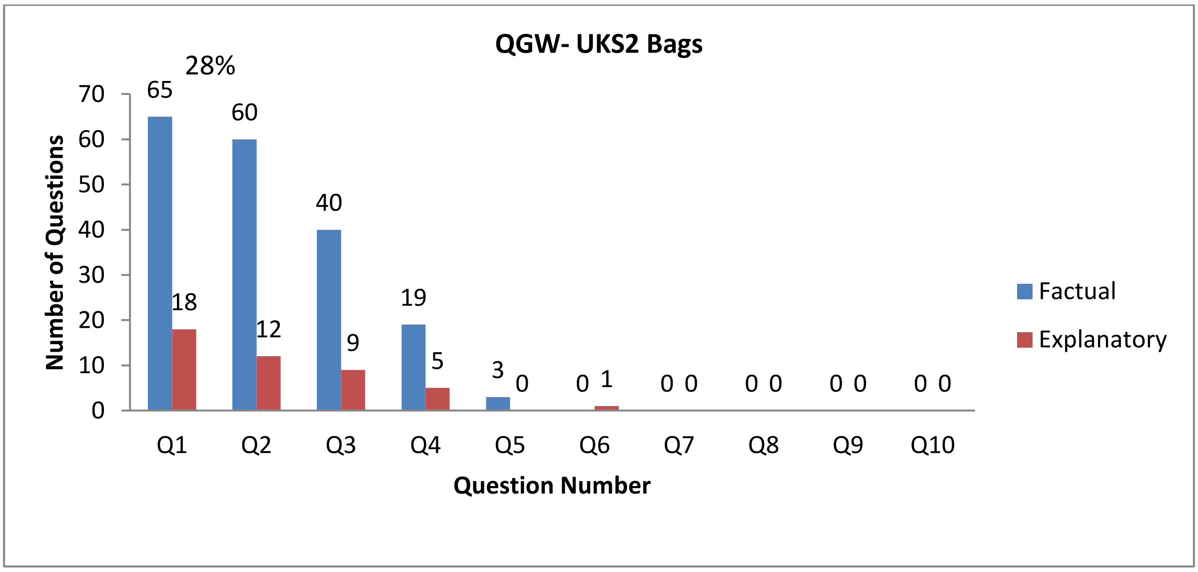


Figure 9.29 Upper KS2 Bags: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

- ***Lower KS2***

When the lower KS2 'Eggs' data was considered separately factual questions were more in the beginning but they decreased gradually and disappeared. Explanatory questions were less at the start but they peaked at Q2 (61%) and then decreased gradually and disappeared. It is likely that younger children with the topic 'Eggs' took slightly longer to ask explanatory questions. See figure 9.31.When the lower KS2 'Bags' data was considered separately factual and explanatory questions were more in the beginning but they decreased gradually and disappeared. A high percentage of explanatory questions emerged from the start for the 'Bags' topic from younger children on contrary to the 'Eggs' topic with which they took slightly longer. See figure 9.32. Tables 9.15 and 9.16 summarise the details of science questions obtained for the Whole KS2 'Eggs' and 'Bags' topics respectively. Table 9.17 summarise the combined whole KS2 responses for both 'Eggs' and 'Bags' topics.

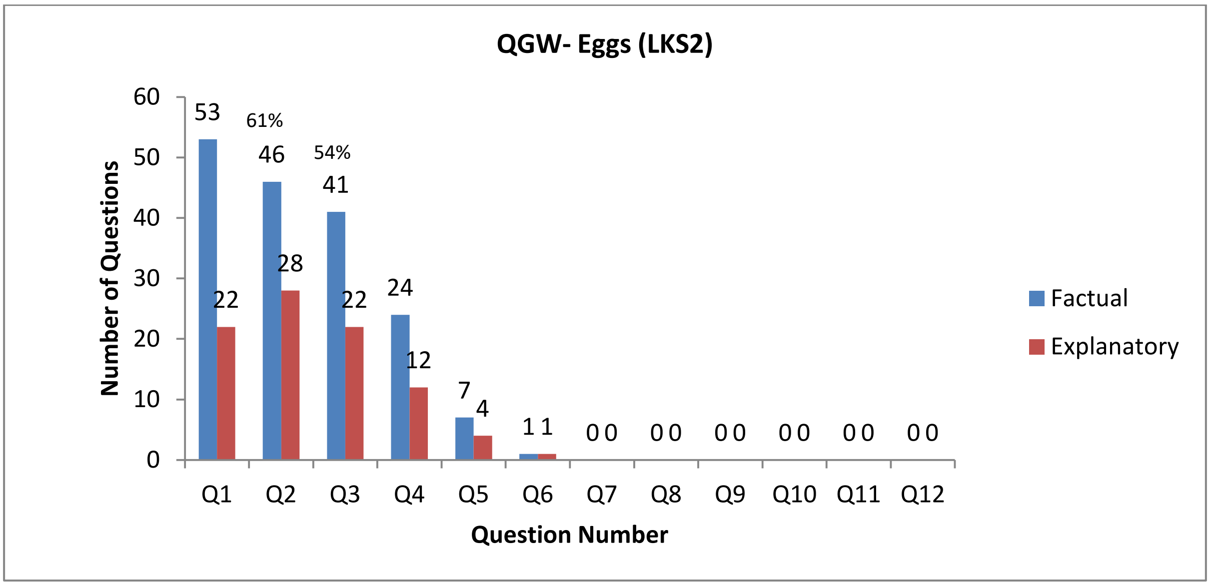


Figure 9.31 LowerKS2: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

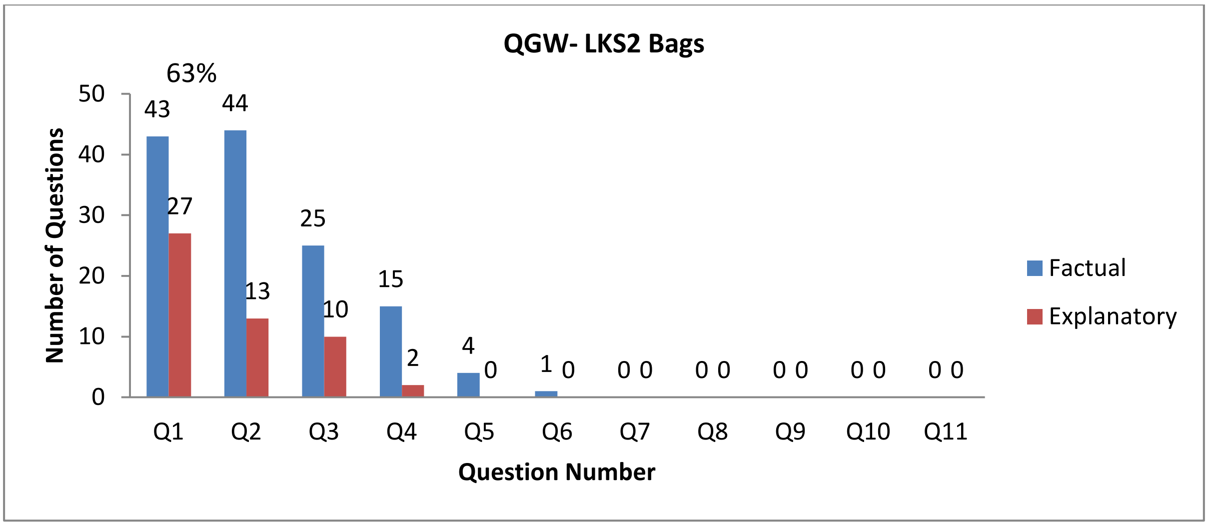


Figure 9.32 Lower KS2 Bags: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

Table 9.15 Whole KS2'Eggs': Summary of Science Questions (both factual and explanatory)

Eggs	Factual Questions	Explanatory Questions	Science Questions
Lower KS2	172	89 (50%)	261
Upper KS2	190	89 (50%)	279
Whole KS2	362	178	540

(Percentages are calculated with respect to the total number of questions in the category explanatory questions.)

Table 9.16 Whole KS2 'Bags': Summary of Science Questions (both factual and explanatory)

Bags	Factual Questions	Explanatory Questions	Science Questions
Lower KS2	133	53 (54%)	186
Upper KS2	187	45 (46%)	232
Whole KS2	320	98	418

(Percentages are calculated with respect to the total number of questions in the category explanatory questions.)

Table 9.17 Whole KS2 Summary of Science Questions Based on Topics 'Eggs' and 'Bags'

Whole KS2	Factual Questions	Explanatory Questions	Science Questions
Eggs	362	178(64.4%)	540 (56.3%)
Bags	320	98(35.5%)	418(43.6%)
	682	276	958

(Percentages are calculated with respect to the total number of questions in the category explanatory questions and science questions.)

From the table, it is clear that the topic 'Eggs' generated approximately 60% of the total explanatory questions while the rest 40% were contributed by the 'Bags' topic for the whole KS2.

9.4.3 **RODIN Analysis**

From RODIN analysis it was observed that 85% of the science questions generated were research questions (researching books, news papers and other online resources, videos etc). 13% of the questions were investigative questions that could be answered through classroom investigations. Less than 1% was observation questions (observing a natural phenomenon, real specimens) that could be answered by conducting observations. A few questions were those that lend to classroom demonstrations. It was noticed that the 'Bags' topic generated 70% of the investigative questions. See Table 9.18 below.

Table 9.18 Number of RODIN Questions Generated from the Topics Eggs & Bags

Topic	Research	Observation	Demonstration	Investigation	None	Total Science Questions
Eggs	491	4	3	40	2	540
Bags	327	3	0	84	4	418
Eggs & Bags	818	7	3	124	6	958

9.4.4 **Summary**

There were 958 science questions raised from 160 children, an average of five science questions per child. Out of the 958 science questions generated, 682 were factual question and 276 were explanatory questions. This shows that only around 30% of the questions were those asking for explanations. They were 'Why...?' 'What.....if...?' and 'What happens when...?'questions. The rest were factual questions. Factual questions included those asking for factual information (What...? When...? Where...? Which...?, Who....?, Will....?, Would....?, Are....?, Can....?, Could....?, Do.....?, Does.....?, Has.....?, Have....?, If......?, In.....?, Is.......?and How.....?).Categories of factual questions evolved were those asking for descriptive, quantitative, procedural and ethical information. Some asks for confirmation of facts, e.g. *'Do the bigger eggs need more incubation?'* A list of both factual and explanatory questions has been provided in the Appendix 6b.This shows that when concrete, real objects were used both younger and older children generated higher level causal questions from the start. The ‘Eggs’ generated more explanatory questions (60%) than those generated by the ‘Bags’ topic (40%). Table 9.19 below summarise the responses obtained for the 'Question Generation Workshop' strategy.

Table 9.19 Summary of Science Questions from the Question Generation Workshop Strategy

Primary Stage	No. of Pupils	Males	Females	Factual Questions	Explanatory Questions	Science Questions
LKS2	76	39	37	305 (45%)	142 (51%)	447 (47%)
UKS2	84	38	46	377 (55%)	134 (49%)	511 (53%)
Whole KS2	160	77	83	682	276	958

(Percentages are calculated with respect to the total number of questions in the category explanatory questions and science questions.)

From RODIN analysis it was observed that 85% of the science questions generated were research questions (researching books, news papers and other online resources, videos etc). 13% of the questions were investigative questions that could be answered through classroom investigations. A few were questions that could be answered by conducting observations and teacher demonstrations.

When upper KS2 'Eggs' data was considered separately, factual and explanatory questions were more in the beginning but they decreased gradually and disappeared. A high percentage of explanatory questions were produced from the start with older children. Having more experience and prior knowledge, older children were quicker to ask explanatory questions. When the lower KS2 'Eggs' data was considered separately factual questions were more in the beginning but explanatory questions were less at the start but they peaked (at Q2 or question 2) and then decreased gradually and disappeared. It is likely that with 'Eggs' topic, younger children took slightly longer to ask explanatory questions. Most of the eggs used in the display except hen's egg were novel or unfamiliar to younger children. Therefore, they asked more factual questions at the start to build their factual base about 'Eggs' and then moved to explanatory questions. With 'Bags' data both upper and lower KS2 children generated more explanatory questions alongside factual questions from the start. A high percentage of explanatory questions emerged from the start for the 'Bags' topic from younger children on contrary to the 'Eggs' topic with which they took slightly longer. Bags being familiar everyday objects, younger children may have found it easier to generate explanatory questions from the start. With real objects, when children had more knowledge base and informal experience, they were quicker to generate explanatory questions.

9.4.5 Preliminary Comments

- The strategy generated 958 questions from 160 participants.
- Only 30% of the science questions generated were explanatory questions that push children to explain, predict or apply their knowledge in new contexts. The rest were were descriptive questions asking for recall of facts.

- With 'Eggs' topic, older children (upper KS2) generated a high percentage of explanatory questions from the start alongside factual questions. On the other hand, with younger children (lower KS2) explanatory questions were less at the start but they peaked (at Q2 or question 2) and then decreased gradually. Younger children took slightly longer to ask explanatory questions with 'Eggs' topic.
- Most of the eggs used in the display except hen's egg were novel or unfamiliar to younger children and therefore they asked more factual questions at the start to build their knowledge base and then moved to the asking of more explanatory questions. Having more experience and prior knowledge, older children were quicker to ask more explanatory questions.
- With 'Bags' topic younger children asked more explanatory questions alongside factual questions from the start like their older counterparts.
- With real objects, when children had more knowledge base and informal experience, they were quicker to generate explanatory questions.
- RODIN analysis showed majority of questions generated by the Question Generation Workshop using real eggs and bags were Research questions. Some of the questions were investigative questions or questions that could be turned to classroom investigations. A few questions that lend to observations and teacher demonstrations were also there.

9.5 Strategy 4: Science Stories

It can be recalled that children were given worksheets with photographs of two real life situations in a story form and were asked to write questions. The two scenarios given were a 'Double Yolk' egg and a 'Foraging Cow'.

9.5.1 Analysis of the number and percentages of factual and explanatory questions a) under whole KS2, upper KS2 and lower KS2

- ***Whole KS2***

The pattern of science questions were analysed and the results are presented as separate sections in the order: KS2 whole group, upper KS2 and lower KS2. In whole KS2, science stories generated more factual and explanatory questions from the beginning and they decreased gradually and disappeared. Explanatory questions peaked at Q1 (55%). See figure 9.33. Children started asking higher order causal questions from the start. When males were considered separately, factual and explanatory questions were high in the beginning and they declined some what gradually. The maximum number e of explanatory questions was seen at Q1 (55%). See figure 9.34. With females, a similar high proportion of factual and explanatory questions were observed from the start. See figure 9.35. In other words, when males and females were considered separately, similar pattern of factual and explanatory questions were observed. Therefore, the data has been combined. It was noticed that the girls ask more questions than boys in all the groups.

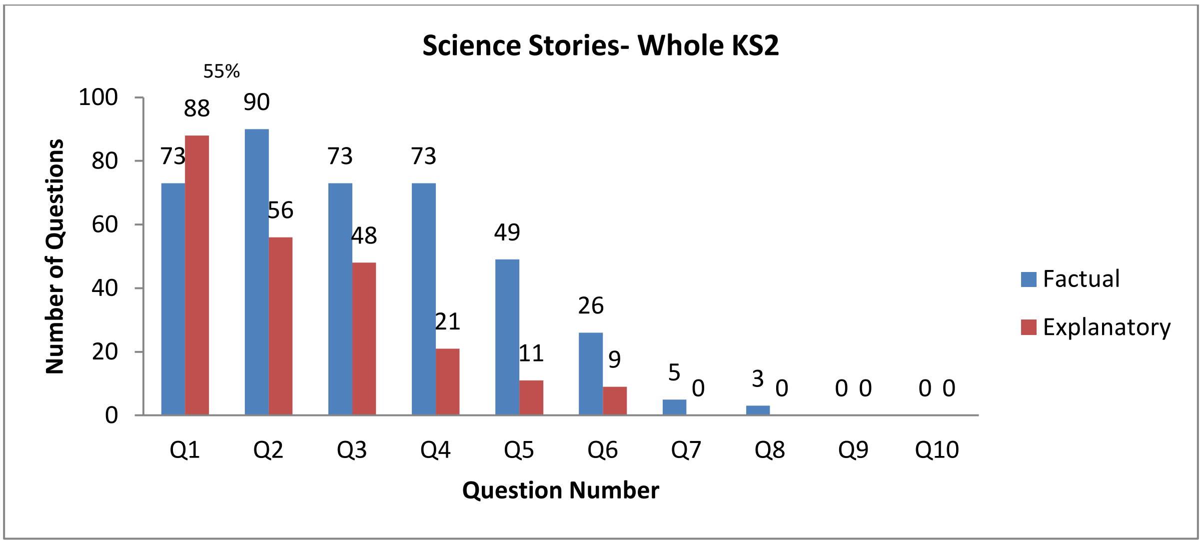


Figure 9.33 Whole KS2: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

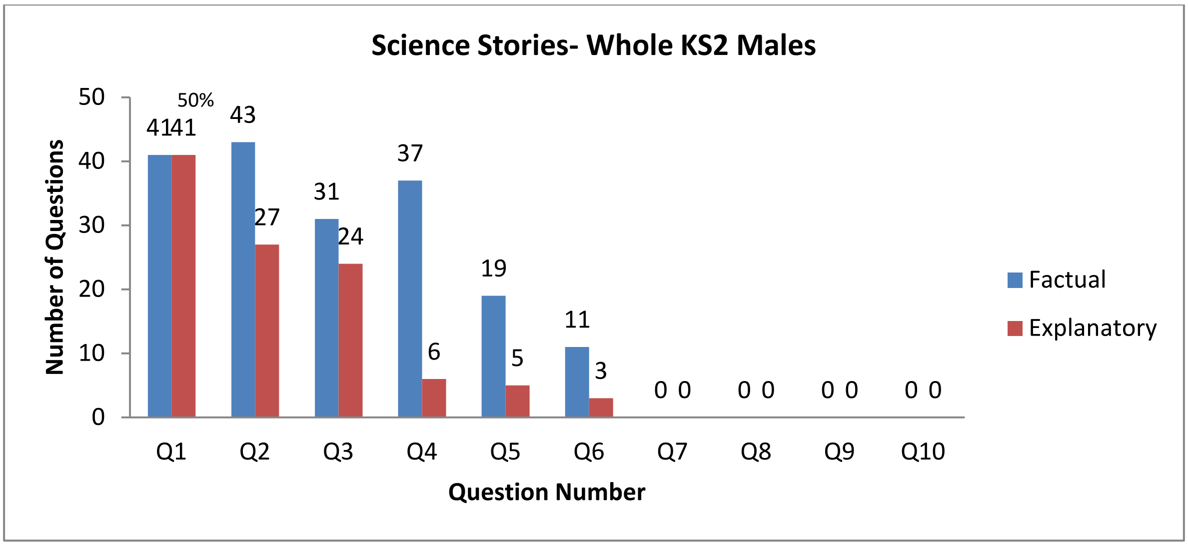


Figure 9.34 Whole KS2 Males-Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

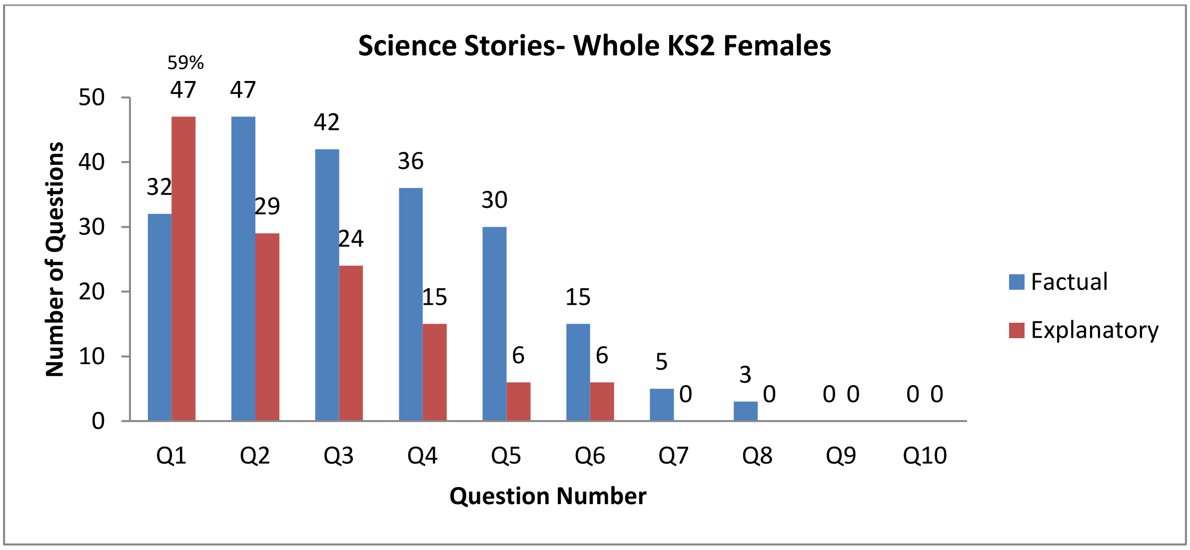


Figure 9.35 Whole KS2 Females: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

- ***Upper KS2***

When upper KS2 data was considered separately, a high proportion of factual and explanatory questions were noticed in the beginning after which they decreased gradually and disappeared. See figure 9.36 given below. When upper KS2 males were considered separately, higher proportion of factual as well as explanatory questions were produced in the beginning, after which they declined and disappeared. Children generated higher level explanatory questions from the start. Maximum percentage of explanatory questions was observed at Q1 (43%). When UKS2 females were analysed separately explanatory questions were generated at the start, especially at Q1 (58%) and they decreased gradually along with factual questions. See figures given in the appendix 6b for males and females separate analysis.

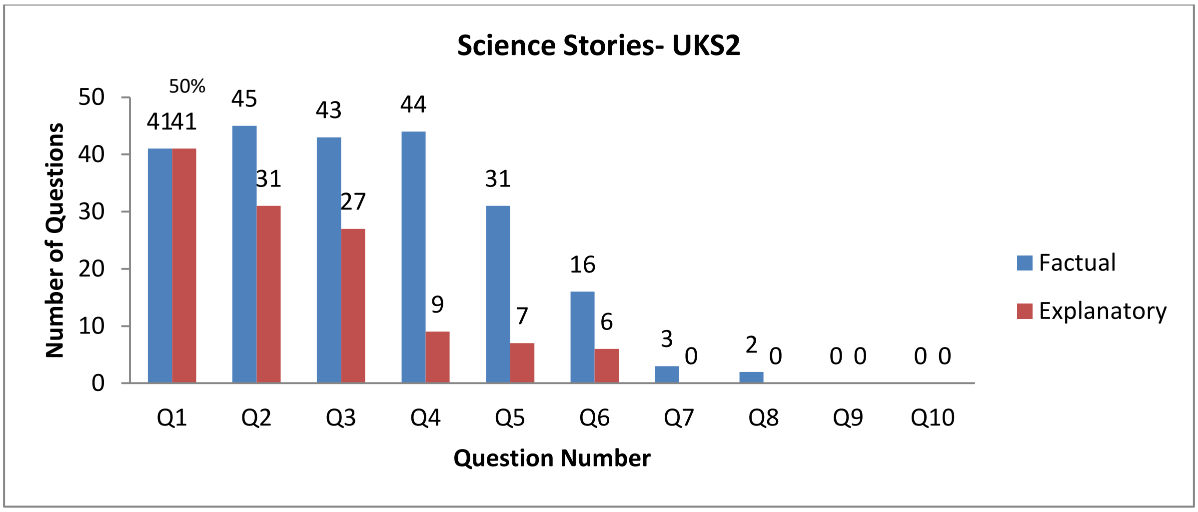


Figure 9.36 Upper KS2: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

- ***Lower KS2***

When lower KS2 was analysed separately, explanatory questions were high in the beginning but they declined gradually and disappeared alongside factual questions. See figure 9.37. When LKS2 males were analysed separately, more explanatory questions were generated at the start, especially at Q1 (58%) and they decreased gradually alongside factual questions. Explanatory questions peaked at Q1 (62%) A similar pattern of factual and explanatory questions were observed with LKS females. See figures given in the appendix 6b.

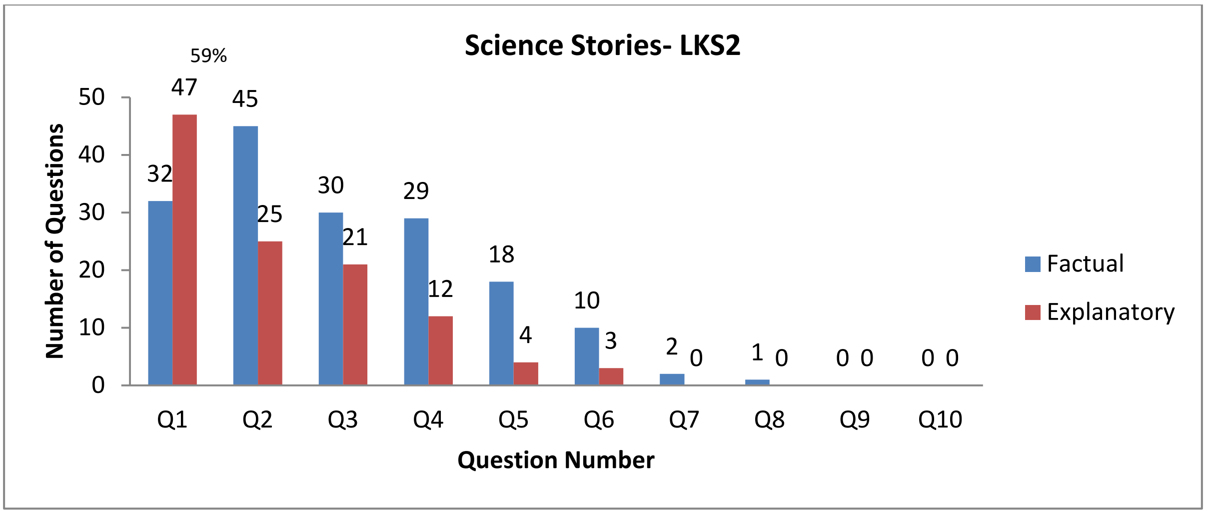


Figure 9.37 Lower KS2: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

The responses obtained from children are summarised in the tables below. Separate tables for lower and upper KS2 have been provided. The data has been combined as the patterns of questions were similar. Tables 9.20 and 9.21 summarise the lower and upper KS2 responses. Table 9.22 summarise the combined whole KS2 responses.

Table 9.20 Lower KS2Gender: Number and Patterns of Factual and Explanatory Questions

Gender	Factual Questions	Explanatory Questions	Total Science Questions
Males	76 (46%)	52 (46%)	128 (46%)
Females	91 (55%)	60 (54%)	151 (54%)
LKS2	167	112	279

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

Table 9.21 Upper KS2 Gender: Number and Patterns of Factual and Explanatory Questions

Gender	Factual Questions	Explanatory Questions	Total Science Questions
Males	106 (47%)	54 (45%)	160 (46%)
Females	119 (53%)	67 (55%)	186 (54%)
UKS2	225	121	346

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

Table 9.22 Whole KS2 Gender: Number and Patterns of Factual and Explanatory Questions

Gender	Factual Questions	Explanatory Questions	Total Science Questions
Males	182 (46%)	106 (45%)	288 (46%)
Females	210 (54%)	127 (55%)	337 (54%)
Whole KS2	392	233	625

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

9.5.2 Analysis of the number and pattern of factual and explanatory questions b) Based on the topic content

When the whole KS2 'Double Yolk' egg data was considered separately factual and explanatory questions were more in the beginning but they decreased gradually and disappeared. The maximum proportion of explanatory questions was noticed at Q1 (24%). Though, children asked explanatory questions from the start, they were less when compared to the proportion of factual questions (shorter bars). See figure 9.38.When the whole KS2 'Foraging Cow' story data was considered separately, factual and explanatory questions were more in the beginning but they decreased gradually and disappeared. There was higher proportion of explanatory questions, alongside factual questions from the start. See figure 9.39.

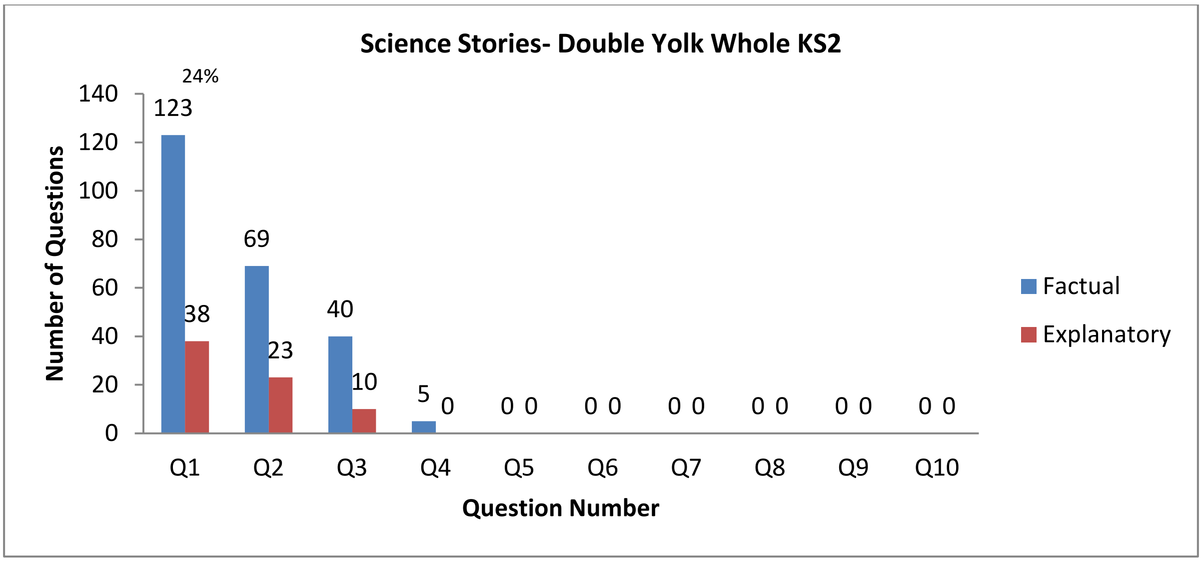


Figure 9.38 Whole KS2 Double Yolk: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

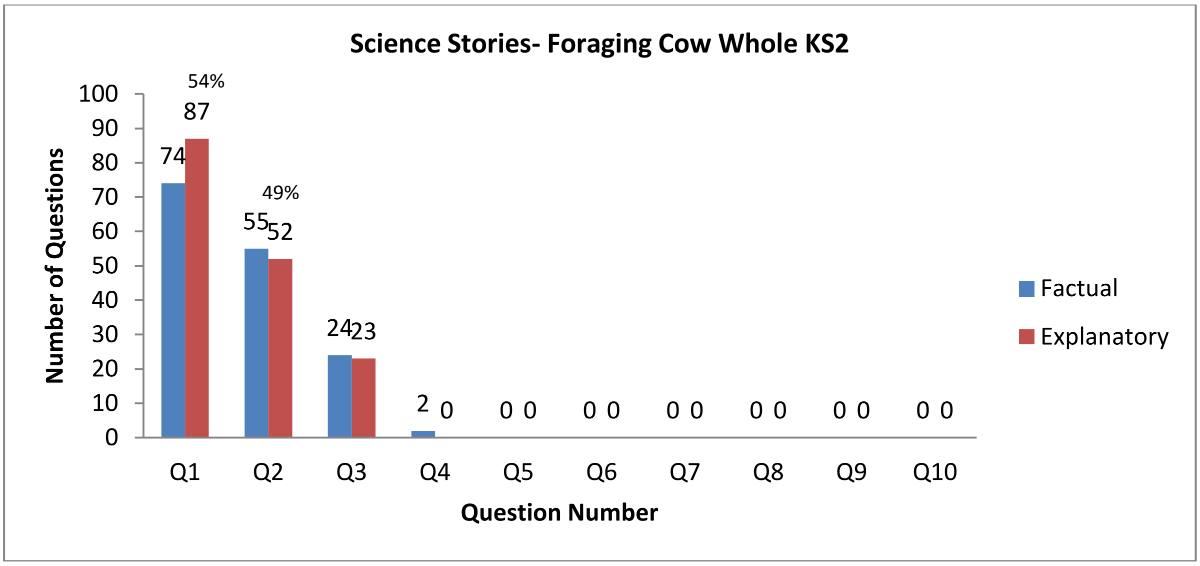


Figure 9.39 Whole KS2 Foraging Cow: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

- ***Upper KS2***

When the upper KS2 'Double Yolk' egg data was considered separately factual and explanatory questions were more at the start but they decreased gradually and disappeared. The maximum proportion of explanatory questions was noticed at Q1 (20%). See figure 9.40. When the upper KS2 'Foraging Cow' data was considered separately factual and explanatory questions were more in the beginning but they declined gradually. There was very high proportion of explanatory questions alongside factual questions from Q1 to Q3. See figure 9.41. Compared to the topic 'Double Yolk' egg, this generated a higher proportion of explanatory questions.

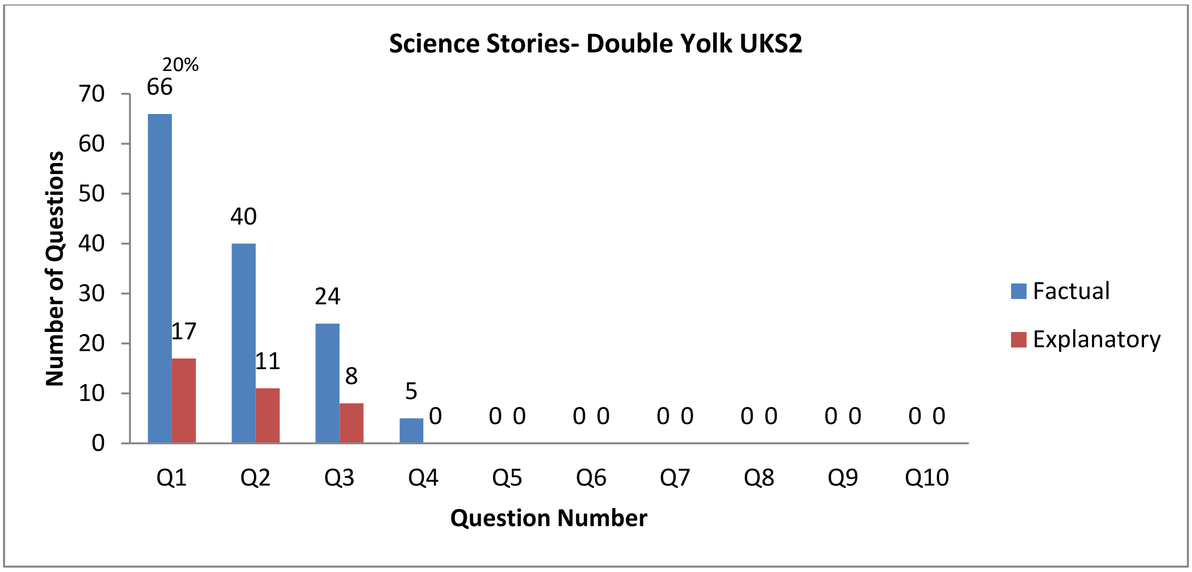


Figure 9.40 Upper KS2 Double Yolk: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

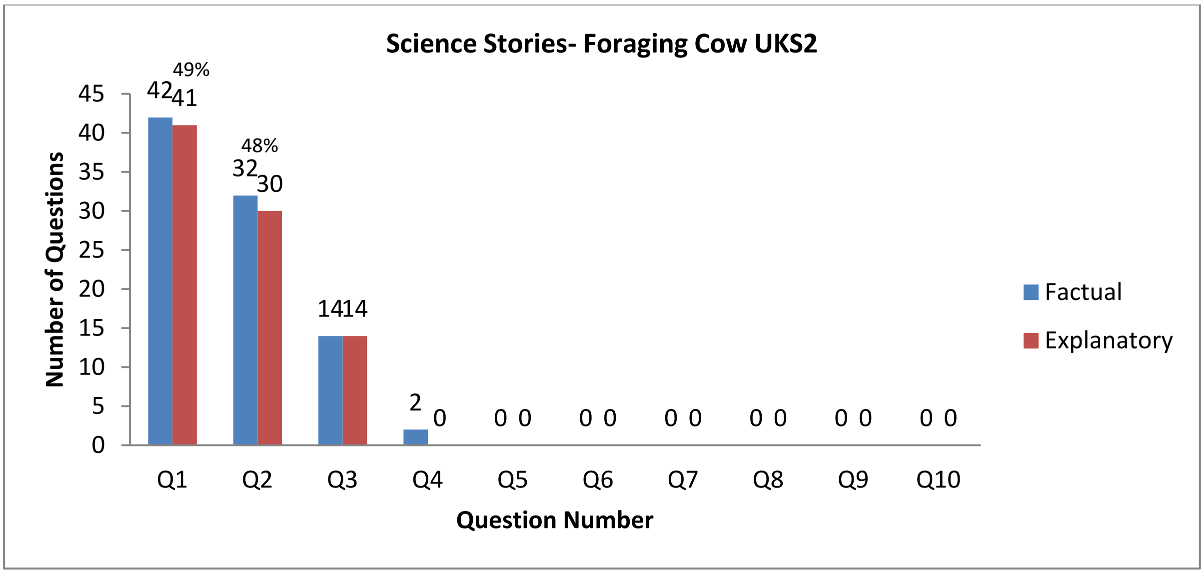


Figure 9.41 Upper KS2 Foraging Cow: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

- ***Lower KS2***

When the lower KS2 'Double Yolk' egg data was considered separately factual and explanatory questions showed a similar trend, both were more in the beginning but declined gradually and disappeared. The maximum proportions of explanatory questions were noticed at Q1 (27%). Although, children asked explanatory questions from the start, their proportions were less when compared to factual questions (shorter explanatory (browns) bars). See figure 9.42.When the lower KS2 'Foraging Cow' data was considered separately factual and explanatory questions were more in the beginning but they declined gradually. There was very high proportion of explanatory questions from Q1 to Q3. The maximum percentage of explanatory questions was noticed at Q1 (59%). Compared to the topic 'Double Yolk' egg, the topic 'Foraging Cow' generated a higher proportion of explanatory questions, from Q1 to Q3 (longer explanatory (brown) bars). See figure 9.43.

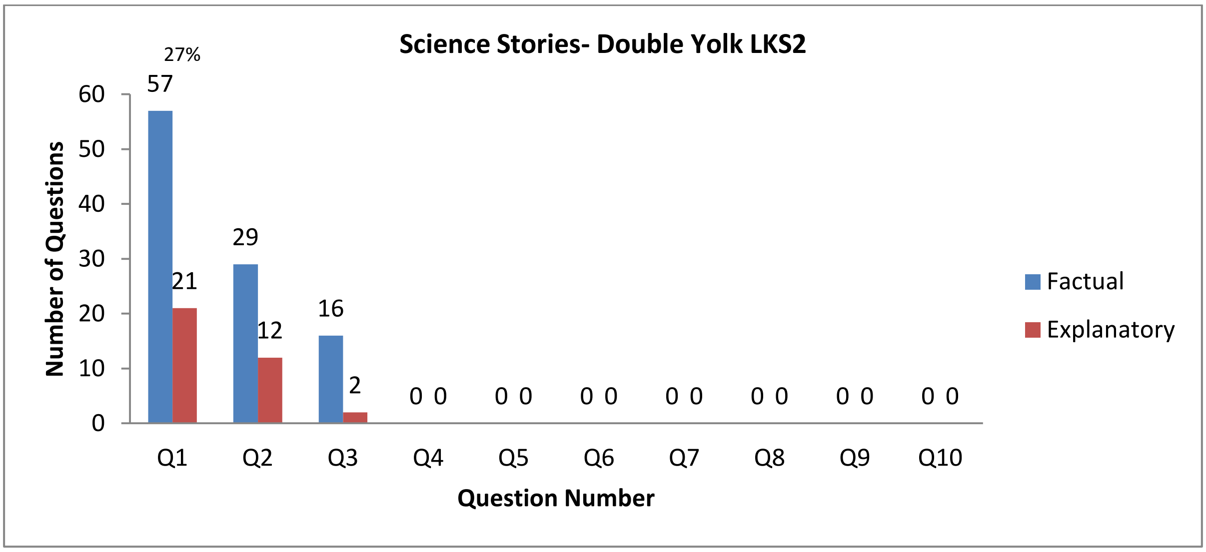


Figure 9.42 Lower KS2 Double Yolk: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

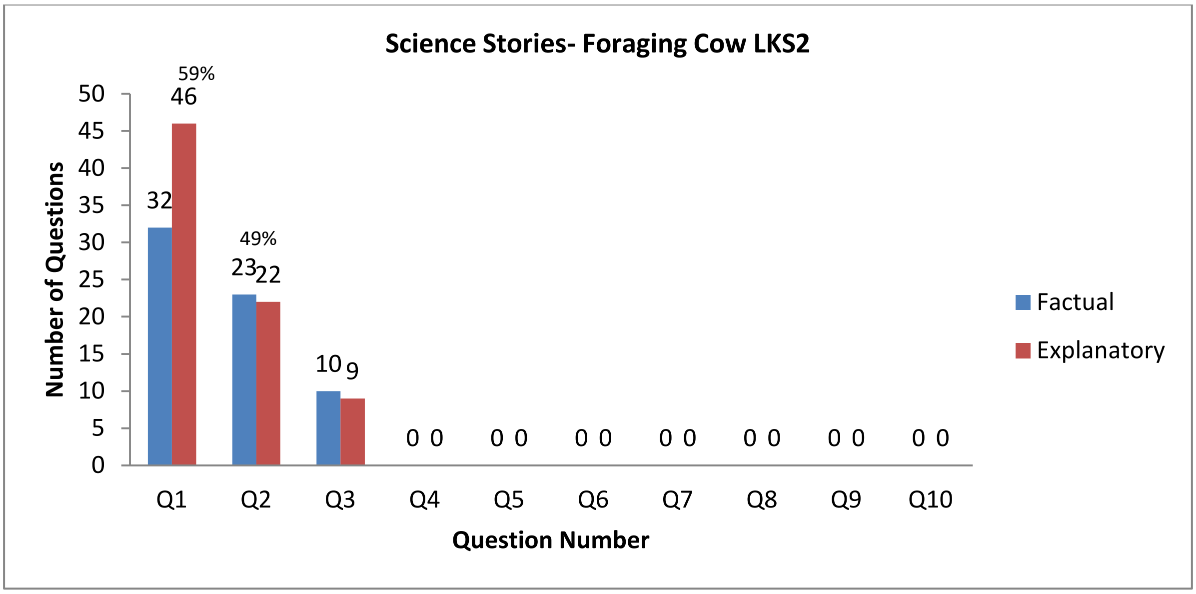


Figure 9.43 Lower KS2 Foraging Cow: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

From the table given below it is clear that the topic 'Foraging Cow' generated 70% of explanatory questions while the rest 30% were produced by the topic 'Double Yolk' egg in the whole KS2. Tables 9.23 and 9.24 summarise the details of science questions obtained for the whole KS2 'Double Yolk' eggs and 'Foraging Cow' topics respectively. Table 9.25 summarise the combined whole KS2 responses for both the topics.

Table 9.23 Whole KS2: Summary of Science Questions (Topic 'Double Yolk')

Double Yolk	**Factual Questions**	**Explanatory Questions**	**Science Questions**
Lower KS2	102	35 (49%)	137
Upper KS2	135	36(51%)	171
Whole KS2	237	71	308

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

Table 9.24 Whole KS2 Topic 'Foraging Cow': Summary of Science Questions

Foraging Cow	**Factual Questions**	**Explanatory Questions**	**Science Questions**
Lower KS2	65	77 (48%)	142
Upper KS2	90	85 (52%)	175
Whole KS2	155	162	317

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

Table 9.25 Whole KS2 Summary of Science Questions Based on Topics 'Double Yolk' and 'Foraging Cow'

Whole KS2	Factual Questions	Explanatory Questions	Total Science Questions
Double Yolk	237	71(30%)	308 (49%)
Foraging Cow	155	162 (70%)	317 (51%)
	392	233	625

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

9.5.3 **RODIN Analysis**

Majority of the questions generated by the strategy Science Stories were Research questions that could be answered through researching by reading books, online resources etc. When separate RODIN analysis was conducted for 'Double Yolk' egg and 'Foraging Cow' topics, it was seen that the 'Double Yolk' egg topic generated around 50% of the science questions while the rest were generated by the 'Foraging Cow' topic. See Table 9.26 below for the details of RODIN analysis of questions.

Table 9.26 RODIN Analysis Summary-Whole KS2

Topics	R	O	D	I	N	Science Questions
Double Yolks	303	0	0	0	5	308
Foraging Cow	309	0	0	0	8	317
Double Yolks & Foraging Cow	612	0	0	0	13	625

9.5.4 **Summary**

There were total six hundred and twenty five (625) science questions obtained from 171 children. An average of three science questions per child was generated. Two hundred and thirty three questions (233) were explanatory questions and the rest were factual questions. Only forty percent (40%) were higher order explanatory questions. Younger children or lower KS2 contributed nearly fifty percent (50%) of the total explanatory questions and older children or upper KS2 generated the rest fifty percent (50%). See Table 9.27 below summarising the responses. Explanatory questions generated comprised of 'Why.....?' questions or causal questions asking for explanations and 'What if...?' questions. Factual questions included those asking for factual information (What...? When...?, Where...? Which...?, Will....?, Would....?, Who....?, Are....?, Can....?, Can't...?, Could....?, Couldn't...?, Should...?, Do.....?, Does.....?, Did...?, Was...?, If......?, In.....?, Is.......? , Has...? , Have...? , How...?). Factual questions were those asking for descriptive information, quantitative information, procedural information, ethical information and confirmation of facts. Also, some revealed children's misconceptions. The main and sub-categories of both factual and explanatory questions have been provided in separate tables. (See Appendix 6b.Some children had some ideas or queries but had difficulty in putting them into a question form. E.g. *'We should invent bin with lock?'*

Table 9.27: Summary of the Factual and Explanatory Questions

Schools	**No. of Pupils**	**Males**	**Females**	**Factual Questions**	**Explanatory Questions**	**Science Questions**
LKS2	85	42	43	167 (43%)	112 (48%)	279 (45%)
UKS2	86	44	42	225 (57%)	121 (52%)	346 (55%)
Whole KS2	171	86	85	392	233	625

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

Discussion on the Pattern of Occurrence of Factual and Explanatory Questions

When factual information was provided to children along with photographs of scientific events in our day to day life in the form of science stories, children asked more explanatory questions from the start. Science stories generated higher percentages of explanatory questions from the start along with factual questions and both declined gradually and disappeared. The factual information in the story has provided, children the knowledge base to think through and generate higher order explanatory questions from the start. With both the stories children asked explanatory questions from the start in whole KS2, upper KS2 and lower KS2. It appears that the 'Foraging Cow' story generated more percentage of explanatory questions compared to the 'Double Yolk' egg story. Therefore, novelty of the topic and how a topic is introduced, matters.

9.5.5 Preliminary Comments

- The strategy, Science stories generated six hundred and twenty five (625) science questions from 171 children, an average of three science questions per child.
- Only forty percent (40%) of the science questions were higher order explanatory questions. The rest were factual questions asking for descriptive information.
- Science stories generated higher percentages of explanatory questions from the start along with factual questions and both declined gradually and disappeared.
- Science stories provided factual information to children in the form of a story along with a photograph. Along with their prior knowledge, the extra factual information in the stories has given children enough knowledgebase making it easier to ask explanatory questions from the start.

- The 'Foraging Cow' story generated more percentage of explanatory questions compared to the 'Double Yolk' story. Novelty of the topic and how a topic is introduced, matters.
- Science stories are useful to establish puzzling contexts to encourage children to ask questions about the natural world. (Loxley, et al., 2018). Science stories transmit both knowledge and values. (Milne, 1998).
- RODIN analysis showed majority of the questions generated using science stories were Research questions that could be answered by research.

9.6 **Strategy 5:'I Wonder' Board/ Folder**

'I Wonder' Board/ Folder strategy was carried out as a plenary activity after teacher introduced a topic. Children were asked to generate questions on teacher's own topic content like in a normal classroom. They were directed to write their questions on individual sticky notes and attach them in a folder to minimize class disruption caused by children walking to the board. Separate 'I Wonder' folders were kept on each table so as to save time and maintain class discipline. The upper KS2 year groups were learning Natural Science topics and the lower KS2 year groups were learning Physical science during the 'I Wonder Board' strategy trial. Therefore, Natural Science topics have been combined for the older children (upper KS2) and Physical Science topics for the younger children (lower KS2) respectively. The questions were later categorised into factual or explanatory questions and RODIN questions and their patterns were analysed.

9.6.1 **Analysis of the number and percentages of factual and explanatory questions a) under whole KS2, upper KS2 and lower KS2**

- ***Whole KS2***

In the whole KS2, factual questions were more at the start but they declined gradually. Explanatory questions were less at Q1, they peaked at Q2 and then decreased and disappeared. See figure 9.44. When males were considered separately, factual questions were high in the beginning but they decreased gradually and disappeared. Explanatory questions were also more in the beginning and they declined. See figure 9.45. When females were considered separately, factual questions were high in the beginning but they showed a gradual decrease from question 1 to question 8. Explanatory questions peaked at Q2 and they decreased graduallly and disappeared. See figure 9.46. It was noticed that the girls ask more questions than boys in all the groups.

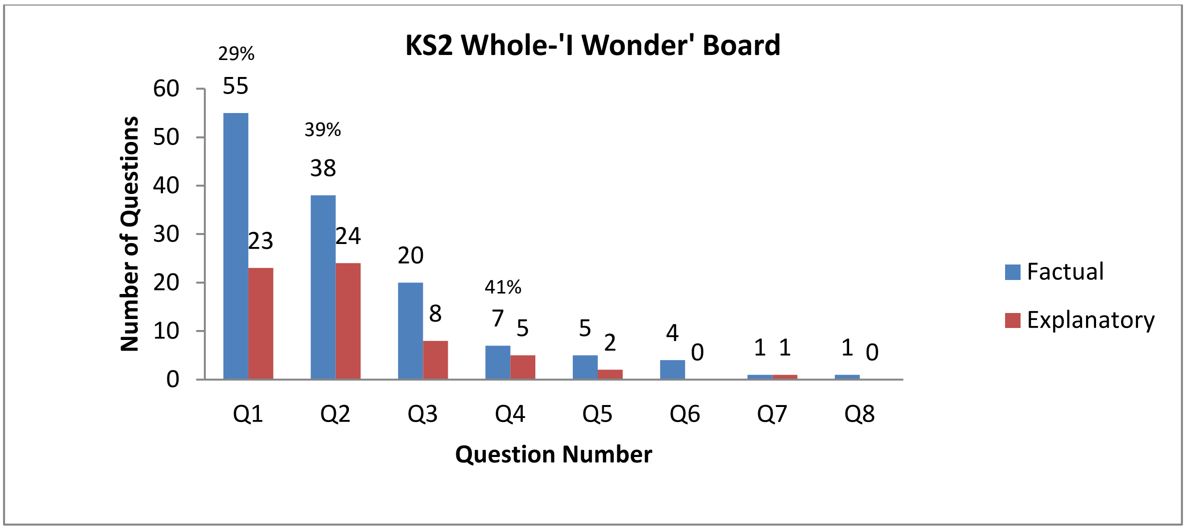


Figure 9.44 Whole KS2- Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

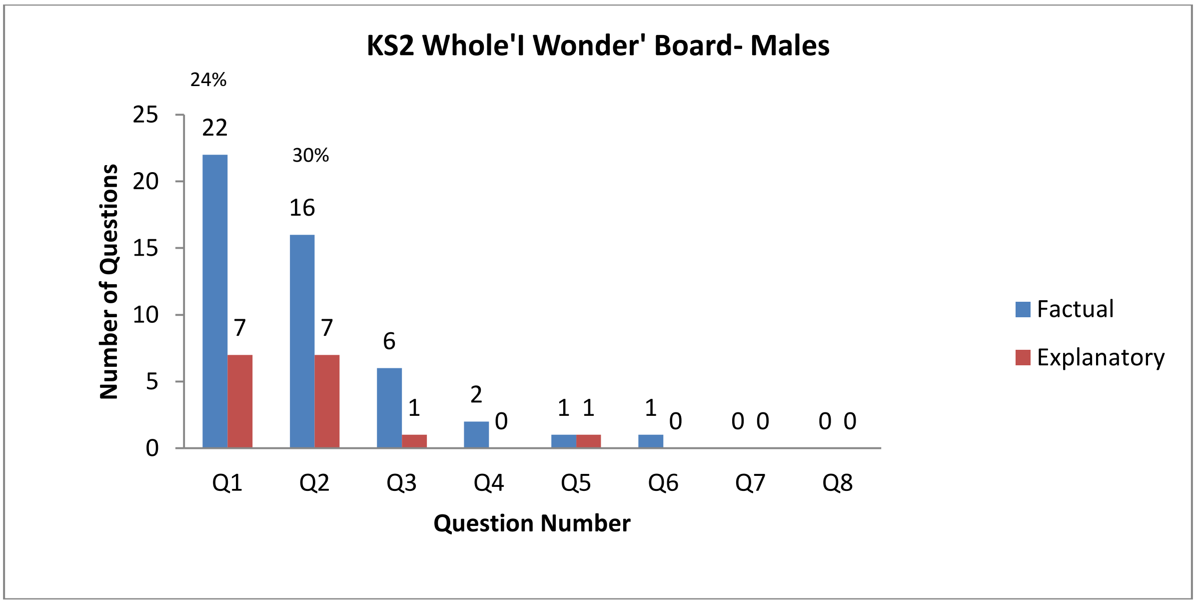


Figure 9.45 Whole KS2 Males- Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

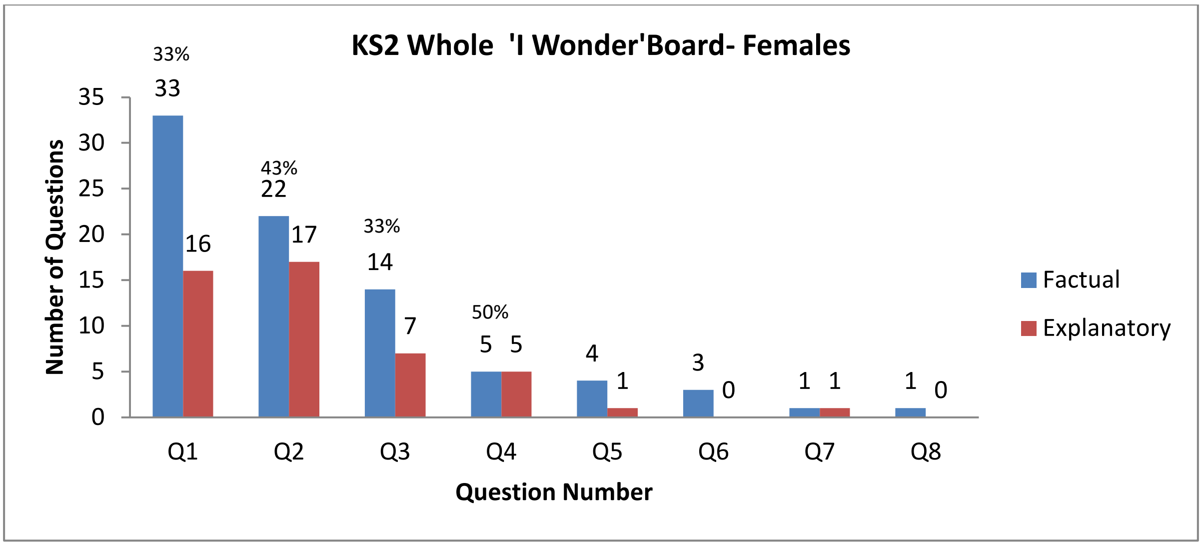


Figure 9.46 Whole KS2 Females- Factual Vs Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

- ***Upper KS2***

When upper KS2 was analysed factual questions were high in the beginning but they decreased gradually. Explanatory questions were less at the start but peaked at Q2 (Question 2) and then declined. This shows a delayed peaking of explanatory questions from older children. The upper KS2 children (older children)were learning physical science topics. See figure 9.47.When upper KS2 males were considered as a separate group, factual questions were high in the beginning but they decreased and disappeared after Q3. Explanatory questions peaked at Q2 (only 18%) and then disappeared.When upper KS2 females were considered separately explanatory questions were less at Q1, peaked at Q2 and decreased.Factual questions were more in the beginning, but they decreased and disappeared. See figures in the appendix 6b for males and females separate analysis. See Table 9.28 and 9.29 showing details of upper KS2 participants and science questions.

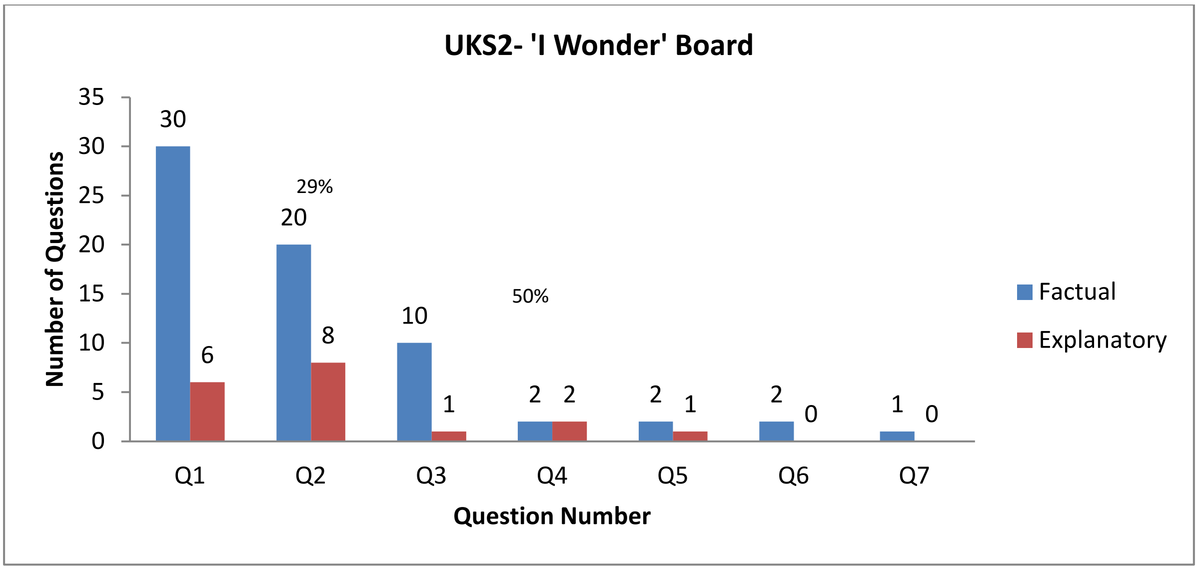


Figure 9.47 Upper KS2 Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

Table 9.28 Upper KS2: Participant Details

Schools	**No. of Pupils**	**Males**	**Females**	**LA**	**MA**	**HA**
S2	18	5	13	4	6	8
S3	20	10	10	4	9	7
UKS2	38	15	23	8	15	15

Table 9.29 Upper KS2 Gender: Summary of Science Questions

Gender	**Factual Questions**	**Explanatory Questions**	**Science Questions**
Males (15)	23 (34%)	3 (17%)	26 (31%)
Females (23)	44 (66%)	15 (83%)	59 (69%)
	67	18	85

(Percentages are calculated with respect to the total number of questions in each category:factual, explanatory and science questions.)

When upper KS2 was considered separately, only 21% of the science questions were explanatory questions, which requires higher level thinking.

- ***Lower KS2***

Lower KS2 when considered separately, children generated more factual questions in the beginning and they decreased gradually and disappeared. Explanatory questions were also more from the start and they decreased gradually and disappeared. A high proportion of explanatory questions were generated from the start. See figure 9.48. This shows that younger children asked explanatory questions from the start and there were more of them. Lower KS2 (younger children) were learning natural science topics. When LKS2 males were analysed separately, it was noticed that the factual questions were high in the beginning but they decreased and disappeared. Explanatory questions were also high in the beginning and they followed a similar pattern with factual questions.When LKS2 females were analysed separately, factual questions were high in the beginning but they decreased and disappeared. Explanatory questions were also high in the beginning and they also declined gradually. See figures in the appendix 6b for males and females separate analysis. See Table 9.30 and 9.31 showing details of lower KS2 participants and science questions.

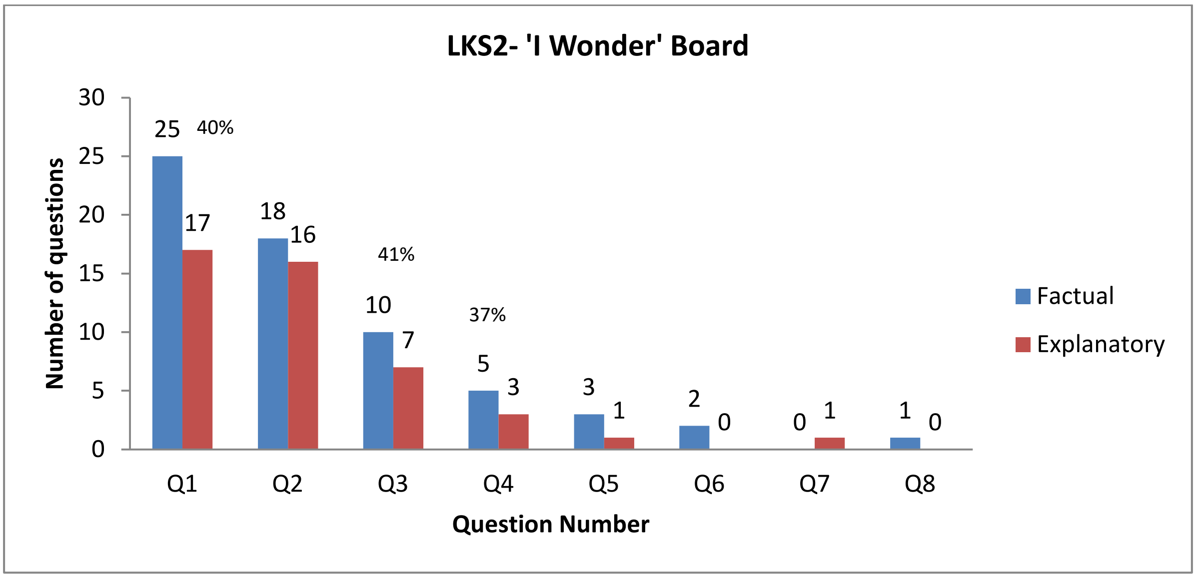


Figure 9.48 Lower KS2- Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions

Table 9.30 Lower KS2:Participant Details

Schools	**No. of Pupils**	**Males**	**Females**	**LA**	**MA**	**HA**
S1	30	12	18	5	13	12
S3	15	6	9	6	5	4
LKS2	45	18	27	11	18	16

There were 45 participants from the lower KS2 year groups of two primary schools.

Table 9.31 Lower KS2: Number and Patterns of Science Questions

Gender	Factual Questions	Explanatory Questions	Total Science Questions
Males	25 (39%)	13 or 29%	38 or 35%
Females	39 (61%)	32 or 71%	71 or 65%
	64	45	109

(Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)

When lower KS2 data was considered, there were total 109 science questions, out of which 35% were explanatory questions.

9.6.2 Analysis of the number and pattern of factual and explanatory questions b) Based on the topic content

- ***Upper KS2***

Wonder folder activity was trialled in two lower and two upper KS2 year groups of 3 schools. When the Upper KS2 data was considered separately, School 3 (S3) was learning the topic 'Earth & Space' (Physical Science). Here, children produced 50 science questions out of which around 20% were explanatory questions and the rest (80%) were factual questions.In the second school, children were on the first lesson of the topic 'Electricity'. Here only 25% of the questions were explanatory questions, the rest were factual questions. See table 9.32 for Upper KS2 summary.

Table 9.32 UKS2: Summary of Topics and Number and Percentage of Factual and Explanatory Questions

School	Pupils	Topic	Factual Questions	Explanatory Questions	Science Questions
S2	18	Electricity*	26 (74%)	9 (26%)	35
S3	20	Earth & Space*	41 (82%)	9 (18%)	50
UKS2	38		67	18	85

(Percentages are calculated with respect to the number of factual and explanatory questions generated from each topic (year group of a school)to the total number of science questions generated by them .) (denotes there is significant difference between the number of factual and explanatory questions generated from that topic or year group of that school.)*

When the pattern of the science questions obtained for the topic 'Earth and Space' (school 3) was considered separately, it was seen that factual questions were more in the beginning but they showed a gradual decrease. Explanatory questions were fewer at question 1 (Q1) but they peaked at Q2 (28%), then decreased and disappeared. See figure 9.49. It was observed that factual and explanatory questions were more in the beginning but they decreased and disappeared very early at Q3 for the topic 'Electricity'. See figure 9.50.

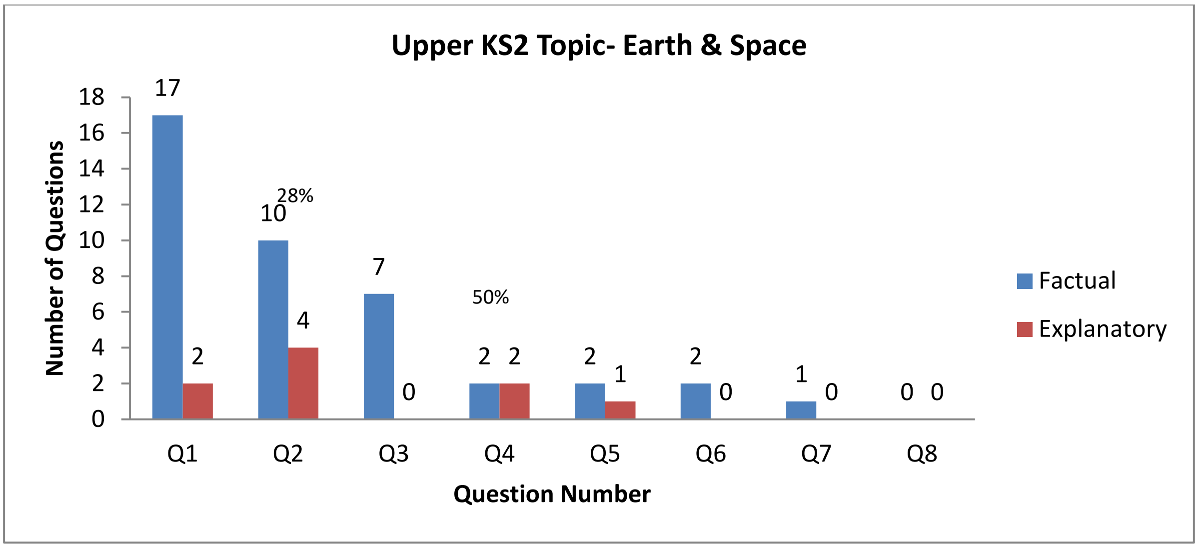


Figure 9.49 Upper KS2 Topic- Earth & Space: Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

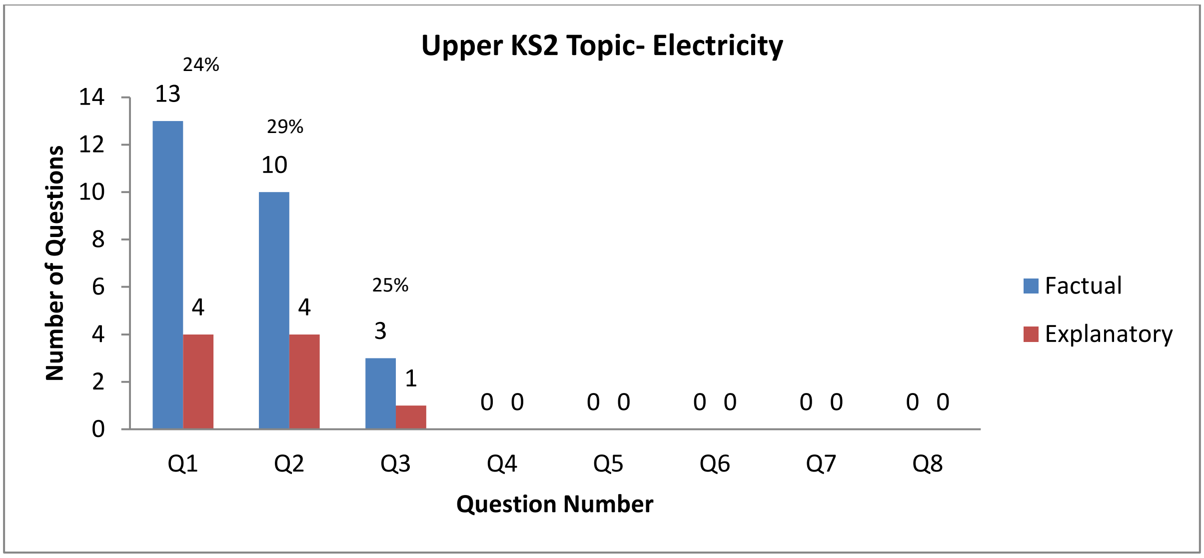


Figure 9.50 Upper KS2Topic- Electricity: Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

- ***Lower KS2***

When the LKS2 wonder folder data was considered separately, School 1(S1) was learning 'Food Chains' (Natural Science). Children produced 79 science questions. Around 46% of those questions were higher level explanatory questions and the rest were factual questions. In school 3(S3) in the Lower KS2, children were on the first lesson of the topic 'Plants'. There were 15 pupils in the class and they came up with 30 science questions out of which 30% were explanatory questions and the rest were factual questions. See table 9.33 for Lower KS2 summary.

Table 9.33 Lower KS2: Number and Pattern of Factual and Explanatory Questions (Topic Food Chain)

School	Pupils	Topic	Factual	Explanatory	Science Questions
S1	30	Food Chain	43 (54%)	36 (46%)	79
S3	15	Plants *	21(70%)	9 (30%)	30
LKS2	45		64	45	109

(Percentages are calculated with respect to the number of factual and explanatory questions generated from each topic (year group of a school)to the total number of science questions generated by them .) (denotes there is significant difference between the number of factual and explanatory questions generated from that topic or year group of that school.)*

When the pattern of the science questions from the school 1 (S1, LKS2, Food Chain) was considered separately, it was noticed that on contrary to the results from the other schools, there were more explanatory questions than factual questions in the beginning (at Q1 and Q2). Factual questions decreased gradually from Q1 to Q8 and disappeared after Q8. When the pattern of the science questions from the school 3 (S3, LKS2, Plants) was considered it was noticed that factual questions were high in the beginning but they declined gradually until Q3 (question 3) and disappeared afterwards. Explanatory questions were few at Q1 but they peaked at Q2 and Q3, then declined and disappeared. Also, the topic 'Plants' is a natural science topic. The familiarity and the every day experience with the topic might have helped pupils to ask more explanatory questions. See Figure 9.51 and Figure 9.52 below.

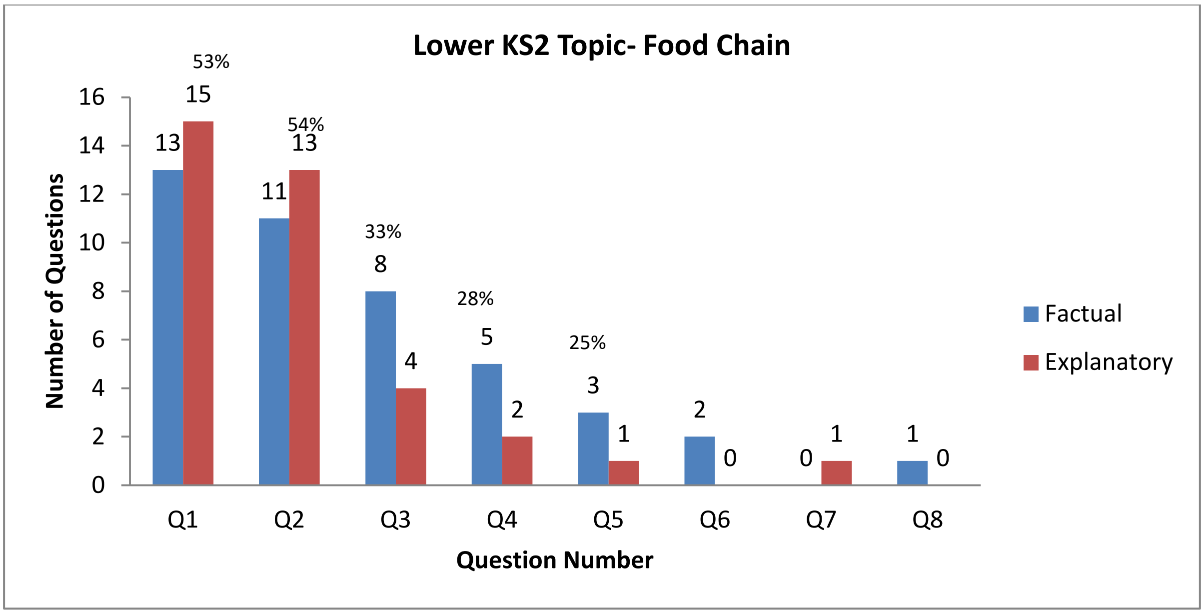


Figure 9.51 Lower KS2Topic Food Chain: Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

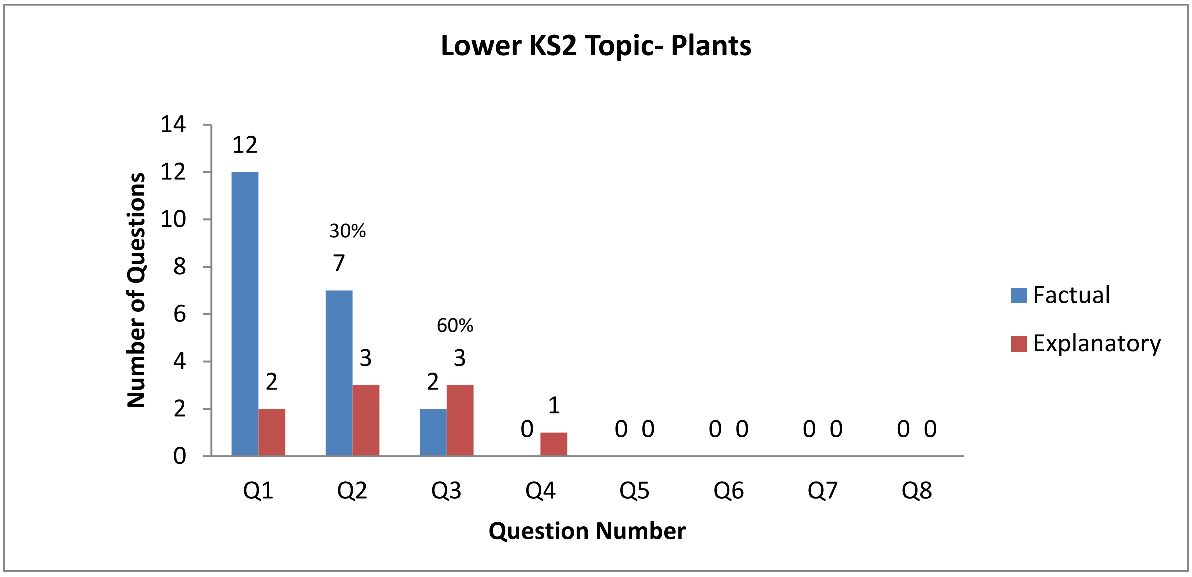


Figure 9.52 Lower KS2Topic Plants: Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

There were total 194 science questions generated from the 83 pupils.Only 30% of the total science questions generated from the whole KS2 were higher level explanatory questions. The rest were factual questions. Of the total explanatory questions generated, the lower KS2 children contributed 70% and upper KS2 around 30%. In other words, younger children contributed three fourth of the total explanatory questions produced. When upper KS2 was considered separately, only 20% were explanatory questions, which requires higher level thinking. When lower KS2 data was considered separatley, only 35% were explanatory questions. See Table 9.34 and 9.35 for whole KS2, Table 9.36 for upper KS2 and Table 9.37 for lower KS2.

Table 9.34 Whole KS2: Summary of Science Questions

Primary School Stage	Factual Questions	Explanatory Questions	Science Questions
LKS2	64 (49%)	45 (71%)	109 (56%)
UKS2	67 (51%)	18 (29%)	85 (44%)
Whole KS2	131	63	194

(*Percentages are calculated with respect to the total number of questions in each category:factual, explanatory and science questions.)*

Table 9.35 Whole KS2 Gender: Summary of Science Questions

Gender	**Factual Questions**	**Explanatory Questions**	**Science Questions**
Males	48(37%)	16 (25%)	64 (33%)
Females	83 (63%)	47 (75%)	130 (67%)
Total	131	63	194

(*Percentages are calculated with respect to the total number of questions in each category: factual, explanatory and science questions.)*

Table 9.36 Upper KS2: Topics and Science Questions (Physical Science Topics)

School	**Pupils**	**Topic (Physical Science)**	**Factual**	**Explanatory**	**Science Questions**
S2	18	Electricity	26 (74%)	9 (26%)	35
S3	20	Earth & Space	41 (82%)	9 (18%)	50
UKS2	38		67	18	85

(Percentages are calculated with respect to the number of factual and explanatory questions generated from each topic (year group of a school)to the total number of science questions generated by them .)

Table 9.37 Lower KS2: Topics and Science Questions (Natural Science Topics)

School	**Pupils**	**Topic (Natural Science)**	**Factual Questions**	**Explanatory Questions**	**Science Questions**
S1	30	Food Chain	43 (54%)	36 (46%)	79
S3	15	Plants *	21(70%)	9 (30%)	30
LKS2	45		64	45	109

(Percentages are calculated with respect to the number of factual and explanatory questions generated from each topic (year group of a school)to the total number of science questions generated by them.)

From the RODIN analysis it was observed that 93% of the science questions generated were research (R) questions that could be answered through research. Observation questions and investigation questions came up to a few. When separate topic wise RODIN analysis was done for each topic, it was observed that the topics 'Food Chain' produced around 40% of the total number of science questions generated. The rest were generated by the other three topics. See Table 9.38 below illustrating RODIN analysis results. See also Table 9.39 showing the details of the number of students and the number of questions generated.

Table 9.38 Whole KS2: Summary of RODIN Analysis

Topics	**Key Stage**	**R**	**O**	**D**	**I**	**N**	**Science Questions**
Food Chain	LKS2	76	2	0	0	1	79 (41%)
Plants	LKS2	24	4	0	1	1	30 (15%)
Earth & Space	UKS2	50	0	0	0	0	50 (26%)
Electricity	UKS2	33	0	0	2	0	35 (18%)
	KS2 Whole	183	6	0	3	2	194

Table 9.39 Whole KS2: Summary of Science Questions Generated and Number of Pupils

Primary Stage	**Number of Pupils**	**Males**	**Females**	**Factual**	**Explanatory**	**Science Questions**
LKS2	45	18	27	64 (49%)	45 (71%)	109 (56%)
UKS2	38	15	23	67 (51%)	18 (29%)	85 (44%)
Whole KS2	83	33	50	131	63	194

(*Percentages are calculated with respect to the total number of questions in each category:factual, explanatory and science questions.)*

It was observed that school 1 with topic 'Food Chain' (S1, Lower KS2, Food Chain) generated 46% of explanatory questions. Explanatory questions generated by School 3 (S3, Lower KS2, Plants) with the topic 'Plants' formed only 30%. School 2 with the topic 'Electricity'(S2 Upper KS2, Electricity)generated only 26% of explanatory questions and the rest were factual questions. With the topic 'Earth and Space' in school 3 (S3, Upper KS2, Earth & Space) only less than 20% of the science questions were higher level explanatory questions. See Table 9.40 below.

Table 9.40 Whole KS2: Summary of Topics and Science Questions

Column1	Stage	Schools	No. of pupils	Topics	Factual Questions	Explanatory Questions	Science Questions
KS2	LKS2	S1	30	Food Chain	43 (33%)	36 (57.1%)	79
		S3	15	Plants	21 (16 %)	9 (14.2%)	30
	UKS2	S2	18	Electricity	26(20%)	9 (14.2%)	35
		S3	20	Earth & Space	41 (31%)	9 (14.2%)	50
			83	All	131	63	194

(Percentages are calculated with respect to the number of factual and explanatory questions generated from each topic to the total number of factual and explanatory questions.)

9.6.3 **Summary**

The 'I Wonder' board/ folder strategy generated 194 science questions from 83 children. An average of two questions per child were produced. Higher order **explanatory questions** formed only 30% of the total science questions generated.Among the explanatory questions, majority (83%) were *'Why...?'* questions asking for explanations. *'What if.... ?'* questions and *'I wonder why...?'* questions formed the rest. Majority of the science questions (70%) were low level factual questions asking for descriptive factual information (*What...? When..? Where..? Which...? Who...? Would...?Are...? Has...? Have...? Is...? I wonder what...? I would like to...? If...would it...?)* or procedural *(How..? How are..? How is...?How can...? How did...? How do...? I wonder how...? Can..? Do...? Does...?)* or quantitative information *(How big...? How small...? How long...? How high...? How far...? How many...?)*. Of the total explanatory questions generated, the lower KS2 children generated 70% and upper KS2 produced 30%. In other words, younger children (Y3&4) contributed three fourth of the total explanatory questions produced. This indicates that the older children asked fewer explanatory questions.

Lower KS2 contributed nearly 60% and upper KS2 contributed around 40% percent of the total science questions generated. In upper KS2 out of the 85 science questions, only 20% were explanatory questions, which are products of higher level thinking. The remaining were factual questions. When lower KS2 data (younger children) was considered separately, there were 109 science questions and around 35% were explanatory in nature. The 'I Wonder' Board strategy was conducted as a plenary activity in the last 10 minutes of a lesson and the topics were not in control of the researcher as it depended on what was being taught at that time by the teacher. This limits what the researcher can say about the results. More factual questions came from younger and older pupils but fewer explanatory questions from the older pupils. The reason for this difference is not clear but may be due to differences in teacher, topic, children's prior experience or some other variable.

9.6.4 **Preliminary Comments**

- The 'I Wonder' board/ folder strategy generated 194 science questions from 83 children (an average of two questions per child).
- Only 30% of the total science questions generated were higher order explanatory questions.
- Younger children asked more explanatory questions from the start while older children showed a delayed peaking of explanatory questions. This may be due to differences in teacher, topic, children's prior experience or some other variable.
- 'I Wonder' board/ folder activity can be used as a plenary activity with any science topic and is not time-consuming.
- RODIN analysis showed majority of questions generated by the 'I Wonder' board strategy were Research questions that could be answered by research.

9.7 **Summary**

Some of the strategies showed themselves able to encourage children to ask questions. These questions were a complex mix of factual and explanatory questions. While interest here is in the explanatory questions, it seems that the factual questions have a necessary role, even pre-requisite part to play in preparing the way for the explanatory questions.

10 Chapter 10: Discussion

10.1 Introduction

This chapter outlines and integrates the key findings (from chapters 6, 7, 8, and 9 for exemplification) and relate them, where appropriate to existing research. It also notes, where relevant strengths and limitations of the elements of the study.

10.2 Key Findings

10.2.1 Primary school teachers' conceptions of creative thinking, problem-solving and problem finding in science

The findings from the questionnaire survey responses (chapter 6) revealed primary teachers' conceptions of science lessons involving scientific creativity, problem solving and problem finding. Fifty percent of teachers saw practical problem solving activities involving thinking and doing as encouraging scientific creativity *(e.g."Waterproof materials-Which material would be best to make a boat that would get the gingerbread man to the other side of the river safely?")*. Other categories of conceptions regarding scientific creative thought include constructing a practical way to investigate a problem or to make a conclusion (e.g.*"Children were asked to find out how to get clean water from a puddle.")*, application of scientific ideas to create a working model *(e.g."Using electric circuits to create a board game.")*, observing nature or natural phenomenon and hypothesising how the world works *(e.g."Seasonal change-observation across the whole year - sun-dials, leaf fall, shadows, temperature, weather patterns etc and then hypothesising...")* and, thinking of solutions to problems without practical tasks *(e.g."Materials-ask the children which material would be the best to make a bucket?")*. In short, teachers had a tendency to see practical problem solving activities involving designing and carrying out fact finding investigations and application of scientific knowledge to make working models as encouraging scientific creativity. Mental problem solving without practical work was suggested by a small percentage of teachers (20%). Teachers favour encouraging scientific creativity in the experiment and application spaces and may neglect opportunities to be creative in the hypothesis space through the generation of reasons or explanations. The remaining fifty per cent of teachers had a narrow, artistic view of creativity and saw reproductive making activities (making models using junk) and non-scientific creative teaching of the science concepts using drama or role-play, reciting, writing etc as incidents of scientific creativity. These findings are consistent with the claim by Newton and Newton (L. D. Newton & Newton, 2010a) regarding teachers' conceptions of scientific creative thinking. The findings from this study also showed that some teachers share an art-based view of creativity focusing on teaching creatively rather than teaching for creativity, as reported by other studies (Bereczki & Kárpáti, 2018;

Bolden et al., 2010; Diakidoy & Kanari, 1999; Kokotsaki, 2012; D. P. Newton & Newton, 2009b; L. D. Newton & Newton, 2010a; Wang & Kokotsaki, 2018). This address the need for providing training.

Around half of the respondents reported it is easy to encourage creative thinking and the reasons suggested were: children's inherent curiosity, easy to promote hands-on activities, investigations involving problem-solving and providing question asking opportunities to promote thinking. Some reported that encouraging scientific creative thinking depends on factors like the curriculum topic, availability of resources and the encouragement from the teacher. This study reaffirms that children's curiosity if properly diverted to the learning of selected curriculum topics through questioning and answering by utilising those easily available resources, can promote scientific creative thought though it requires encouragement from the teacher. Fifty percent of the teachers claimed encouraging creative thinking is hard due to constraints caused by topics, subjects, resources, time and the pressure to meet targets. Similar claims were made by several other studies (Alsahou & Alsammari, 2019; Dobbins, 2009; Kokotsaki, 2012; Longshaw, 2009). Teachers in this study stressed the need for teacher prompting to stimulate children's thinking and the asking of questions which in turn address the lack of training opportunities for teachers to encourage creative thinking. Two recent studies also acknowledge lack of training opportunities and adequate resources as main barriers in promoting creativity in education which is worth considering (Bereczki & Kárpáti, 2018; Wang & Kokotsaki, 2018).

Ninety percent of the teachers saw problem-solving as related to scientific creativity. Nearly all the participants (97%) reported that they encourage problem-solving by providing problems in the form of investigations, experiments, projects and by posing questions. One participant teacher reported that he/ she encouraged children to ask 'wondering' questions and write them on the 'wonder wall' in the classroom to research during their free time. This teacher wanted to encourage students *"to seek ways to answer their questions and not rely on the teacher for everything"*. About seventy per cent of teachers responded positively when asked if children find their own problems to solve in science. A few teachers gave examples of the questions they asked. There is some doubt about the veracity of this as the questions illustrated instances of provided problems, like those offered in textbooks *(e.g. 'How can I make a spinner fly the longest?'* Two or three questions, however, seemed to be genuine wondering questions *(e.g.' Why are some objects magnetic?' 'Why can you only see the stars at night?')*. Some teachers (30%) reported that they don't encourage problem finding because of the lack of time, the pressure to finish certain areas of the curriculum and meet targets that are assessed, large class size, lack of assessment on areas like creative thinking and problem finding, lack of awareness among teachers and children's difficulty in generating problems, especially with some topics in science (for example, Evolution and Earth and Space). Similar reasons were suggested as barriers for encouraging creative thinking by the teachers.

Most of the participant teachers (90%) saw problem finding as related to creative thinking because children have to think creatively to find problems, children are active, engaged and interested when thinking about problems, posing problems, exploring and finding answers to them makes learning active and child-led. Among the small proportion of respondents who couldn't see any relationship between problem finding and creativity, one had a narrow artistic view of creativity while the other felt creative thinking is required to solve problems.

About seventy per cent of the teachers who participated in the survey reported that problem finding in science is hard. The reasons suggested were the difficulty to set the context to find questions, time constraints, topic constraints, pressure on teachers to meet targets, large class size with no support, need for teacher prompts or scaffolds, the assessment system which tests pupils' understanding and the difficulty to access resources and funding for encouraging problem finding. Child's ability for independent thinking and reasoning, prior knowledge/ understanding to notice a problem, observational skill and perseverance were also suggested as limiting factors. A small proportion of respondents commented that problem finding in science is easy due to the possibility of learning science through independent and open-ended learning activities, asking questions from real life, availability of resources, and the ease to encourage children to do so.

Properties and Changes of Materials, Electricity and Plants were suggested by teachers as topics offering most opportunities for problem finding. The presence of these topics in everyday life, availability of resources, more opportunities for hands-on investigations, visual cues (experience), opportunities for problem-solving, opportunities for open-ended investigations and presence of more quality real-life problems were suggested as the main reasons for their selection. Evolution, Earth and Space and Rocks were seen as offering the least opportunities for problem finding. Lack of connection to everyday life, lack of resources, lack of opportunities for hands-on investigations, abstract and difficult concepts, lack of opportunities to encourage children's interests and lack of visual cues or experience made them hard for problem finding. A copy of the questionnaire is provided in the Appendix 3b.

Although this is a small sample of 29 teachers it serves to suggest that:

- Teachers (50%) mostly perceived practical problem solving activities including designing and carrying out a fair test to investigate a problem/ to make a conclusion, applying scientific ideas to construct a working model and observing nature and hypothesising as incidents of scientific creativity. Mental problem solving without practical work was also suggested as an example of scientific creative thinking.

- About half of the teachers had a narrow, artistic view of creativity
- Teachers provide ready-made problems for children to solve.
- Though, 70% of teachers said they encourage children's problem finding, only a few gave examples of children's questions but most of them resembled common textbook problems.
- Though 90% of the respondents saw problem finding as related to creativity, majority (70%) said it was hard to encourage scientific problem finding due to several factors like time and topic constraints, pressure to meet curriculum targets and factors affecting child.

10.2.2 Student Teachers' conceptions of creative thinking, problem-solving and problem finding in science

Student teachers (nearly 40%) perceived practical fact-finding problem-solving tasks *(e.g. "investigating materials which float")*, conducting tests to confirm children's ideas about the world and application of scientific knowledge in real life *(e.g. "constructing a garden at home")* as examples of scientific creative thinking. Problem-solving without practical work and demonstration of experiments to elicit thinking and understanding in children were also considered as encouraging scientific creative thinking by a few *(e.g. "experiment to demonstrate surface tension using a razor blade which floats in water but sinks when soap solution was added")*. Here, problems were given by the teachers. Similar narrow conceptions of scientific creativity among student teachers focussing on fact finding practical work and practical problem solving were reported by Newton and Newton (D. P. Newton & Newton, 2009b). Recent findings by Alsahou & Alsammari (Alsahou & Alsammari, 2019) also confirmed pre-service teachers' narrow conceptions of scientific creative thought focussing on experiments and practical work. A small proportion (30%) of student teachers viewed lessons involving hands-on reproductive making tasks and non-scientific creative activities, like teaching using a story or a poem, as encouraging scientific creativity. This shows that some student teachers hold misconceptions about creativity in science which is likely to thwart its development.

Most of the student teachers said that it is difficult to encourage creative thinking in science and the reasons suggested were their perception about the factual nature of science, children's varied interests, difficulty in encouraging independent thinking, lack of teacher's subject knowledge, difficulty in planning and implementing lessons, lack of books in some areas of science, curriculum and target constraints, topic constraints and narrow views of creativity among teachers. Four student teachers expressed that the factual nature of science makes it hard to encourage creative thinking, *e.g. "Because it's such a set subject, hard facts etc''*. Student teachers with similar attitudes may not have adequate background knowledge in science and may need support in developing a scientific attitude and love for science in children. The need for in-service training is very relevant, here. The words of student teachers copied below show how the pressure for attaining curriculum targets within a limited time force some teachers to ignore encouraging thinking in the classroom. *"Teachers are v. focussed on ticking off knowledge in the national curriculum. Sometimes it can be easier * to tell children facts and give instructions for an experiment rather than letting them design an experiment themselves (*in terms of organisation, logistics, classroom management etc)."* Student teachers claiming lack of time and effort as a major barrier in encouraging scientific creativity was reported by a recent study by Alsahou & Alsammari (Alsahou & Alsammari, 2019). A small proportion saw encouraging scientific creativity as an easy task because of children's inherent curiosity, easy to promote thinking about real-life situations and investigations that could lead to creativity.

Most student teachers (93%) saw problem-solving as related to creativity as one should think creatively to solve problems by designing and conducting novel experiments. Most participants (97%) reported that they encourage problem-solving in science by providing problems in the form of investigations, posed questions and supported children to think and generate their solutions.

Most of the student teachers reported that they will try to encourage problem finding in the future. The majority (85%) of the participant student teachers saw problem finding as related to creative thinking because one should think creatively to discover problem situations. Some commented that problem finding encourages deep learning, seek new information and applies it to investigate and solve problems and promote critical thinking and student engagement. Six student teachers (15%) reported that they see no relationship between problem finding and creativity. Three of them had the opinion that creativity is used to solve problems and not to find them. One respondent noted that being observant and inquisitive is sufficient to find problems and that creativity plays no significant role. This is a possible misconception that should be corrected.

A small proportion of respondents (30%) commented that problem finding in science is easy because children are inquisitive and they naturally ask questions. Also, science being an interesting and explorative subject with interrelated facts, problem finding was perceived to be easy.

The majority (around 60%), however, suggested that problem finding is hard as it depends on several factors which include, child factors like the ability to think independently, prior knowledge and understanding, individual differences and interest, the perceived factual nature of science, misconceptions associated with some topics (e.g. Evolution and Inheritance, Earth and Space), teacher's subject knowledge and resourcefulness, curriculum and target pressures from government and authorities like Ofsted. Three respondents suggested that to problem find, children should think deeply about science topics, asking and answering how and why questions and therefore require a good understanding of the topic. Two respondents reported individual differences in children's interests may act as a challenge for teachers in encouraging problem finding. A few noted teachers' subject knowledge as an important determinant in encouraging children's questioning, one student teacher commented that *"Both finding out the problem and finding out the solution to the problem is a difficult task for a teacher. A teacher should possess good subject knowledge."* In addition to the above, the perceived factual nature of science (for e.g*. "Is often taught in schools in a more factual way ("how something happens) as questioning and discussion often seem more reserved for subjects like English.")* was suggested by a few. Five student teachers reported encouraging children's problem finding is a daunting task for the teacher as it is not practical to know each child's question and solve, though it makes science real. Pressure on teachers to cover the curriculum to meet the attainment targets within the limited time forces them to focus more on ticking off targets rather than to spend time encouraging children's thinking and understanding. A few suggested it can be both easy and hard as some children may be good at problem finding but some may not be, though all children are curious. One respondent suggested that if children have opportunities to clarify their questions with their teacher, they will be interested in finding more problems.

The topics Forces, Earth and Space and Electricity were chosen as the three best topics for problem finding by the student teachers. The topics Forces and Electricity were good because of their presence in everyday life, availability of resources, easy access of required equipment, more opportunities for hands-on investigations, easy to encourage children's interests, the occurrence of misconceptions and opportunities to tackle them. The topic, Earth and Space has plenty of unanswered questions requiring good thinking and simple resources. When asked to name three worst topics for problem finding, Rocks, Evolution and Inheritance and Plants were suggested. Less investigative and abstract nature of the topic and less prior knowledge were suggested as reasons that make them harder for generating problems. See Appendix 3b for a copy of the questionnaire.

Although this is a relatively small sample of 58 student teachers from only one institution, it serves to suggest that:

- Student teachers (nearly 40%) perceived practical fact-finding problem-solving tasks including conducting experiments or tests to confirm facts and application of scientific knowledge in real life *(e.g. constructing a garden)* as examples of scientific creative thinking. Also, mental problem-solving without practical work, eliciting children's thinking through the demonstration of experiments and by asking thought-provoking questions were viewed as encouraging scientific creativity.
- A small proportion (30%) of student teachers had narrow artistic view of creativity.
- Student teachers encourage problem-solving by providing children problems to solve.
- Though, most student teachers don't encourage children's problem finding, they (85%) saw problem finding as related to creative thinking.
- Sixty per cent of student teachers reported encouraging problem finding is hard because of the dependence on factors like the teacher's lack of confidence in subject knowledge and misconceptions associated with some topics, pressure to meet curriculum targets, factual nature of science and factors affecting child.

10.2.3 Strategies primary teachers use to promote creative thinking, problem-solving and problem finding in science

The researcher conducted classroom observations (eight lessons) of teachers teaching science in both upper and lower KS2 year groups in two schools. It was very difficult to get access to observe lessons as teachers were very busy. The researcher looked specifically for behavioural cues of teacher and pupils in connection with creative thinking, problem-solving and problem finding. Problem-solving opportunities were relatively frequent,–problems being given to students by the teachers. A lot of them (4 of the 8 lessons) were in the form of fact-finding investigations, mostly conducted in the classroom *(e.g. 'Do taller people have longer bones?')* except one which was an outdoor investigation *('What kind of animals lie in the hedgerow and why?')*. It was observed that teachers explained the test procedure to children and they took the time to talk about the independent and dependent variables and the need to keep one constant (aspects of fair testing). Also, children were asked to make predictions or choose a prediction from a given list and provide a reason for the prediction before doing investigations. Children were encouraged to work in small groups which stimulated talk and negotiations between the members on some aspects of the investigation *(e.g. 'how to put the tissue paper to measure the brightness of the bulb, fold it or tear it into pieces and arrange one on top of the other')* which may also generate some creative outcomes. If children had the opportunity to engage in a productive discussion with the teacher using some probing questions and feedback to direct their thinking to design a test and carrying it out afterwards would have been an excellent strategy to stimulate creative thinking in the experimental space. Teachers may need more awareness on ways of encouraging creativity in science, broadly speaking, to encourage productive thought.

During lessons without practical work, teachers asked questions including 'Why?' questions to guide their lessons, and some children were given opportunities to generate reasons. Some problems given to children as an end of the lesson task were in the form of questions asking for descriptive information or reasons encouraging them to be creative within the hypothesis space *(e.g. 'Describe the animal (picture displayed), it's habitat and adaptations,' or, 'Why is it important to scatter the seeds away from the mother plant. Give examples.')* Some teachers allowed some children to ask questions during or at the end of the lesson and most of them were simple factual questions. A few times, as an end of the lesson activity, all children were given the opportunity to ask questions but limited to one question per child. None of the questions was recorded or used as the basis for further study, hypothesis or investigation. Please see Chapter 8 for details.

Although this was a small sample of science lessons (8 lessons in both upper and lower KS2) in two schools, it serves to suggest that:

- Teachers provide more opportunities for problem-solving in science. Problems or questions were given to children by the teachers to solve.
- Most of the investigative problems provided (4 of the 8 lessons) were in the form of fact-finding investigations, mostly conducted in the classroom except one which was an outdoor investigation.
- Non-investigative problems given to children were in the form of questions asking for descriptive information or reasons encouraging them to be creative within the hypothesis space
- Some teachers allowed children to ask questions and most of them were simple factual questions. A few times, as an end of the lesson activity, all children were given the opportunity to ask questions but limited to one question per child.
- None of the questions were recorded or used as the basis for further study, hypothesis or investigation.
- Teachers are unlikely to use questions (if asked by children) as starting points for further study.
- Teachers may limit children's questioning opportunities because of factors like time constraints, target pressure and large class size.

Table 10.1 below provides a basic and non-exhaustive list of teachers' and student teachers' conceptions about creative thinking, problem solving and question-asking or problem finding in science, showing where they are similar and where they differ (according to what was observed in this study).

Table 10.1 A comparison of teachers' and student teachers' beliefs about children's creative thinking, problem solving and problem finding or questioning in science

Student teachers (pre-service)	Teachers (in-service)
1. Student teachers mostly saw **practical problem solving activities** as encouraging scientific creativity. One respondent suggested **thinking of solutions** without practical work as promoting scientific creative thought. A small percentage (30%) of student teachers had a **narrow artistic view** of creativity.	1. Most teachers saw **practical problem solving activities** as encouraging scientific creativity. Some teachers suggested **mental problem solving** without practical work as promoting creative thought. Half of the respondent teachers had a **narrow artistic view** of creativity.
2. Student teachers encourage problem solving **by providing ready-made problems** to solve.	2. Teachers encourage problem solving **by providing ready-made problems** to solve.
3. Most student teachers reported they **don't encourage problem finding** but they will try to do so in the future.	3. Though 70% of teachers reported that they encourage children's problem finding, only **a few gave examples** (less than 10) of children's questions. They illustrated instances of provided problems, given in textbooks.
4. Most student teachers (85%) saw problem finding as related to creative thinking.	4. Most teachers (90%) saw problem finding as related to creativity.
5. Sixty per cent of student teachers reported encouraging problem finding is **hard** due to the dependence on factors: • affecting the child (the ability to think independently, prior knowledge, individual differences and interest) and • affecting the teaching and learning environment(teachers' subject knowledge and misconceptions associated with some topics,	5. Seventy per cent of the teachers reported encouraging problem finding is **hard** due to the dependence on factors: • affecting the child (like the ability to think independently, prior knowledge, observation skill, and perseverance), • affecting the teaching and learning environment (time constraints, topic constraints, pressure to meet curriculum targets, difficulty to access resources and funding, difficulty to set the context to

curriculum and target pressure, factual nature of science) 6. A few suggested it can be both **easy and hard** as some children may be good at it but some may not, though all children are curious. 7. Topics offering **most** opportunities for problem finding: **Forces, Earth and Space, Electricity** 8. Topics reported as offering **fewest** opportunities for problem finding: **Rocks, Evolution and Inheritance, Plants**	find questions, large class size, need for teacher prompts, the assessment system which tests pupils' understanding) 6. Some respondents (30%) commented that problem finding is **easy** due to the possibility of learning science through independent and open-ended learning activities, asking questions from real life, and availability of resources and easy to encourage children. 7. Topics offering **most** opportunities for problem finding: **Properties and Changes of Materials, Electricity, Plants** 8. Topics reported as offering **fewest** opportunities for problem finding: **Evolution, Earth and Space, Rocks**

10.2.4 Textual materials primary teachers use in the school to support creative thinking, problem-solving and problem finding in science

After observing the lesson the researcher had a short, purposeful discussion with the teacher to find out if textual resources are available in school or online, to support lesson planning. Teachers in both schools used online resources from the Hamilton Trust to plan and deliver their science lessons. They also found the resources available on the BBC school science website very useful for planning learning activities. One teacher reported using the text series Rising Stars resources for reference and assessment purposes. A good textbook could be a reliable pedagogical aid for teachers particularly for those who are not very confident in the subject area (L. D. Newton, 2017).

- It was noted that most teachers (6 of them) in both schools where the researcher observed lessons used online resources to plan lessons, specifically Hamilton Trust resources. (This is discussed further below.)

10.2.5 Content Analysis of text materials (textbooks, schemes of work, online textual resource) to see if they directly support creative thinking, problem solving and, of particular interest, problem finding in science

In order to answer this research question, content analysis of textbooks, schemes of work available for student teachers at the university library and an online resource used by teachers in various schools were analysed. The researcher looked for opportunities for creative thinking, problem solving and problem finding in these text materials. The learning activities identified as encouraging both creative thinking and problem solving were recorded under separate columns in tables (please see Appendix 5a and Appendix 5b) for details. Both quantity and quality were analysed. The list of textual materials (belonging to key stage two-Year 3, 4, 5, and 6) analysed are listed below.

1. Collins Science Directions (Sunley, Bourne, & Norman, 2000a, 2000b, 2000c, 2000d, 2000e, 2000f, 2000g, 2000h)
2. Scholastic Hundred Science Lessons (Anderson, 2007; Clifford Hibbard, 2007; Glover, Mitchell, Petheram, & Riley, 2007; McMahon, 2007)
3. Folens Science in Action (Harris, Smith, Whitehead, & Sizmur, 2004; L. Petheram, P. Szczesniak, Anne Whitehead, & Steve Sizmur, 2004; L. Petheram, P. Szczesniak, Anne Whitehead, & Steve Sizmur, 2004; Powell, Smith, Whitehead, & Sizmur, 2004)
4. Letts Teaching and Learning Science Teachers' Book and Science Activity Book (Jarvis, Baldry, et al., 2001a, 2001b, 2001c; Jarvis, O'Sullivan, Baldry, et al., 2001; Jarvis, O'Sullivan, Hart, et al., 2001; Jarvis, Szczesniak, et al., 2001)
5. Pearson Longman Exploring Science (Johnson & Levesley, 2004a, 2004b, 2004c; Levesley & Johnson, 2004)
6. Hamilton Trust Online Resource ("Hamilton Trust Online Resource, KS2 ")

Creative thinking opportunities identified were mostly learning activities asking children to plan and carry out a test to find reliable descriptive information thereby encouraging creativity within the experiment space *(e.g. 'Design a fair test to investigate the effect of cola, sugar and water on teeth?')*. Creative thinking could be encouraged in the experimental space, i.e. either child constructing a test to find reliable descriptive information, or a practical way to test a tentative explanation of an event. The latter was rare in the analysed texts. An example of encouraging creative thinking by designing a method to test a tentative explanation found was *(e.g. 'Someone tells you the water on the outside of the drinks can come from the ice inside the can. Plan a test to prove it hasn't'.).* Creative opportunities in the hypothesis space through the generation of tentative explanations or reasons were also noticed, but not many. A few examples of encouraging creative thinking were found, sometimes almost defeating themselves by pointing firmly towards the solution, as in this example asking for a creative application of scientific knowledge *(e.g. 'Design and draw two cars: one that will move through the air quickly and one that will move slowly. Explain why you have designed the cars the way you have. Use the* *idea of air resistance to help make your answer more scientific.')* Some questions like *'In what way do you think walking on the Moon would be different from walking on the Earth?'* prompt children to integrate scientific information in imagined situations, an example of constructive thinking within science. They could act as good starting points for further creative thinking through teachers' wise use of questions, especially higher-order 'Why..?' and 'What happens if...?'questions. This depends on how teachers use these questions to scaffold children's thinking which may also stem from their notions of scientific creative thinking. Plenty of scientific problems were provided in the textbooks to solve. Problems encouraging thinking about solutions without practical work *(e.g. 'How could plants living in small ponds spread their seeds to new ponds?')* and practical problem solving were there *(e.g. 'An ice cube made from freshwater and saltwater are given to kids. Which one melts more quickly?').*

Problem finding opportunities asking children to generate their own science problems or questions to solve were absent. A few problem situations had an example investigative question and children were asked to generate similar questions that could be tested *(e.g. 'Investigation into body measurements - do taller kids weigh more? Ask questions that can be tested.')*. A similar but a better example of a problem situation identified from one of the above texts is given in the brackets. *(Problem: 'Ben has grown some bean plants in the dark and they are yellow and thin. Ben wants to know if they will go green if he puts them in the light. Write a question for Ben to investigate. Make a prediction.')* This problem seemed to act as a bridging activity from a teacher given problem solving to a pupil driven problem finding. These types of bridging problems within which children can raise questions to investigate would be a great starting point for encouraging children to come up with their scientific problems to investigate, but they rarely occur in texts.

Though this content analysis has included a small sample of text materials and online resources used by teachers, it serves to suggest that:

- Creative thinking opportunities identified were mostly (in the experiment space) learning activities asking children to *plan and carry out a test* to find reliable descriptive information. Creative thinking opportunities asking to plan a practical way to test a tentative explanation of an event were rare in the analysed texts.
- Creative thinking opportunities in the hypothesis space through the generation of tentative explanations or reasons were also noticed, but not many. A few examples of problem solving contexts that could encourage creative thinking if presented in a slightly different way without directing towards the solution were found.

· Text materials provide both investigative and non-investigative problems to support teachers. Most of the investigative problems were those involving practical fair testing to find reliable factual information.

· Text materials didn't seem to provide children opportunities for generating questions or finding problems out of their curiosity on a particular topic.

· A few problems provide children with the opportunity to generate testable questions within a problem situation provided. These may act as bridging problems between problem solving and problem finding, as they prompt question asking, a good model to try out. Table 10.2 treats textual resources as surrogate teachers and describes some of their features for comparison with Table 10.1 showing teachers' and student teachers' conceptions.

Table 10.2 Some features of the textual resources analysed

Textual resource as a teacher
1. Text materials provide problems, both investigative and non-investigative problems to solve in the classroom.
2. Most of the investigative problems were those asking to design a test to find reliable factual information.
3. Investigative problems asking to design a practical way to test a tentative explanation of an event were rare in the analysed texts.
4. Questions asking to generate tentative explanations or reasons were also noticed, but not many.
5. Text materials didn't seem to provide children opportunities for generating questions or finding problems out of their curiosity on a particular topic.
6. A few problems provide children with the opportunity to generate testable questions within a problem situation provided. Similar problems may serve as a bridging activity between problem solving and problem finding, as they prompt question asking, a good model to try out.

10.2.6 **Strategies stimulating question generation, types of questions asked and the model to guide thinking about helping children find scientific problems**

From the teachers' questionnaire survey and observations of their classroom teaching, it was noticed that teachers encouraged problem solving in science by providing problems to solve. Student teachers ' survey responses revealed they promote children's problem solving but problem finding is something new to them. The content analysis of some text books, schemes of work and an online resource used by some of the participating schools revealed that they provide ready-made problems, both investigative and non-investigative, to solve. Despite the fact that, a few of the text book problems gave children opportunity to generate testable questions within a problem context, text materials didn't seem to provide children opportunities to raise questions out of curiosity on a particular topic. It was observed that though teachers sometimes allowed children to ask questions, none of the questions were recorded or used as the basis for further study or investigation. Therefore, this study set out to see if children (aged 7-11 years) could be encouraged to ask scientific questions that can be turned into scientific problems to solve in science lessons. For this, the study explored the effect of some relatively simple strategies designed to stimulate children to generate questions related to science. Six strategies were trialled and the key findings are discussed in this section. These findings would also inform reflection on the determinants of children's question-asking in contexts related to primary school science.

10.2.6.1 *Strategies Stimulating Question Generation*

- **Question starters or question stems on Giant Dice**

Several studies that used question starters have found them useful not only in generating questions (Jarman, 1991; King & Rosenshine, 1993), but also in using questioning as a strategy to encourage problem solving (Ge & Land, 2003; Gu et al., 2015). Jarman (Jarman, 1991) found question starters very useful in encouraging children to ask investigative questions. In this study, children were provided with six question starters and were asked to complete them to form questions. Most question stems except the first, were meant to generate descriptive questions. The first question starter 'What would happen if...?' was meant to encourage children to anticipate scenarios, explore possibilities, consider alternatives, test relationships and predict outcomes thereby promoting more higher order thinking leading to the generation of higher level explanatory questions (C. Chin, 2004; Jarman, 1991). Explanatory questions forces children to generate reasons or explanations using one's prior knowledge and it goes beyond the strict premises of the content leading to an increase in information (Johnson-Laird, 2010). The question starter strategy generated 658 science questions. By providing specific questions starters the strategy suppressed factual questions and generated explanatory questions (What if...? and Why...? questions) and the task was made into a game using a giant dice with different question stems written on the faces. Some examples of explanatory questions generated by the children are: *'What would happen if a plastic bag fell in the ocean?', 'What would happen if you drop a boiled egg in cider vinegar?'* To answer these questions children have to think ahead and make predictions using their scientific knowledge. Also, the strategy produced a variety of factual questions which are evidences of extension of their thinking *(e.g. 'Which bag is the best for the environment?', 'What happens when you cook a egg?', 'Will the plastic bag break if you put it in water?')*. Children finding answers to these factual questions would improve their scientific understanding and may generate more questions in their mind. Though, this strategy was useful to remind children of the variety of questions possible and generate desired kinds of the question (e.g. 'How would you...?', 'What would happen if...?', 'Why...?'questions), the questions these generate are forced responses, and not necessarily spontaneous motivating questions generated by child's own curiosity or interest. However, the researcher has doubts about suppressing factual questions as these may serve an important role on the way to the development of understanding. Therefore, more focus was given on the generation of less constrained questions in the subsequent strategies trialled.

- **The 'Elephant Strategy' (Vicarious experience as stimulus)**

Several studies suggest the use of vicarious experience, like photographs to introduce a problem situation when real objects aren't accessible (Dahlgren & Öberg, 2001; Mark A. Runco, 1993; Share, 2015). Interest motivates people to acquire new knowledge (Silvia, 2008). A novel and interesting stimulus is known to arouse curiosity and a desire for learning (Pluck & Johnson, 2011). In this explorative strategy, photographs of an elephant in the wild, one in captivity and one of an elephant embryo in the womb were shown to children and they were asked to write some questions about what they would like to know about the elephants. It was obvious from children's interest in asking questions that the photographs, particularly the elephant embryo picture, presented information that was new to the children and captured their attention and curiosity. All the three photographs produced a similar pattern of factual and explanatory questions. Children asked more factual questions at the start while explanatory questions emerged slowly, peaked and declined. This shows that, when the topic is novel (unfamiliar), factual or description questions initially predominated, while explanation questions grew in number, peaked then and fell away. With novel topic, children have less prior knowledge and therefore appear to ask more factual questions at the start to build a factual knowledge base leading to the asking of higher order causal or Why..? or What if..? questions. A more delayed peak of explanatory questions with younger children (8-9 years) indicates that they might take longer to ask explanatory questions than their older counterparts (10-11 years). Presented with a context, a mental model of the situation has to be generated. If the situation is novel, it seems likely to start with the construction of a descriptive, situational model (e.g. setting some attributes and the spatial disposition of the components (Johnson-Laird, 2005). At this stage, factual questions about the context will likely support this process. If the children’s question asking process moves beyond this stage, it could then prompt thinking about causal relationships and raise Why?, What if? questions. Along with the answers, a descriptive mental model may grow into a causal, explanatory model (D. P. Newton, 1995, 2012b). The unanswered questions are of particular interest, as they may serve as starting points for problems to investigate in the classroom. The findings point to this very important observation that children when presented with a problem situation that is novel (or with less prior knowledge) they tend to ask more factual questions at that start to update their factual knowledgebase leading to the construction of a *descriptive mental model*. After gaining adequate factual knowledge about the topic, they are likely to generate more explanatory questions that pushes one to reason, predict and apply knowledge in new contexts leading to the construction of an *explanatory mental model.*

The findings are consistent with the view that a *descriptive mental model* is constructed which then facilitates further thought of a more causal nature, prompting explanatory questions. This shows that when introducing a new topic, it would be very useful if teachers allowed pupils to ask more questions at a time, as higher order causal questions ('Why..?'. 'What if..?', 'What happens if...?') emerge later. In other words, *persistent questioning* should be encouraged. This is not easy to put into practice because of time and target constraints in a normal classroom. One option of doing this would be the teacher, after introducing a new topic or a concept, selects four or five children and allow them to ask more questions (at least 3 or 4 questions each) which may lead the whole class to engage in productive discussion leading to better causal questions. The teacher may take children's ideas from their questions and re-direct them to their peers to create a collaborative learning atmosphere leading to better conceptual development and generation of more causal questions. The unanswered questions could act as starting points for tentative hypothesis generation, further research, investigations, observations, teacher demonstrations, and discussions.

- **Question Generation Workshop using Real Eggs and Bags (Direct experience as stimulus)**

Direct experience with elephants is not usually possible for children in the UK. Piaget stressed the benefits of providing concrete objects to encourage thinking in younger children (Piaget, 1959). Two practical displays were provided, one about eggs which included different types of eggs and one about bags with shopping bags made from different materials like paper, jute, cotton, plastic, leather and silk. Except for hen's eggs, the collection of eggs which included an ostrich egg, goose egg, duck egg and quail egg were less familiar and likely to be new to children particularly to younger children in the UK. Although a variety of bags were provided, they were more mundane and offered little novelty to a UK primary school-aged child. With Eggs, younger children appeared to ask far more factual questions at the start and then turned to more causal or explanatory questions later. Bags, on the other hand, followed the patterns expected for more familiar topics, with both factual and explanatory questions declining together. In other words, with Eggs younger children took slightly longer to ask explanatory questions (Why? What...if..?) that pushes children to predict, explain or apply their knowledge in new contexts. On the other hand, older children were able to ask explanatory questions from the start for both Eggs and Bags topics. This shows that with real objects, when children had more familiarity and informal experience, they were quicker to generate explanatory questions. With older children, bags generated fewer questions, perhaps for the same reason. This supports that novelty of the topic matters. This also confirms the views of Chouinard et al., (Chouinard et al., 2007) that the stimulus type affects the questions asked by children in the domain of Biology (Natural Science). Real objects have a richer source of cues that help to tap into one's conceptual knowledge more effectively producing a better engagement (Chouinard et al., 2007). It was evident from the wonder on the children's faces, and their engagement during the activity confirms the value of using real specimens as the stimulus in capturing children's attention. Children begin to learn about the world by asking descriptive questions that collect isolated facts leading to explanatory questions that relate facts to one another creating a whole (Chouinard et al., 2007). With eggs being novel (less familiar) to younger children, it is likely that the children lacked prior knowledge at the outset. Therefore, they began asking descriptive questions to collect facts which then lead, in turn, to the asking of explanatory questions. According to Yekovich et al. (Yekovich, Thompson, & Walker, 1991), having some prior knowledge helps children to discriminate between relevant and irrelevant facts, and to construct a relationship that will integrate the relevant facts. Bags being familiar, it would have been easier to make causal connections sooner for younger and older children resulting in the quicker generation of explanatory questions.

- **Science Stories (Providing factual contexts/ scenarios)**

Miyake and Norman (Miyake & Norman, 1979) claimed that it requires a considerable amount of domain-specific knowledge for students to ask ‘good’ questions. Providing children with an initial conceptual knowledge appeared to be more effective when conducting a practical investigation (Cavalcante et al., 1997). As reported under section 4.8.8 a study by Baumfield & Mroz (Baumfield & Mroz, 2002) reported stories, particularly moral stories or stories with a puzzling context were useful in generating complex questions from primary school children. Loxley et al., (Loxley et al., 2017) suggested the need for developing puzzling contexts to encourage children's questioning about the real world. As explained in section 4.8.8, some studies recommend the use of stories to provide context for a problem (Loxley et al., 2017; D. P. Newton, 2002). Piaget (Piaget, 1959) considered causal explanations to be amongst the most powerful we can construct in science as they allow prediction, application and adaptive behaviour in new situations. Therefore, helping children ask causal or explanatory questions early could be of practical use in the science classroom. One way of helping children ask causal questions early could be by constructing a descriptive mental model to think with before they create their questions. This could be made possible by providing children with a factual knowledge base in the form of a brief context or a story to initiate thinking to construct a descriptive mental model of events. Accordingly, a photograph of a double yolk egg, accompanied by some brief facts about the parts of an egg and a very short 'story' about Rahul's joy at finding he had a boiled 'twin egg' was presented to the children on one half of a worksheet. On the other half of the worksheet was a photograph of a cow foraging in domestic refuse in India accompanied by some brief facts about the source of plastic waste and a very brief 'story' about Gowri, the cow who ate so many plastic bags that she died. Of the two 'stories' the second attracted more interest. The stories were read with the children, and they were encouraged to write up to four questions about what they would like to know about the situations. As before, their questions were categorised into description and explanation. The pattern of questions of the younger and older children to the Double Yolk Egg scenario was similar, so they were combined. The same applied to the Foraging Cow scenario. The proportion of explanatory questions for the cow eating plastic scenario was strong from the start while it was much more muted (subdued) in the Double Yolk Egg scenario. This response is consistent with the view that the novelty of the topic is important and also how it is introduced. In addition to this, the Foraging Cow story may also have persuaded children to empathise and ask rhetorical questions about human actions and their consequences on animals and nature (Solomon, 2002). Oberg & Dahlgren, also found that scenarios or contexts on environmental issues were successful in generating questions from undergraduate students, which initiated a discussion on problems and solutions (Dahlgren & Öberg, 2001). Therefore it is worth investing time on developing science stories connected to curriculum areas to communicate science knowledge (Loxley et al., 2017) as well as problem scenarios to support children’s question-asking and learning.

- **The ‘I Wonder’ board to support question generation**

Although the above strategy increased the number of explanation questions asked early, teachers are unlikely to have a story for every topic. At the same time waiting for every single child to ask sufficient questions to reach those explanatory questions Piaget would value highly, may take longer and may not be practical. The 'I Wonder' board, used after a teacher introduces a topic, may be one solution to encourage every child to generate several questions at a time. The children write their questions on individual sticky notes and attach them to the board or in a folder for the teacher to sort and discuss in the next lesson. Four teachers in three schools tried this strategy. Each introduced a science topic (Younger children: Food Chains, Plants; Older children: Electricity, Earth and Space) then the 'I Wonder' board was explained and provided. The questions were collected and sorted by the researcher. The topics were not in control of the researcher as it depended on what was being taught at that time. Although this limits what might be said about the outcomes, there were some practically significant observations.

The strategy generated questions and was not time-consuming, though teachers would be required to sort and consider the questions after the lesson. Both natural science topics data were combined for younger children and both physical science topics data combined for the older children. The strategy generated a similar number of factual questions from the younger and the older children, but fewer explanatory questions from older children. It is not clear whether the variation was due to differences in teacher, in the topic, in children's prior experience, personality traits such as energy to push oneself to find questions or to some other variable. With the older children, there was again the indication of a delayed peak in explanatory questions, but what weight could be put on this is uncertain. This strategy is a time-saving activity that can be used with any science topic, provided the teacher should sort and consider the questions after the lesson. For a similar account of the strategies and the kinds of questions asked by children, see Newton, Newton, and Abrams (2018) in Appendix 8a.

10.2.6.2 *The Factual and Explanatory Questions Children Asked*

All the strategies generated science questions, both factual and explanatory questions. 'The Elephant' strategy generated an average of four science questions per child. A small proportion (25%) of the science questions were explanatory questions that pushes children to explain, predict or apply their knowledge in new contexts (e.g. *'Why do elephants and humans have water in the womb?', 'What would happen if the chord was broken?'). The rest were* factual questions like *'I wonder how the baby elephant eat food in the mum's tummy?'* These factual questions ask for information on some important life processes and therefore, their value in the development of scientific understanding cannot be underestimated. These questions are true expressions of children's curiosity that emerged when a novel content from the same science curriculum was provided as a context for problem generation. The subject of this strategy is Asian Elephant which comes under the topic 'Living things and their habitats' in key stage 2 science, national curriculum in England. Teachers can utilise similar novel and interesting ideas linked to science curriculum topics, to engage children in question asking and answering thereby leading them to become independent thinkers and learners.

With question generation workshop using the real eggs and bags, children produced an average of six science questions per head. Eggs come under the topic 'Living things and their habitats' and bags under the topic 'Properties and changes of materials' in key stage 2 Science, National curriculum in England. Around 30% of science questions were explanatory questions comprising mainly 'Why..?' and 'What...if..?' questions. Explanatory questions like '*Why does the ostrich egg have little dents?', 'Why do plastic bags not disintegrate?'* show when children were allowed specific time to observe real objects and engage in question asking under adult guidance they were able to stretch their thinking to raise causal questions. A lot of explanatory questions children produced were on the external observable features of the display, which again confirms the value of real specimen in stimulating children's curiosity and mental engagement. Teachers asking some guiding questions might be useful to direct children's focus of observation and thinking in the right directions *(e.g. Have you thought about why shops are charging 5p for shopping bags? What happens to the plastic bags after we put them in the bin?)*. Examples of factual questions children asked about the real eggs and bags include those asking for: descriptive information e.g. *'Which bag would last the longest?'*; procedural information e.g. *'What happens inside of an egg before it is laid by the mother?'*; confirmation of facts e.g. *'Do bigger eggs need more incubation?',* and confirmation of some ethical issues e.g. *'Are animals killed in a painful way or good way?'.*This again points to the value of factual questions not only in the building of knowledge base but also in developing the right attitude towards science and scientific issues, in young children.

Providing factual situations using science stories generated an average of three science questions per child. Explanatory questions constituted nearly 40% of the science questions produced. Some of the examples of explanatory questions generated using science stories were: *'What would happen to the two yolks if they hatch?', 'Why don't we stop making plastic bags?'* Factual questions were those asking for descriptive information e.g. *'Does the egg have more protein if there is 2 yolks?'* procedural information e.g. *'Can cows eventually digest plastic?',* ethical information e.g. *'Is it fair that people throw bags and it makes some animals die?'* and for the confirmation of facts e.g. *'Wolud Ther bee To twin chicks if you keep them warm?'.*Examples of factual and explanatory questions generated through the three strategies described above ('Elephant' strategy, Question Generation Workshop and Science Stories) are given in the figure 10.1 below.

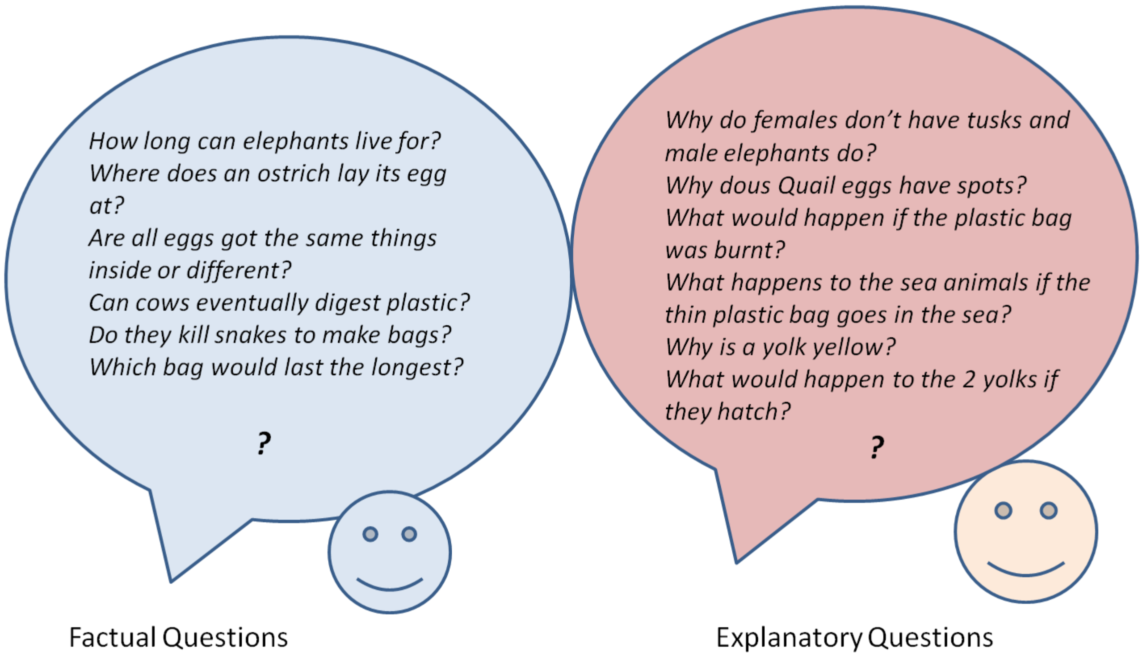


Figure 10.1 Examples of children's factual and explanatory questions generated through 'The Elephant' strategy, Question Generation workshop (real eggs & bags) and Science Stories

The least time-consuming 'I wonder' Board strategy produced an average of two questions per child. Though majority were factual questions asking for descriptive factual information and procedural information (e.g. *'How do cars work?'),* they play a role in the building of conceptual knowledge as stated before. Explanatory questions formed around 30% of the science questions and they comprised mostly 'Why..?' and 'What...if..?' questions. Like other strategies the 'I Wonder' board strategy also generated both factual and explanatory questions but based on the science topics they were learning in the classroom (e.g. Food chain, Plants, Electricity and Earth & Space). Some of these questions are provided in the figure below. See figure 10.2 showing examples of children's factual and explanatory questions generated using the 'I Wonder' board strategy.

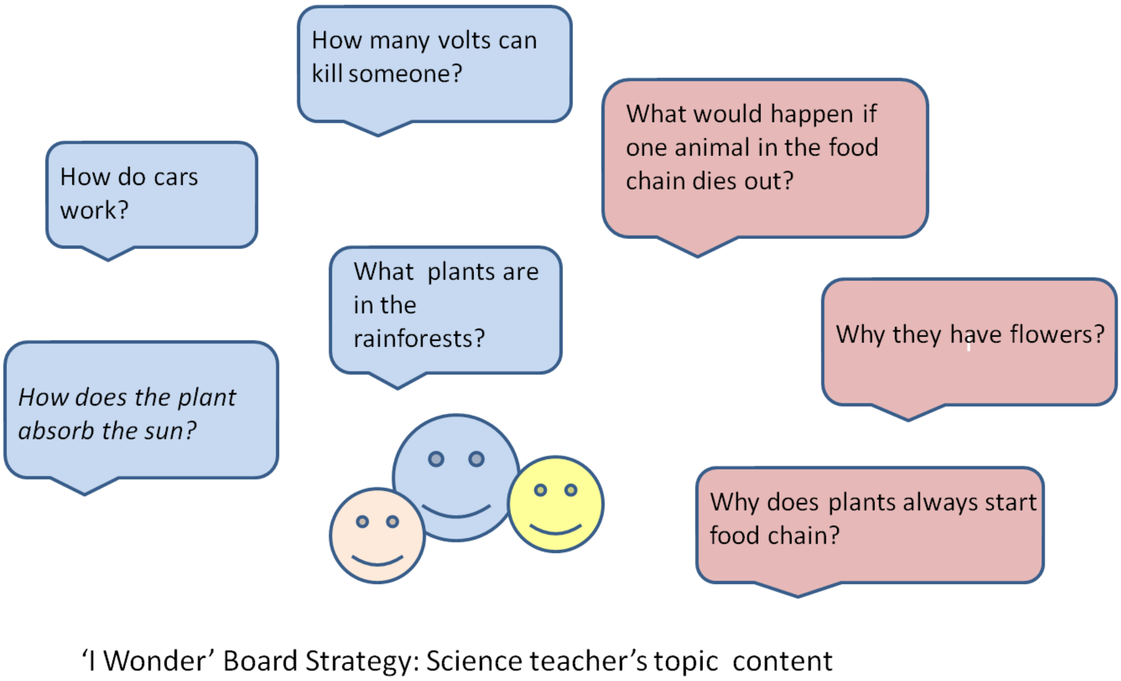


Figure 10.2 Children's factual (blue) and explanatory questions (purple boxes) generated by the 'I Wonder' Board/ Folder strategy

To conclude, majority of children's questions were factual questions asking for more information about a phenomenon or life process, clarification of facts and confirmation of ethical aspects of issues connected with science. Children also raised explanatory questions asking for reasons or causes and those that push them to predict or apply their knowledge in new contexts. Though children asked explanatory questions, they were lesser (25- 40%) when compared to factual questions. As generation of explanations are central to science, children should be encouraged to ask more explanatory questions utilising their prior knowledge in the classroom. Vygotsky (1978) using the zone of proximal development (ZPD) explained how to facilitate children's cognitive development with teacher guidance utilising their prior knowledge. His theory thus emphasise the role of teacher in scaffolding and modelling children's thinking and questioning (Sylva, 1997). Piaget (Piaget, 1959)also supported teachers encouraging children's causal thinking through questioning and argumentation (Wadsworth, 1978). Teacher modelling the asking of similar questions and encouraging children's questioning may generate more of them. A few children had difficulty to put their query in a question form though they were curious and were able to think and come up with a question with a little support from the researcher (*e.g. ' goose egg is white and shiny?' The shell is different than the other eggs?').* Similar less confident children might benefit if they could be paired with a peer, may be another medium ability child with patience to work together than working as a small group. Also, technology might be handy to support these children with difficulty to write or voice their questions.

10.2.6.3 *The questions children asked based on the RODIN analysis*

Children may ask for explanations, reasons, causes and why phenomena occur, but it may be that their questions cannot become problems which lend themselves to useful classroom activity in elementary science. The questions raised by the students were, therefore, sorted using the RODIN scale into those that might provide a basis for answering through:

· **Research** *(e.g. 'Why are some eggs bigger than other?', 'Do the bigger eggs need more incubation?');*

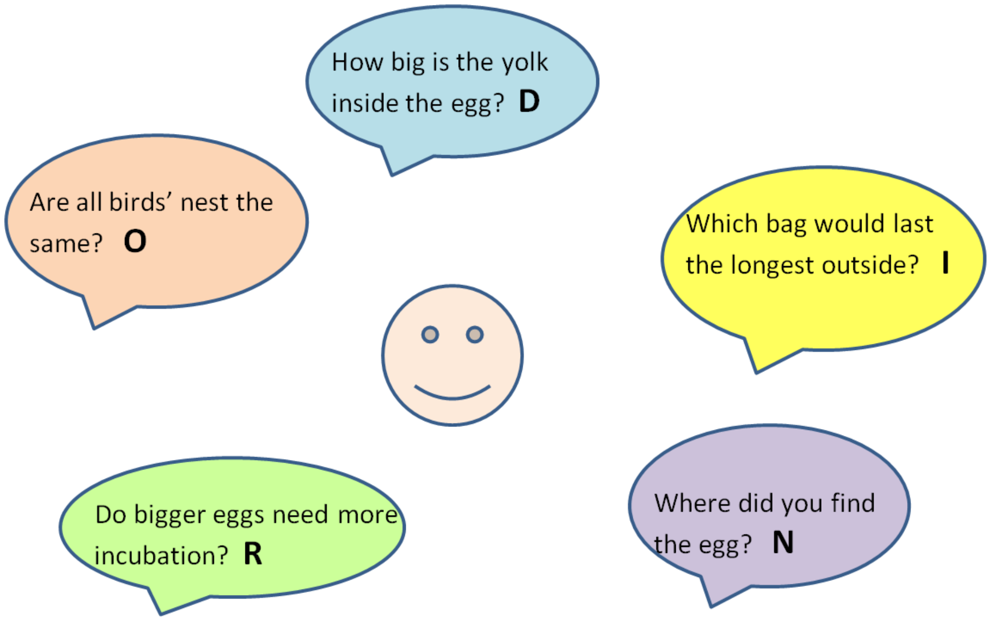
· **Observation** *(e.g. 'Which (egg) is the biggest?', 'Are all birds nest the same?');*

· **Demonstration** *(e.g. 'How big is the yolk inside the egg?', 'How big is the yolk inside the eggs?');*

· **Investigation** *(e.g. 'Why do paper bags rip in the rain?', 'Which bag would last for the longest outside?', 'Are all the eggs got the same things inside or different?', 'Is the smallest egg always the most fragile?');*

· **None of these** *(irrelevant and ambiguous questions, e.g. 'Where did you find (the eggs?', 'Have you saw a dodo egg?').*

Allocation of questions to these categories depends on the context. For example, questions answerable by Direct Observation in one part of the world, maybe answered only by Research in another. Similarly, what may be appropriate as a hands-on Investigation for older children may become a Demonstration with younger children. Similarly, one teacher may be better than another at reframing a question to make an opportunity for an Investigation in the class. Cultural forces, expectations, opportunities, time, resources and classroom routines can determine how, or if, a question becomes a found problem (Runco & Nemiro, 1994). Therefore, categorising questions this way is somewhat subjective and context-bound. Here, it reflects common expectations and practices in science teaching in England, although we should keep in mind that differences between teachers can be expected. See Figure 10.3 showing examples of RODIN questions children asked.



Sorting questions into RODIN (answered by Research, Observation, Demonstration, Investigation and None)

Figure 10.3 Examples of children's questions sorted into RODIN questions

Regarding the Question Starter strategy, some question stems forced children to generate a small set of questions that could be answered through investigations (e.g. *'How would you find out witch egg has the weakest shell without breaking them?', 'How would you see if what bag would dry from water the quickest?'.*Reflecting on the geographical context, the vast majority of questions about elephants (97% or 516) can only be answered through Research *(e.g. 'Why do only male elephant has tusks?', 'What happens to the elephant when they are getting tamed?').*Eggs and Bags, however, are more available in the UK context, and while the majority (818) were Research questions, 40 and 84 questions respectively could be, or could readily be reframed to become Investigations. The smaller number of Investigative questions arising from the Egg topic was largely because some of the eggs (e.g. ostrich) are not readily available in the UK and others which are available are not commonly seen in the super markets where most people generally shop. The question *'Are all the eggs got the same things inside or different?'* can be easily explored in the classroom. On the other hand, the question *'Which bag will rip easily?'* could be reframed as *'Which bag or material will be the easiest to rip in the rain-plastic, leather, jute, cotton, silk and paper?'.* The question *'Which egg is the smoothest?'* if reframed as *'Are all eggs smooth on the outside? Which egg has the smoothest shell? Which egg has the roughest shell? Why?'* can make it more investigative as well as researchable. Children can be encouraged to research more about different birds, their habitats, nesting patterns and think about the association between where the eggs are being laid and the roughness of the shell. Teachers' wise use of simple thought provoking questions can lead children to generate their own explanations for the variations in the colour and thickness of different eggs (e.g. Ostrich).

Though the provision of factual content, partly through stories, greatly increased the number of explanation questions (particularly for the Foraging Cow), all questions were seen as better answered through Research. Examples include: *' What would happen if you put it in an incubater (incubator)?', ' Why didn't the acid in the cows stomache burn the bag?', ' Are plastic bags a danger for nature?', 'Why do they Have 2 yokes?'* The time saving 'I Wonder' board concluded four teacher-led topics. The question patterns were similar for all topics, again with the majority open to Research. This pattern was not surprising, given that two of the topics (Food Chains and Earth and Space) were not of a kind which led readily to feasible, short term, classroom Investigations. Examples of questions that could be answered through research generated by the 'I Wonder' board strategy: *'What would happen if one of the animals in the food chain died out?', ' Why do things die of old age?', ' Why do birds not get electricuted (electric shock)) when they sit on pillors (pylons)?'* A few questions raised were those that could be answered by conducting observations, for example, *' I wonder what the inside of a plant looks like?', ' are seeds a layr (layer) of nut?' and ' Do Birds eat slugs?'* In the Investigation groups for the topic Plants and Electricity, however, there were some questions which could provide useful starting points for practical enquiry. For example, one pupil asked, *'What would happen if plants didn't get any water?', and another asked, 'What other circuits can be made?'* which are or could become practical investigations in the classroom. To conclude, the majority of the questions generated were questions that could be answered through Research. Even given the essentially context-bound nature of this classification of children's questions, there are some useful messages for teaching practices in these data which will be discussed here. Please see Appendix 6b for more details on the questions generated.

10.2.6.4 ***Reflections***

This study sought to gain some insights into children's problem finding or questioning and to see if their questions might strengthen their further learning in the science classroom. Reasoning involves the formulation of explanations utilising prior knowledge and it depends on one's ability to foresee the possibilities based on a perception, a set of assertions, a memory or a mixture of them (Johnson-Laird, 2010). Explanation or causal questions, particularly those asking for reasons, are of special interest as they facilitate the construction of powerful understandings, which can lead to prediction (C. Chin, 2006; C. Chin & Brown, 2000a; C. Chin, Brown, & Bruce, 2002; Piaget, 1959; Scardamalia & Bereiter, 1992). They are spontaneous questions generated out of children's curiosity and could lead to a cascade of generative activity and initiate fruitful discussion by stimulating students to hypothesize, predict, investigate, thought-experiment, and experiment, and generate explanations (C. Chin et al., 2002).

The process of question-asking, however, is complex and likely to depend on many variables involving the child, stimulus (topic), learning environment and their interaction. Because of this, the researcher cannot assure that the findings would be the same for all possible contexts. However, the study would like to offer some useful observations, which educators may be able to apply directly or, at least, relate to their work with children and teachers. The notion of 'relatability' is a useful one in such contexts, where variables are manifold and are rarely fully controlled or even controllable, as is the case in most realistic educational contexts (Bassey, 2001), and for the inherent complexity of human behaviour outside the laboratory (Deaton & Cartwright, 2018). Readers with a practical interest should be able to relate the findings to their own situation and, if necessary, adapt them to suit it. But, beyond that, there are outcomes of the research which complement the findings of others (as described above) and which fit the broader picture of mental model making theory so that the findings hang together in a convincing and practically useful way. These are worthy of particular attention. In addition, there are some beliefs amongst teachers about younger children's inability to ask certain kinds of questions. Teachers perceive child factors like ability to think independently, prior knowledge and understanding, topic interest, observation skill, moods and personality traits may limit their ability to find problems. These are contradicted by the findings, with useful observations about how to reach the point where such questions begin to appear.

First, primary school children (between the age of 6.5 to 11 years) here showed they could ask questions when given the opportunity and encouragement. These questions were most often about matters of fact; requests for reasons or causes were fewer in number. Similar dominance of lower-order questions asking for facts among students' questions was reported in primary (Eshach et al., 2014; Jarman, 1991), secondary (Jarman, 1991) and in university settings (Madsen & Nielsen, 2013). Children begin to learn about the world by asking descriptive questions that collect isolated facts which then lead to explanatory questions that relate facts to one another to create a coherent, causal whole. Therefore, the role of factual questions in the process of generation of understanding cannot be ignored however children should be encouraged to extend their thinking leading to the generation of causal questions. Where the stimulus was novel and interesting, the pattern of questioning was consistent with the view that children constructed a descriptive mental model of the situation, and this may then prompt questions to make it an explanatory model. The construction process is not entirely separate, one may lead to the other and they may overlap to some extent, or stop with the descriptive model. The generalised diagram of Figure 10.1 captures the essence of this process of descriptive and explanatory mental model making. Unfortunately (and understandably, given the time constraints), teachers often stop before the children reach the second stage of asking for explanations. This is not however, an insurmountable problem. Simple strategies, like using the 'I Wonder' Board, can help to overcome it. Having an understanding about the significance of children's questioning and the process of the construction of descriptive and explanatory mental models, a teacher can consciously try to encourage the asking of factual questions and slowly lead them to explanatory questions through the effective use of teacher's own questions. See Figure 10.4 below which illustrates this process of descriptive and explanatory mental model making.

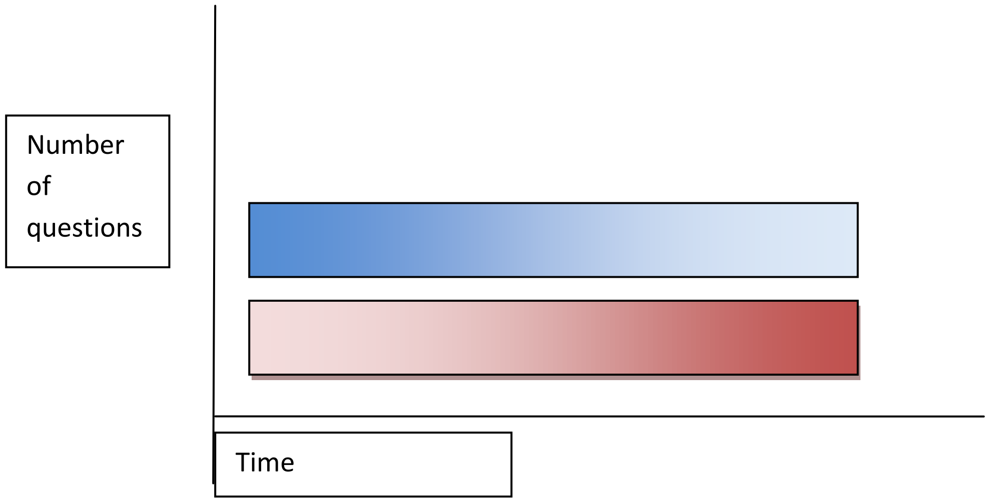


Figure 10.4 An idealised representation of children's question asking in science

The blue block represents an initial, declining phase of factual questions-asking (children thinking towards a descriptive mental model). The lower block represents a potentially later phase of asking for reasons, causes, and explanations (thinking towards an explanatory/causal mental model).

Younger children, being less experienced, would find more that was novel in the world than older children. This notion is consistent with the responses to real Eggs which provided direct concrete experiences. It also seems likely that Bags would be of less interest to the older children, which may be why they elicited fewer explanatory questions from them. In comparison to other strategies, real objects were very effective in capturing children's attention and participation in the questioning activity. This could be because real objects have richer cues to tap into one's conceptual knowledge more effectively producing a better engagement (Chouinard et al., 2007). Real specimens and objects from everyday life with some degree of novelty like the collection of eggs could act as better resources as they could provide children direct concrete experiences to think, with the use of their sense organs. Looking back, teachers may find more application for similar resources during a lock down like situation to make online lessons more engaging.

Though observation is a powerful tool for scientific reasoning, the way children observe and the inferences they make about the things in the natural world is not necessarily like those made by an expert with in-depth scientific knowledge (Eberbach & Crowley, 2009).When provided with a supportive learning environment with teacher scaffolding children were able to use observations as a basis for explanation, argumentation and investigation (Lehrer & Schauble, 2006). Therefore, by providing adequate prior knowledge and asking appropriate guiding questions teachers can help children focus on relevant features of the phenomenon or object under observation and scaffold their thinking towards the posing of causal questions and the development of the explanatory mental model. Teacher's dialogue and questions have an important role in this process and so, thinking about the quality of teachers' questions in the science classroom is crucial. Some studies expressed concerns about teachers' (L. D. Newton, 1996; Smart & Marshall, 2013)(Newman & Mahler, 1989) and surrogate teachers like textual resources' (L. D. Newton, 1996)heavy reliance on lower-order factual questions. Lack of awareness on the types of scientific questions and their significance in promoting thinking might be a reason for the heavy reliance on factual questions in the classroom. Can professional development programmes be useful to create more awareness on this?

Providing factual information in the form of brief contexts and short 'stories' could be expected to help children construct a descriptive mental model relatively quickly and so ask *Why?* questions (explanatory questions) sooner. In other words, having some factual knowledge about the situation made it easier to move to the construction of an explanatory mental model manifested by the asking of explanatory questions. There was evidence of this with the Foraging Cow scenario, but of course, the effect is only as good as the information or story provided, and it depends on the interest and curiosity that the topic generates. It may be that either the factual information or interest or both of these were deficient in the case of the Double Yolk egg scenario. Both stories included some factual information to make children familiar with the topic and both stories generated causal questions early, even though one topic generated significantly more of them than the other. This is supported by Scardamalia & Bereiter (Scardamalia & Bereiter, 1992) who reported that children asked factual questions for the less familiar topic and wonderment questions for the familiar topic. A similar incident of children generating clarification questions in response to unfamiliar text was reported by Baumfield & Mroz (Baumfield & Mroz, 2002). With some topics it requires a considerable amount of domain-specific knowledge for students to ask good questions (Miyake & Norman, 1979). Several studies stress the importance of subject-specific knowledge (scientific facts, concepts etc) for generating quality questions or problems out of genuine wonderings (Baumfield & Mroz, 2002; Gu et al., 2015; Lee & Cho, 2007; Miyake & Norman, 1979; Scardamalia & Bereiter, 1992). Science scenarios or contexts on environmental issues (Dahlgren & Öberg, 2001), particularly those which generate emotions and empathy(Solomon, 2002) are successful in generating questions from students (Dahlgren & Öberg, 2001). This seems to be true in this study concerning the Foraging Cow scenario.

If there is value in such questions, this strategy may have practical use in the classroom, but attention needs to be given to several variables simultaneously to ensure a useful effect (e.g. stimulus (e.g. topic/ interest/ novelty); environment (e.g. expectations/opportunities); child (e.g. age/experience/ mood/ personality)). As mentioned above, it might be expected that the effect of introducing a lesson first and asking for questions for the 'I Wonder' board at the end would also be a useful practice as it has the potential to provide a descriptive mental model to think with. This strategy appeared to be effective for younger children learning about Natural Science topics (Strategy 4) but was not evident with the older children learning about Physical Science topics. It could be that older children were already familiar with Electricity and Earth and Space, so these topics failed to attract their interest. If this was the case, a general suppression of both kinds of questions might be expected, but many factual questions were asked. And, of course, if the topics were known to the children, why would the teacher choose to teach them? It was suggested that topics will be neither equally interesting nor will they be equally easy to process (or presented in equally interesting ways). In other words, such differences may be due to the attributes of the topic. However, it does show that the 'I Wonder' strategy has practical value as it did produce questions with the economy of effort and classroom time.

The sorting of children's questions into activities best suited to answer them, suggests that those which could lead to feasible practical investigations in the classroom are not always abundant. This scarcity of children's investigative questions was highlighted by studies conducted by other researchers (C. Chin & Kayalvizhi, 2002; Jarman, 1991). Biggers

(Biggers, 2018) also claimed that elementary school children have no opportunity to pose questions for investigations. Many topics do not lend themselves readily to such questions. In topics which do, such investigations were often of a factual nature (e.g. 'What happens if you leave a bag outside?'), rather than of a causal nature (although they do occur, as in, 'Why do paper bags rip in the rain?'). These findings point to the need for a teacher to have some skill in helping children reformulate their questions to make them investigative, more causal. Where there is a scarcity of causal questions, such a skill is probably a valuable attribute of a teacher. This confirms the claim made by (Harlen, 1993; Jarman, 1991)and Chin & Kayalvizhi (C. Chin & Kayalvizhi, 2002) that children's science questions were not in a form that directly lead to investigations and so, need help from teachers to reformulate them into an investigative form. While introducing each strategy, a few examples of questions were also given verbally. Chin& Kayalvizhi (C. Chin & Kayalvizhi, 2002) observed a significant increase in the number of investigable questions generated when children worked in groups after examples were shown. Therefore, it would be easier if children are provided with different types of investigative questions along with examples before question generation. Different categories of investigative questions and examples generated by Chin & Kayalvizhi (C. Chin & Kayalvizhi, 2002)and by other researchers (Harlen, 1993; Jarman, 1991)have been provided in the literature reviewed which would be worth mentioning to teachers and children. Strategies, such as the use of Question Stems (Ge & Land, 2003; Gu et al., 2015; Jarman, 1991; King & Rosenshine, 1993) and Question Dice (C. Chin, 2004)used in this study may remove the motivating spontaneity of children's questioning, but teachers may still find them useful to remind children of the variety of questions possible, and as activities to hold in reserve. Also, providing question stems or starters would give children something to start with rather than having nothing while building a question.

From the strategy trials and the analysis of children's questions it is clear that question asking involves the interaction between several variables like the: *stimulus, learning environment, and child.* When planning a stimulus (topic/ artefact/ specimen/ object/ experience) for problem finding it would be better if it has some degree of novelty or unfamiliarity to catch children's attention and sustain it. Children's science interests manifested through their questions could be valuable information for curriculum development (Baram-Tsabari et al., 2006). Baram-Tsabari and Yarden (Baram-Tsabari & Yarden, 2005) studied primary school children's questions outside school and found that most of their questions were related to biology (zoology), technology and astrophysics. Chin & Kayalvizhi (C. Chin & Kayalvizhi, 2002)reported primary aged children asked questions from a wide variety of topics outside the school science curriculum and were mostly on why certain things exist or happen. Information on children's genuine wonderings can be a valuable aid for developing resources to enhance their curriculum learning through question asking. Several studies suggest the need for a favourable learning environment that encourages question asking (C. Chin & Kayalvizhi, 2002; Jarman, 1991; L. D. Newton, 2012), where teachers use scaffolding to stimulate children's creative thinking and risk taking (L. D. Newton, 2012). Learning environment involves factors like teacher's expectations, opportunities for children to ask questions and availability of support in the form of prompts, scenarios etc. Teachers' subject knowledge, mis-conceptions and issues like maintaining class discipline may limit the opportunities and hence, extending support to teachers in the form of online textual resources or tool kits may be advisable. This is also governed by expectations from the school authority and government. Child factors that determine the process of question asking include age, prior knowledge or experience, mood, personality traits such as energy to persuade oneself to find problems (Lee & Cho, 2007), how observant children are, how much attention they pay to science-related issues in daily life and how rapidly and creatively they use existing knowledge of a topic (Hu et al., 2010). Figure 10.5 given below illustrates some of the important factors influencing the process of question asking. As children require subject knowledge to stretch their thinking to ask good/ original questions, the development of conceptual understanding in science should not be ignored when pushing for practical skills.

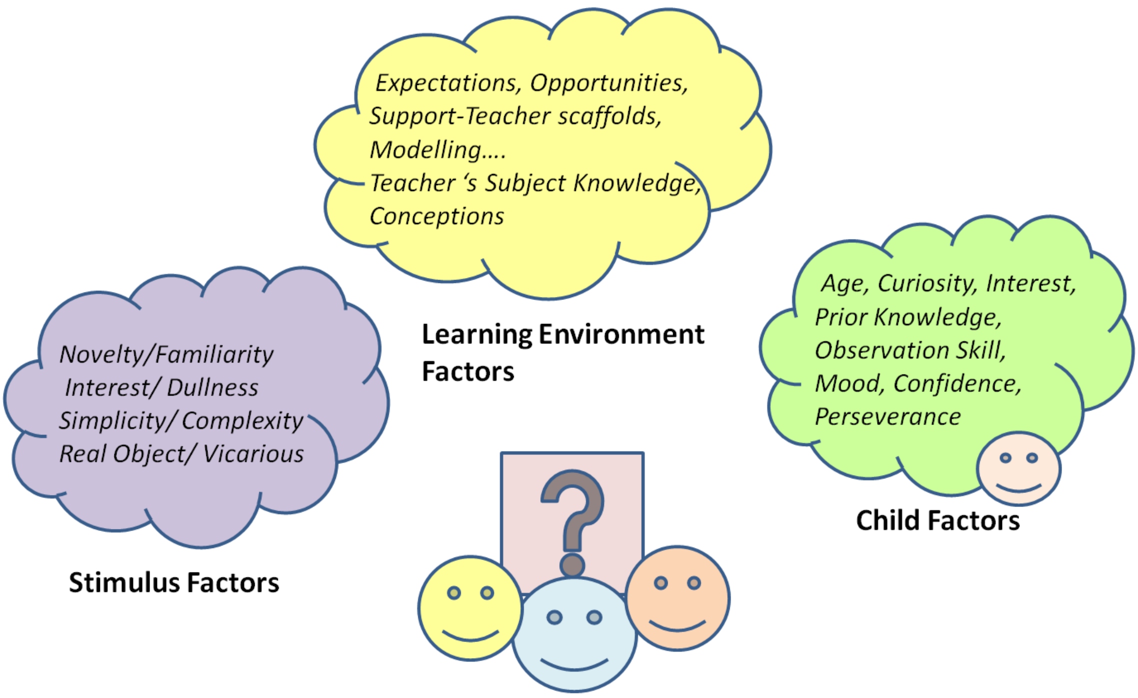


Figure 10.5 Factors influencing children's question asking/ problem finding in science

Runco & Nemiro (Mark A Runco & Nemiro, 1994) reported that certain broad approaches, like a blend of inquiry-led and more didactic teaching, can prompt deeper thinking. Many primary school teachers do not have a strong scientific background, and so tend to lean towards didactic teaching (D. Newton & Newton, 2000). Some teachers blindly believe that a practical investigative task would improve conceptual knowledge along with the development of scientific enquiry skills. An investigation may become more productive when conducted after gaining some initial understanding of the topic and so supports providing children with the conceptual structure before moving to practical investigation particularly (Abrahams & Millar, 2008), with less familiar topics (Cavalcante et al., 1997). To interpret a problem and to identify necessary information, one should have a good grasp of domain-specific knowledge (Gu et al., 2015). Some studies give great value to teacher scaffolding in development of understanding (Abrahams & Millar, 2008; Darby, 2005) and suggest that practical work along with teacher scaffolding is necessary to develop strong conceptual understanding in children (Abrahams & Millar, 2008). A combination of inquiry and didactic teaching, utilising children's prior knowledge, interest and curiosity may better engage children in deep thinking. As interest motivates learning (Silvia, 2008) it would be fruitful if teachers could give children opportunity to generate problems they are interested in (C. Chin & Li-Gek, 2005; Cuccio-Schirripa & Steiner, 2000; Lee & Cho, 2007), from real-world situations (Lee & Cho, 2007). Given appropriate topics, some of the question-generating strategies are easy to apply, but a teacher may need to reformulate children's questions if they are to become feasible activities to merge in with teaching which includes practical inquiry. Runco and Nemiro (Mark A Runco & Nemiro, 1994) suggest it might be useful if teachers modelled their thinking, and in this context, that would mean modelling the asking of questions with the potential for classroom investigation and reframing them into a practical form. Also, providing children with some examples of investigative questions would be handy especially to those shy and slower learners who face a starting trouble.

11 Chapter 11 Conclusion

11.1 Introduction

The researcher began by launching an online questionnaire survey to explore teachers' and student teachers' conceptions of creative thinking, problem solving and problem finding in science. Classroom observations were conducted to explore what teachers do in practice to encourage children's creative thinking in science. The researcher looked specifically for strategies teachers use to promote children's creative thinking, problem solving and problem finding in science. Short interviews were carried out with teachers after the observation to determine if they used any textual resources to plan their lesson and if they were available at school or online for them to use. In addition to this, a content analysis of textual resources was conducted to understand the extend to which they encourage creative thinking, problem solving and problem finding in science and thus recognise if they offered any support to teachers in doing so. Generally teachers and text resources seemed to provide children problems or questions to solve in science. If children themselves can notice a puzzling event or observation from everyday life that needs an explanation (a problem in science) and frame it into a problem with the help of a teacher (or an adult) to solve in the class, then learning would become more engaging. Keeping this in mind, strategies encouraging children to come up with their own scientific questions were trialled with children and questions were generated. Also, a theory explaining the complex process of question asking along with several factors affecting children's question asking emerged from the study. A continuing professional development (CPD) course has also been shaped as a practical outcome of the study (see Appendix 7a). The research process was driven by six research questions that explored the main issues addressed in the study and useful results have been obtained (see Chapter 10, Discussion). Briefly, these sought to learn about the fostering of children's question asking for problem finding in key stage two (KS2) primary science from teachers, textual materials, lessons, strategies intended to support causal questioning, and, hence, to understand children's mental processes when asking such questions. The study employed mixed methods to collect data using questionnaire survey, classroom observations, interviews, content analysis and controlled interventions with children. It used phenomenography to analyse the data and derive useful conclusions thereby following an interpretivist approach. This chapter presents the conclusions obtained from the research findings of this study along with the implications and directions for future research.

11.2 Essence of the Key Questions

The study answers the six research questions discussed below.

Q1. What are primary teachers' conceptions of creative thinking, problem solving and problem finding in science?

Q2. What are student teachers' conceptions of creative thinking, problem-solving and problem finding in science?

Q3. What are the strategies primary teachers use, to promote creative thinking, problem solving and problem finding in science?

Q4. Are textual materials available for teachers in schools or online to support creative thinking, problem solving and problem finding in science?

Q5. Do textual resources support creative thinking, problem solving and problem finding in science?

Q6. What strategies can be used to engage children in question asking to raise scientific questions that can serve as problems to solve in the classroom?

The following conclusions have been drawn from the findings obtained from this study. The questionnaire survey findings (see Chapters 6 and 7) revealed that both student teachers and primary school teachers associate activities involving scientific creative thinking with fact seeking practical investigations and practical problem solving by the application of scientific knowledge. Some student teachers and teachers hold narrow artistic view of creativity focussing on hands-on reproductive tasks and non-scientific creative teaching of science. Majority of the teachers and student teachers encourage problem solving by providing ready-made problems to solve. Most student teachers do not promote children finding problems or questions in science. Though, some teachers responded positively when asked if children find problems or questions to solve in science and gave a few examples, there is some doubt about the sincerity of this as the questions demonstrated instances of readymade problems given in textbooks. Two or three questions, however, seemed to be children's genuine wondering questions. Although most teachers (90%) and student teachers (85%) support the idea of encouraging scientific creativity through question asking or problem finding, they viewed it as a difficult task due to several barriers affecting the teaching and learning process and the environment, the teacher, the child and the nature of the subject/ topic in hand. A small proportion of teachers suggested promoting children's problem finding as an easy task due to their inborn curiosity, the explorative nature of science and the possibility of learning science by asking questions from real life.

The findings from the classroom observations (see Chapter 8) led to the conclusion that teachers encourage creative thinking by providing children scientific problems or questions to solve. These include problems involving practical investigations as well as those encouraging thinking without practical work. Though teachers sometimes allowed children to ask questions at the end of the lesson, it is limited to one question per child and none of the questions was used or developed as starting points for further study, hypothesis or investigation. This lack of provision for exploring children's questions can be, because of time constraints, pressure to meet attainment targets, teacher's lack of awareness, discipline issues and lack of policy statements. Short interviews with these teachers revealed that they relied more on online text resources (mainly Hamilton trust, BBC Bite Size) for planning lessons.

The information obtained from the content analysis of textual resources (see Chapter8) used by teachers suggests that they provide plenty of ready made problems for children to think and solve in science. Most of the investigative problems were those asking children to plan and carry out a test to confirm facts (creative thinking in the experimental space). Textual resources didn't seem to provide children opportunities for generating questions or problems out of their curiosity on a particular topic. A few (two or three) problem situations in the text materials gave children the opportunity to generate testable questions thereby acting as a bridging activity between teacher given problem solving and child initiated problem finding and solving.

The findings from the strategy trials (see Chapter 9) conducted to stimulate children to raise questions show that children of primary school age can ask questions related to science, but question generation out of interest and curiosity is likely to involve multifarious variables possibly interacting in a variety of ways. The process of question-asking was found to be complex involving the construction and articulation of descriptive and causal mental models of situations. When the problem situation was novel, children have to build an understanding about the situation by asking factual questions and then move on to explanatory questions to develop deeper causal understanding. When teaching something new to children, the children need to construct a descriptive mental model, and their questions need to reflect this constructive process and <u>lead</u> questioning. Such questions act as a basis for children to engage in further research. But, to develop a causal mental model, questions need to lead to explanations. Such questions may have the potential to support hypothesis construction and testing in the classroom. Some topics facilitate this process better than others. Depending on the topic, it was found that, though not numerous, some questions are generated that could lead to feasible, practical investigations, but the teacher might require some skill in reformulation to make them suitable for the classroom. If children's problem-finding is to be encouraged, teachers will have to recognise that children's question-asking should not always be the short interaction it often is, and that more useful questions can take time to emerge. These findings also highlight the need to ensure that teachers, both in training and in service, are equipped with these skills. Therefore, continuing professional development opportunities for teachers, both in-service and student teachers should be offered. Teachers should reflect on the overarching variables: the situation or the stimulus, the teaching and learning environment, and the child's attributes, the mental model construction process, and how these may affect children's responses in particular contexts. Teachers may also need to be aware of various strategies for stimulating children to ask questions and the strengths and weaknesses of these strategies in a given context. Therefore, as a practical outcome of this research a continuing professional development workshop has been designed (see Appendix 7a) and administered to student teachers and teachers. A detailed discussion of all these findings have been provided in the 'Discussion' chapter (see Chapter 10), and the workshop showed signs of being potentially useful. On this basis, it is possible to conclude that children can ask scientific questions and there are strategies that can support this process. Causal questions may not be numerous but by having children construct a descriptive mental model, causal questions can follow.

11.3 **Contributions to Knowledge and Some Implications for Practice, Teacher Training, and Education Policy**

The current study on its own provides some important new contributions to the body of knowledge as well as some implications for practice and teacher training. First of all, through the generation of descriptive and causal mental model to explain the process of children's question asking, the study offers a new theoretical contribution to the understanding of children's questioning in science (see the copy of the published article in International Journal for Talent Development and Creativity provided in the Appendix 8a). The study confirms the importance of subject specific prior knowledge in raising scientific questions or problems. When the topic is novel (e.g. elephant topic or real Eggs) children have less prior knowledge and they are likely to ask more descriptive questions to gain some factual knowledge and then move on to explanatory questions to build deeper causal understanding. Here, a descriptive mental model is constructed which then facilitates further thought of a more causal nature, prompting explanatory questions. When the topic is familiar (e.g. real Bags) children are likely to ask explanatory questions quicker leading to the construction of a causal mental model. They might already have constructed a descriptive mental model prior to questioning as they have had some prior understanding about the topic. The study stresses the need for the development of children's factual and conceptual knowledge in science to support children asking causal questions. This reinforces the findings from earlier studies that support the need for the development of science conceptual knowledge to generate good questions or problems (Hu et al., 2010; Lee & Cho, 2007; Miyake & Norman, 1979; Scardamalia & Bereiter, 1992), to interpret problems to solve (Gu et al., 2015) and to make practical investigative tasks more productive

(Cavalcante et al., 1997). Accordingly, I recommend that student teachers and practising teachers be made aware of the process which leads to children asking causal questions in science, and the need to allow time for descriptive questions to smooth the way for causal questions, as indicated in figure 11.1 (a version of the model shown in figure 10.4).

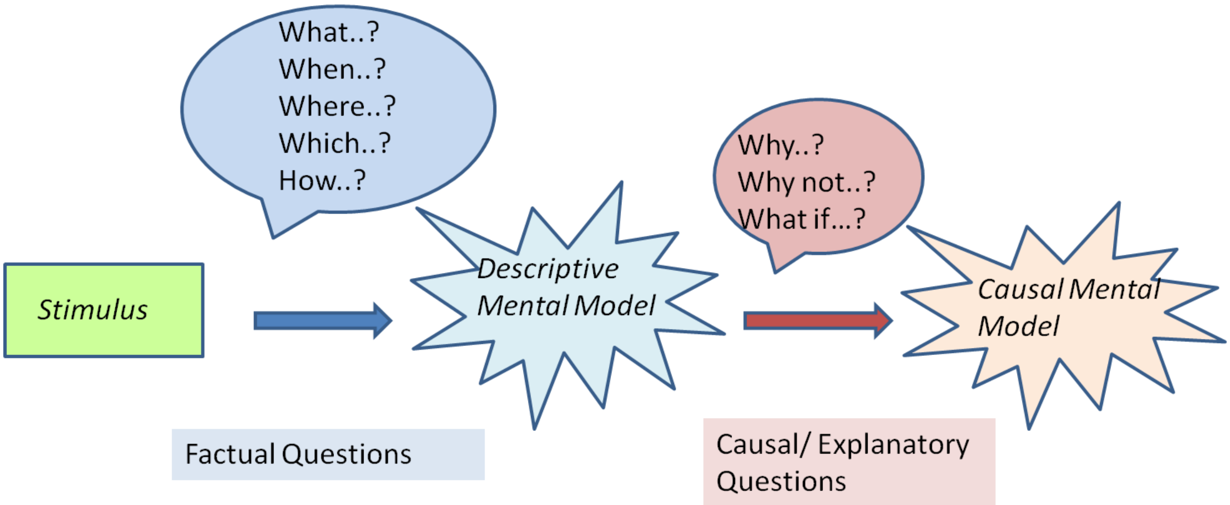


Figure 11.1 A sequential model of a child's thinking about an observed event (stimulus)

The study also suggests the three overarching variables which influence and order the process of question-asking which teachers should be made aware of. This includes:

- the situation or stimulus with attributes such as, perceived novelty/familiarity, interest/ dullness and complexity/simplicity;
- the teaching and learning environment which determine expectations and opportunities; and
- the child attributes like age, experience, prior knowledge, curiosity, confidence and mood.

Secondly, it introduces several simple strategies for eliciting children's science questions for problem finding and the strengths and weaknesses of each in a particular context. For instance, a potentially useful class time-saving strategy with any topic was to use the 'I Wonder' board. Teachers might also use concrete, in-expensive easily available resources related to science, if with some amount of novelty would be an added advantage to attract children's attention and curiosity and elicit questions. When real life objects are not available vicarious objects like photographs can be used. To help children ask causal questions (Why?) early, teachers might use strategies like science scenarios or science stories which provide factual information in the form of brief contexts and short 'stories' to aid with the quick construction of a descriptive mental model. Depending on the topic, some of the children's questions can lead to practical investigations, though most of them were not in a form that could directly lead to practical work. Therefore, the teacher may need to re-formulate them to make them more suitable for investigation. Strategies like the use of question stems and question dice (C. Chin, 2004)may remove spontaneity, teachers may still use them to remind children of the variety of questions possible. As the strategies mentioned above are simple and fruitful in helping children to think and generate questions, teachers should be made aware of them.

Thirdly, the findings from the teachers' questionnaire survey and the classroom observations reveal the lack of provision for children to think and generate scientific questions with the potential to become problems to solve in the class. Most teachers and student teachers associate scientific creativity with activities involving practical investigations and practical problem solving. Teachers provide children questions or problems to solve in science. Though teachers sometimes provided children opportunity to ask questions it was limited to one question at a time and these questions were never followed up through research or investigations. Teachers promote children's creative thinking by encouraging them to find solutions to given problems in science. Teachers can promote creative thinking by encouraging children to ask questions about a topic in science and support them to generate a problem out of it to solve in the class but this is not being done.

Lastly, the content analysis of a small sample of textual resources which includes textbooks, schemes of work and an online textual resource used by teachers gave relevant information about the creative thinking and problem solving opportunities they provide. Text materials provide plenty of ready-made problems for children to think and solve in science. Generally, text materials do not provide children opportunities for generating scientific questions or problems out of their curiosity on a particular topic. This draws light on the need for more research on updating these resources to include opportunities for question generation. Collectively, this study makes significant contributions to academic research and teaching practices by enriching the content of knowledge on children's question asking for problem finding and creative thinking in science.

As far as teacher training is concerned an important practical outcome of the study is a continuing professional development (CPD) course for primary school teachers on promoting children's creative thought through the asking of questions in science**.** The study explains the complex process of children's question asking which involves the construction and articulation of descriptive and causal mental model which teachers have to be aware of, to lead children to ask higher order explanatory questions, with the potential to support hypothesis construction and testing in the classroom. It provides various strategies for eliciting children's questions, the strengths and weaknesses of each in a particular context, handy for teachers to facilitate question asking. It also suggests that the teacher may need some skill in reformulating children's questions to make them more feasible for practical investigations in the classroom. All these point to the need to ensure that teachers, both in training and in service are equipped with these skills. Therefore, a continuing professional development (CPD) course on encouraging children to think and ask questions related to science has been generated as a practical outcome of this study. A detailed description of the continuing professional development course, its development, trial workshops with student teachers and teachers and their feedback comments is included as Appendix 7a. Table 11.1 below shows some of the comments from teachers and student teachers. This shows that the study begins to bridge the gap between research and practice.

Table 11.1 Teachers' and student teachers' feedback comments on the trial Continuing Professional Development Workshop

Questions	Teachers	Student Teachers
1) Which part (s) did you enjoy most?	*'Various strategies for developing questions'* *'Hearing the work after what had gone at school'* *'Egg & Bag ideas'*	*'Having real objects'* *'diff ways of presenting issues to pupils'*
2) Which part did you learn most from?	*'stories/ dice'* *'Practical ways to encourage questioning'* *'Practical activities, Question time is valuable'*	*'scenarios and science stories from real life'* *'photos to generate questions'*
3) What did you find most difficult or challenging?	*'Understanding the role of data'* *'Need to consider allowing time for questioning'*	*'thinking of what children would want to know'* *'thinking of questions without prompts'*
4) If I was to do this again, what should I add/remove/change?	*'Too many graphs'* *'Perhaps summarise findings to make implications for teachers clearer'*	*'how to adapt this for ks1'* *'how to link this to diff science topics?'*
5) What did you learn?	*'Importance of real life objects'* *'About how to facilitate question asking in school'*	*'using real objects effective'* *'How range of strategies opens up world of questions'*

11.4 Post-study Reflections, Caveats, and Qualifications

11.4.1 Regarding Methodology

An important characteristic of the study is the research methodology, including Marton's (Ference Marton, 1981) phenomenography, which describes how people experience various aspects of the world. Peoples' conceptions of reality are considered as categories of description. Starting from the observation of teachers' teaching science in a real classroom context the study set out to explore what is being done to promote children's creative thinking, problem solving and problem finding in science. A non-participant structured observation method has been followed with a list of behaviour cues to look out for and an observation schedule to record them. The behaviour cue list and the observation schedule were used to ensure the observation to be objective. In other words, the behaviour cue list and the observation schedule were adopted to attend the problem of internal validity that is to ensure that the researcher is observing exactly what she thinks she is observing. Combining observation with a short purposeful discussion with the teacher to collect information about the textual resources used for planning the lesson made it more focused. Also, an online open-ended descriptive questionnaire survey was launched at the same time to collect in-depth information about teachers' conceptions of creative thinking, problem solving and problem finding in science. The descriptive nature of the survey ensures clarity and tackles the problem of mis-interpretation. However, caution is needed with online questionnaires as it is never clear, who responds, why they respond, or how many respond. Content analysis of a small sample of textual resources which includes textbooks, schemes of work and an online resource used by teachers were also conducted to identify if they provide children opportunities for creative thinking, problem solving and problem finding. Mixed methods were employed to gain data from multiple sources to develop an in-depth understanding of the phenomenon being studied. To ensure accuracy and credibility, the researcher examined different sources of data to find evidence to support separate themes of the study (Creswell, 2012). It was noted that there was consistency between the various sources of information, which I feel, adds strength to the findings. As teachers or textual resources didn't seem to provide children with opportunities to raise their own scientific problems, or questions with the potential to become problems to investigate in the class, the researcher trialled some strategies to elicit children's questions. Conducting empirical research by visiting primary schools carrying out strategy trials with children in natural settings made the study vastly relevant to classroom pedagogy. Overall, it was felt that this approach worked well given the prevailing tendency in schools to limit participation in research of this nature because of the frequency of demand and the obligation to meet the requirements of the National Curriculum.

11.4.2 **Regarding underlying learning theory**

Another strength of the study is that it is based on the principles of constructivist theorists like Piaget (Piaget, 1959) and Vygotsky (Vygotsky, 1978). Though, Piaget proposed that learner constructs knowledge through hands-on practical work while the teacher acts as a stage setter, he also stressed on the role of teacher in encouraging children's thinking especially causal thinking through questioning and argumentation (Wadsworth, 1978). Pursuing the ideas of Piaget, there has been too much stress on practical work in primary schools. Practical work without students' mental engagement does not make learning effective. Therefore, it was suggested that teachers should try to engage student minds by allowing them to discuss, think and reflect before practical work. Piaget suggested that teachers should utilise children's spontaneous interests' whenever possible as they manifest a high level of motivation (Wadsworth, 1978). Children should be allowed to manipulate concrete objects or materials and they do not have to be expensive or ordered from shops (Wadsworth, 1978). The strategies used in this study utilise children's interest, curiosity and motivation to stimulate children's mental engagement. The strategies are based on the science topics from the primary school national curriculum, which are also connected to children's everyday real life with some element of novelty to sustain their curiosity, interest and motivation.

Piaget's theory (Piaget, 1959) is focused on individual cognition while Vygotsky explained cognition as a social process. The zone of proximal development (ZPD) put forward by Vygotsky (Vygotsky, 1978)facilitates cognitive development with adult guidance or through peer collaboration utilising children's prior knowledge to evolve to a higher level of cognition to generate questions. Teacher scaffolding and modelling children's thinking and questioning underpin Vygotsky's principle of social learning (Sylva, 1997). In this study, in the presence of the researcher, children worked alongside their peers in small groups to generate questions. Vygotsky's theory paid special attention to the role of language in learning. According to Vygotsky, to understand science concepts children are required to build mental representations or mental models of them. For this to happen, children should interpret scientific ideas based on their prior knowledge. Children may need to rethink and modify their existing knowledge to accommodate scientific ideas. They need cognitive tools which include ways of talking such as explaining, persuading, negotiating, arguing and summarising (Loxley et al., 2017). According to Piaget (Piaget, 1959), causal explanations make the world predictable, and are at the heart of the scientific process. To formulate explanations, one uses prior knowledge to go beyond the strict premises of the subject content and therefore, increases information (Johnson-Laird, 2010). The mental model generated from this study supports utilising children's prior knowledge to lead the questioning process from a lower descriptive level to a higher causal level manifested by the asking of explanatory questions with the potential for hypothesis construction and testing in the classroom. Though Piaget (Piaget, 1959) gives the teacher a peripheral role as the provider and manager of a suitable environment in which learning subsequently occurs, Vygotsky (Vygotsky, 1978) gives teacher a central role, leading children to new levels of conceptual understanding through social interactions mediated by language (Hodson, 1999). Both these theories support the importance of modelling and joint participation of both teacher and children in learning and solving problems. This research study also argues that the teacher has a great role in encouraging children's questioning through modelling, scaffolding and sometimes reformulating children's initial questions to make them more suitable for classroom investigations.

11.4.3 **Regarding Generalisation**

Regarding generalisation of the findings in this study,

(i) the schools I used varied in size, intake, environment, and area, so collectively cover a wide range of schools, teachers, and pupils.

(ii) Ofsted Reports for these schools show that they are very like a mix of state schools in other parts of England.

On this basis, I have some confidence that useful, tentative generalisations can be offered about teaching practices more widely, and have confidence in the generality of my findings regarding the strategies and the explanatory theoretical framework of the associated findings (as summarised in figure 11.1). Teachers in diverse contexts may also find it useful to relate the contexts and findings here to their own situations, and adopt or adapt them for their own practices, in accordance with Bassey's (Bassey, 2001) notion of the relatability of research to specific and different contexts. Nevertheless, it would be useful to test the findings and framework in other contexts, regions, and cultures, with a view to strengthening or qualifying them. Regarding culture, some schools which took part here were culturally less diverse than might be the case elsewhere, so this aspect is worth further investigation. (Out of the nine schools who participated in the strategy trials, three had children from ethnic backgrounds while the rest were predominantly of White British Heritage. Among the three, one school had one-fifth of their children from other Ethnic Backgrounds.)

In addition, there are many more textual resources than could be examined here, and there is now multimedia teaching resources and digital intelligent tutoring systems (ITS) available which extend the capability of text. It would be useful to know if such resources currently do more for problem finding than was found in text in this study. Furthermore, digital modes of instruction, like ITS, may lend themselves better to helping pupils ask causal questions than blind and deaf text alone. The construction and testing of such an approach could be worth investigation.

The current study does not attempt to over-generalise its findings. Though the study used a questionnaire survey to collect in-depth information about teachers' and student teachers' conceptions of creative thinking, the participants were mostly from local schools and university. However, Bassey (Bassey, 2001) points out that such research can be of great use through his notion of 'relatability'. Researchers and practitioners can see similarities between contexts and adapt and adopt the ideas to suit those contexts.

11.5 Ways Forward and Recommendations for Further Research

As one might expect, with a study of this nature there were several limitations upon the researcher in terms of lack of funding, time, sample sizes and access to participants. As the study progressed, new questions started to emerge and therefore, if I was to start the research again, there are a number of things I would alter:

a) I would wish to conduct more observations of teachers teaching science over a series of primary science lessons to get a prolonged view of their science teaching in different contexts, particularly with investigative practical work and without practical work.
b) It would be interesting to conduct some further investigations with individual children of different ages to determine how these strategies or combinations of strategies operate, for example science stories with question starters on the dice.
c) It would be worthy to do further research on designing more varied and engaging strategies to promote children's problem finding, particularly those involving practical work and outdoor learning activities based on the primary National Curriculum science topics.
d) I would wish to carry out further research on examining textual resources (text books and more online textual resources used by the teachers) for creative thinking opportunities.

Some of the points given above are modification of past practices and more refinements in the light of questions posed during the study. Some further questions for future research include:

a) Does teachers' scientific question asking pattern match scientific questions generated by his/ her pupils? Are there any differences between the science questions or problems generated by primary aged children taught by teachers who are science specialists compared with their non-specialists colleagues?

12 APPENDICES

12.1 APPENDIX 1a: Ethics Approval for Stage One

Appendix1aEthicsApprovalone.pdf

12.2 APPENDIX 1b: Participant Information Sheet and Voluntary Informed Consent Form

16.11.15

Participant Information Sheet

Title: **Invitation to participate in a survey on creative thinking, problem solving and problem finding in science and the follow up work** (lesson observation and post observation interview)

You are invited to take part in a research study of Creativity and the Role of Problem Finding with Particular Reference to Primary Science Teaching. Please read this form carefully and ask any questions you may have before agreeing to be in the study.

The study is conducted by Prathibha Susan Abraham as part of her PhD studies at Durham University. This research project is supervised by Prof. Lynn Newton (l.d.newton@durham.ac.uk) and Prof. Doug Newton (d.p.newton@durham.ac.uk) from the School of Education at Durham University.

The purpose of this study is to explore primary school teachers' notions of creative thinking, problem solving and problem finding in science and how it influences educational practice.

If you agree to be in this study, you will be asked to answer an online questionnaire or hard copy, by providing some general demographic information and honest answers to questions on creative thinking, problem solving and problem finding in science. If you are willing to be involved in the follow up work, we will contact you and your Head Teacher to arrange to set up observation of your science teaching and a post observation interview. An observation schedule and an observation cue list have been prepared to collect in depth information. A post observation interview with the teacher will be conducted to get information regarding the schemes of work, textbooks and other textual materials they use to support their science teaching. A copy of the lesson plan and works sheets used by the teacher will be collected.

Those teachers who we have contacted personally to set up observation of their science lesson and have agreed to participate in the study will be interviewed after observing their lesson. The same on line questionnaire will be used together with some additional questions based on the observed lesson (semi- structured interview). Also, information about the scheme of work if any, textbooks, websites and other textual materials and resources they use will be collected and data will be recorded in the space provided for textual materials in the observation schedule. A copy of the lesson plan and works sheets used by the teacher will be collected.

Your participation in this study will take approximately *15 minutes*.

You are free to decide whether or not to participate. If you decide to participate, you are *free to withdraw during the process* without any negative consequences for you.

All responses you give or other data collected will be anonymised and kept confidential. The records of this study will be kept secure and private. All files containing any information you give are password protected. In any research report that may be published, no information will be included that will make it possible to identify you individually. There will be no way to connect your name to your responses or your school at any time during or after the study.

This study is self funded.

If you have any questions, requests or concerns regarding this research, please contact me via email at *Prathibha Susan Abraham (p.s.abraham@durham.ac.uk)*.

This study has been reviewed and approved by the School of Education Ethics Sub-Committee at Durham University (date of approval: 26/11/15)

Prathibha Susan Abraham

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Durham University is the trading name of the University of Durham

Durham University
School of Education

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Declaration of Informed Consent

- I agree to participate in this study, the purpose of which is to explore primary school teachers' notions of creative thinking, problem solving and problem finding in science and how it influences their educational practice
- I have read the participant information sheet and understand the information provided.
- I have been informed that I may decline to answer any questions or withdraw from the study without penalty of any kind.
- I have been informed that data collection will involve the use of recording devices (tape recording).
- I have been informed that all of my responses will be kept confidential and secure, and that I will not be identified in any report or other publication resulting from this research.
- I have been informed that the investigator will answer any questions regarding the study and its procedures. Prathibha Susan Abraham, School of Education, Durham University can be contacted via email: p.s.abraham@durham.ac.uk .
- I will be provided with a copy of this form for my records.

Any concerns about this study should be addressed to the School of Education Ethics Sub-Committee, Durham University via email to ed.ethics@durham.ac.uk.

____

Date Participant Name (please print) Participant Signature

I certify that I have presented the above information to the participant and secured his or her consent.

Date Signature of Investigator

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12.3 APPENDIX 2a: Ethics Approval for Stage Two

PDF

Appendix2aEthicsApprovaltwo.pdf

12.4 APPENDIX 2b: Participant Information Sheet and Voluntary Informed Consent Form

Durham University
School of Education

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13/05/16

Participant Information Sheet

Title: **Invitation to participate in a strategy testing trial for problem solving in science**

You are invited to take part in a research study of Creativity and the Role of Problem Finding with Particular Reference to Primary Science Teaching. Please read this form carefully and ask any questions you may have before agreeing to be in the study.

The study is conducted by Prathibha Susan Abraham as part of her PhD studies at Durham University. This research project is supervised by Prof. Lynn Newton (l.d.newton@durham.ac.uk) and Prof. Doug Newton (d.p.newton@durham.ac.uk) from the School of Education at Durham University.

The purpose of this study (Stage 2) is to test some teaching strategies for problem solving in science.

If you agree to be in this study, you will be asked to allow the researcher to work alongside you in the classroom with small groups of children to try out to test some teaching strategies to encourage pupils to ask questions for problem solving in science. Pupils will be encouraged to ask scientific questions and they will be collected.

Your participation in this study will take approximately 4 or 5 science lessons for trying out all the 5 strategies. Otherwise 1 or 2 lessons to try selected strategies.

You are free to decide whether or not to participate. If you decide to participate, you are *free to withdraw during the process* without any negative consequences for you.

All responses you give or other data collected will be anonymised and kept confidential. The records of this study will be kept secure and private. All files containing any information you give are password protected. In any research report that may be published, no information will be included that will make it possible to identify you individually. There will be no way to connect your name to your responses or your school at any time during or after the study.

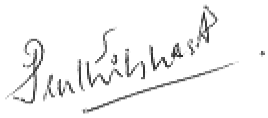
This study is self funded.

If you have any questions, requests or concerns regarding this research, please contact me via email at *Prathibha Susan Abraham (p.s.abraham@durham.ac.uk)*.

This study has been reviewed and approved by the School of Education Ethics Sub-Committee at

Durham University (date of approval:DD/MM/YY)

Prathibha Susan Abraham



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Declaration of Informed Consent

I agree to participate in this study, the purpose of which is to to try out to test teaching strategies for problem solving in science.

- I have read the participant information sheet and understand the information provided.
- I have been informed that I may decline to answer any questions or withdraw from the study without penalty of any kind.
- I have been informed that data collection will involve the use of recording devices (tape recording).
- I have been informed that all of my responses will be kept confidential and secure, and that I will not be identified in any report or other publication resulting from this research.
- I have been informed that the investigator will answer any questions regarding the study and its procedures. Prathibha Susan Abraham, School of Education, Durham University can be contacted via email: p.s.abraham@durham.ac.uk .
- I will be provided with a copy of this form for my records.

Any concerns about this study should be addressed to the School of Education Ethics Sub-Committee, Durham University via email to ed.ethics@durham.ac.uk.

____

Date Participant Name (please print) Participant Signature

I certify that I have presented the above information to the participant and secured his or her consent.

Date Signature of Investigator

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12.5 APPENDIX 3a: Letter to schools with the link to the online survey

Dear Science Co-ordinator,

I am Prathibha Susan Abraham. I am in the second year of my PhD studies at the School of Education, University of Durham where I am exploring aspects of primary science and thinking.

Previously, I worked as a primary and middle school specialist science teacher in India. During that time, I was selected to be one of four members of the Rotary Group Study Exchange team to visit the UK (Somerset) for cultural and professional exchange. I stayed with British families for a month, visiting primary and secondary schools, rotary clubs and giving presentations about schools and life in India. After moving to the UK, I have worked voluntarily in two primary schools in Stockton-on-Tees and also worked as a part time supply teaching assistant in and around Cleveland.

I am supervised by Prof. Lynn Newton and Prof. Doug Newton. Our research aims to promote creative thinking and problem solving abilities in children, through primary science learning. We are hoping to develop a CPD package for teachers, on strategies to promote creativity in science. As a first step, we have launched a questionnaire to understand primary teachers' notions of creative thinking in science. It would be very much appreciated if you yourself could spare a little of your time (<15 minutes) to answer this questionnaire and also ask some of your KS2 teachers to answer it. The link to the questionnaire is given below.

https://durham.onlinesurveys.ac.uk/primary-teachers-notions-of-creative-thinking-in-science-7

We would be happy to share our major findings with you at the end of our study, if you are interested. If you have any concerns regarding this, please feel free to e mail me (Prathibha Susan Abraham, e mail: p.s.abraham@durham.ac.uk).

Kind Regards,
Prathibha Susan Abraham

Supervisors:
Prof. Lynn Newton & Prof. Doug Newton
School of Education, Durham University

12.6 APPENDIX 3b: Questionnaire

Case No. | | |

Part A Biographical Information
Please fill in your answers. Circle the appropriate. **Name** *(Optional)*: **Gender:** Male/Female **Date:** **Role:** Class Teacher/ Science Co-ordinator/ Other *(Please specify)* -- **Number of years teaching :** 0-5, 6-10, 11-15, 16-20, 21-25, 26-30, 30+ **Teaching Year Group:** Y3, Y4, Y5, Y6 **School:** **Would you be willing to be involved in the follow up work?** Yes/No **If yes, please provide your contact details.** **Telephone:** **E mail:**

Part B Creative Thinking in Science *(By this the focus is on* ***learner's creative thinking****)*

Please circle and fill in your responses. Follow the word limit when specified.

1. Do you think science as a creative subject? Yes/No/Sometimes/Don't know

2. Do you encourage scientific creative thinking in your classroom? Yes/No/Don't know

3a. Give me an example of a science lesson which involves scientific creativity. (Maximum 100 words or 6 to 7 lines) (Topic and a brief description)

3b. Which was the creative part?

3c. What was creative about it?

4a. Do you think that encouraging creative thought in science is easy or hard? Easy/ Hard

4b. Why do you think this?

Part C Problem Solving in Science
5a. Do you see problem solving in science as being related to creativity? Yes/ No   5b. If yes, in what way?   6. Please give me an example of a problem which children might solve in science? (Maximum 60 words or 3 to 4 lines)   7a. Do you encourage problem solving in science lesson? Yes/No.   7b. If yes, in what way?   7c. Who is finding the problem to solve? Teacher/ Pupil/ Other, please specify-----------------------

Part D Problem Finding in Science
9. Do children find/ pose their own problems to solve in science? Yes/No 10a. Do you encourage problem finding in science lesson? Yes/ No 10b. If yes, give me an example of a problem which children might find in science? (Maximum 60 words or 3 to 4 lines) 10c. If no, why do you think so? 11a. Do you see problem finding as being related to creativity? Yes/ No 11b. If yes, in what way? 11c. If no, why do you think so? 12a. Do you think encouraging problem finding in science is easy or hard? Easy/ Hard 12b. Why do you think this? 13. Is there anything you want to add about problem finding in science?

Part E Opportunities for Problem Finding in Science

14a. Here is a list of aspects of science. Which three of them do you see as offering the best opportunities for problem finding? Put a tick besides them.

Plants	**Properties and changes of materials**
Ourselves and other animals	**Earth and space**
Rocks	**Magnetism**
Light	**Electricity**
Forces	**Evolution and inheritance**
Living things and their habitats	**Sound**
States of matter	

14b. Looking at your list, what makes the ticked ones the best? (Answer in one/ two sentences)

15a. Here is a list of aspects of science. Which three of them do you see as offering the fewest opportunities for problem finding? Put a tick besides them.

Plants	**Properties and changes of materials**
Ourselves and other animals	**Earth and space**
Rocks	**Magnetism**
Light	**Electricity**
Forces	**Evolution and inheritance**
Living things and their habitats	**Sound**
States of matter	

15b. What makes the ticked ones the worst? (Answer in one/ two sentences)

12.7 APPENDIX 3c Questionnaire Survey Results: From Chapters 6 and 7

Tables from Chapter 6 Teachers' Questionnaire Survey

Q3a. Give me an example of a science lesson which involves scientific creativity

Table 6.3 summarising the responses to Q3a in the questionnaire

Categories & Sub-categories	Characteristic responses
1.Hands-on/ Do (8) 28%	
1a.Model Making (3)	• "Human digestion- children made a junk model of the human body, involving all major organs involved in digestion." • "Creating animal habitats in shoe boxes."
1b. Practical Activity (5)	• "During a topic on the Water Cycle children had a range of activities to work through...." • "Help Harry Potter with his potions-separating liquids and solids over a number of weeks-using sieves/ filter paper/ evaporation etc....." • "Germination of seeds- To make students learn about the development of seeds into seedlings and to observe different stages of growth."
2. Think & Hands-on/ Do (14) 48%	
2a. Practical Problem-solving (testing materials to find the suitable one) (5)	• "Waterproof materials - Which material would be best to make a boat that would get the gingerbread man to the other side of the river safely?" • "Houses and homes topic linked to materials. Children investigate properties of materials to which would be best for building a model house for the three little pigs."
2b. Constructing a method or a practical way (2)	• "Children were using various types of exercise to measure their pulse rates. They were able to identify that exercise increased pulse rates which was beneficial to the body. " • "Children were asked to find out how to get clean water from a puddle."
2c. Applying ideas to construct something which works (D&T) (6)	• "In year 4 'electricity' children create circuits using simple components. They work in groups to incorporate the circuit into a model to demonstrate the practical use of a circuit in everyday life. " • "Using electric circuits to create a board game." • "Forces. Air resistance: children make spinners using a range of materials and designs. Link their knowledge of forces to create a spinner which will take longer to fall to the ground."

2d. Conducting observations and hypothesising (Nature Study) (1)	• "Seasonal change - observation across the whole year - sun-dials, leaf fall, shadows, temperature, weather patterns etc and then hypothesising how the world works to create such before considering what to observe to support theory."
3. Think (Mental Problem-solving) (1)3%	• "Materials - ask the children which material would be the best to make a bucket?"
4. Creative Teaching/ Teacher's Creativity (5)17%	• "Topic: Sound- We learnt actions to understand the process of hearing sound. We recited these as a whole class. Then, we extended pupils' learning by listening to different well known songs and writing what the song was called. Pupils had to describe the sound and explain how they could hear it." • "Lunar and Solar eclipse- To make the children understand the movement of the sun, earth and moon, we made three kids as the sun moon and earth and explained how when they stand in a straight line the eclipse occurs." • "Cities in the country." (Writing about an imaginative city (creative writing)
Ambiguous Response (1)3%	• Testing muscle fatigue

Q 3b: Which was the creative part?

Table 6.4 below summarises the responses to sub question 3b

Categories & Sub-categories	**Characteristic Responses**
1. Hands-on/ Do (6)	
1a. Model making - finding suitable materials for the model (3)	• "Using different materials and finding suitable materials for each body part. As a class we put it all together." • "The junk modelling." • "The children used their knowledge of a habitat to recreate it."
1b. Collection & Preparation (2)	• "Preparation of a pot with sand and manure and collection of seeds." • "Preparation of First Aid box."
1c. Doing a test (Activity part) (1)	• "Children standing up and exercising."
2. Think (8)	

2a. Thinking about properties of materials and the most suitable material (how to find the most suitable material) (3)	• "the thinking on the children's part of how to make the bucket and select the correct material." • "The children had to think about why certain materials have certain properties and which materials would be most suitable for their models." • "Open ended question so the children have to think about which materials they might like to choose and how they would design an investigation to solve this problem."
2b. Thinking how to investigate a problem (or design an investigation or tests or observations) (4)	• "They came up with the learning question and decided how they would investigate the problem." • "It could be considering how to observe; or record observations; or the hypothesis; or the design of further tests/observations; or the theory."
2c. Thinking of problems/ questions and coming up with explanations (2)	• "When children have to think about the questions: what will happen if ....., when..., to come up with explanations."
3. Think & Hands-on/ Do (8)	
3a. Testing, thinking and finding out suitable materials (3)	• "Finding out which materials would be suitable through enquiry and investigation." • "Testing materials to fix the leak in the boat. Thinking about how the objects in the sack could be used (linking to the materials and their properties)."
3b. Applying ideas, seeing a use & practical construction. (5)	• "The creative part is thinking of ideas to create and practically constructing it from boxes and craft materials. Some groups make a dolls house with a ceiling light that switches on and off, others create bedtime lamps, door bells and games such as a spinning clown's bow tie." • "making ,designing the spinner. linking design to their science understanding."
4. Creative Lesson or lesson involving activities like listening, reciting, acting, writing, role playing, reading stories etc (7)	• "The creative part of the lesson involved including sounds that pupils could recognise them. Using actions helped pupils to remember the process of hearing and was also creative." • "Moving about the room to represent a solid, liquid or gas." • "the topic context- Help Harry Potter with his potions - separating liquids and

	solids over a number of weeks - using sieves/filter paper/evaporation etc...."

Q 3c: What was creative about it?

Table 6.5 summarise the responses to sub question 3c

Categories & Sub-categories	**Characteristic Responses**
1. Hands-on/ Do (5)	
1a. Recipe following practical science activity (1)	• "Pupils could use a variety of circuit designs depending on the style of game e.g. quiz, steady hand game etc."
1b. Collection of items and preparation (2)	• "Students collected items for the first aid box like antiseptic cream, cotton, band-aid, etc and got training to execute first aid." • "Preparation of proper environment for a seed to grow, watering watching and recording the different stages of growth."
1c. Children using different materials, designs to build a model (still or working) (2)	• "Children had not used junk material to make a model before and were very interested in making a life size model with different materials."
2. Think (7)	
2a. Think to come up with own ideas that would work (plausible) (5)	• "It is open ended and allows children to come up with their own ideas - solve problems, pursue questions and adjust their world view in light of observations." • "They have to think about how they would prove which material was the best, using resources available to them."
2b. Decision making about materials to be used (1)	• "Deciding what materials they would use, how they would attach it, scale it, colour it, create texture."
2c. Imaginative writing (any idea) (1)	• "Pupils imagine their imaginative city where they wish to live."
3. Think & Hands-on/ Do (11)	

3a. Freedom to think, test and find out (7)	• "Investigating and finding out - considering alternatives." • "Students had to use readily available objects. All of them had to make changes to their original plans as trial and error showed them which materials gave them best results. "
3b. Applying ideas & practical construction (3)	• "making, designing the spinner. Linking design to their science understanding."
3c. Coming up with creative solutions while doing a practical task (1)	• "How are they going to touch the wires even if they do not have crocodile clips? How are they going to measure the brightness of the bulb? (tear paper and arrange in layers (better)/ folded) How many wires they could use? (Coming up with creative solutions)."
4. Creative Lesson/ Teacher's Creativity (5) (lessons involving activities like listening, reciting, acting, writing, role playing, reading stories)	• "Pupils imagine their imaginative city where they wish to live." • "Children could represent how to portray each state of matter and how they changed as a result of freezing, melting, evaporation etc."

Q 4a: Do you think encouraging creative thought in science is easy or hard?

Table 6.6 summarise the responses to question 4a

	Easy	Hard	Other
Do you think encouraging creative thought in science is easy or hard?	16 (55%)	12 (42%)	1 (3%)

Other= 1Response ('I think it is easier earlier in the curriculum but probably harder to meet for specific aspects of the curriculum.")

Q 4b: Encouraging creative thought in science is easy or hard. Why do you think so?

Table 6.7 summarise the responses to question 4b

Encouraging creative thought in science is easy because...	
Categories & Sub-categories	**Characteristic Responses**
1. Inquisitive/ Curious Nature	• "because children are by nature inquisitive and are keen to 'buy into' engaging contexts..." • "Kids by nature are inquisitive and science fascinates them."

	• "children are naturally curious and want to explore practical science in a range of different ways. Starting off a topic with any wondering questions they may have makes their learning more meaningful and exciting to them."?
2. Hands-on/ Do (Practical activity/ physically active)	• "Because children are by nature inquisitive and are keen to 'buy into' engaging contexts..." (separating solids & liquids) • "I think that Science is generally a subject that lends itself to active learning processes and it can often be an enquiry based approach." (CT-gestures, drama...) • "It is always easy to make the students do something creative because they are interested in doing things than learning something by heart." (first aid box) • "I feel that it is easy because children show great enthusiasm in doing things on their own and enjoy the outcome." (seed germination)
4. Think	
4a. Creative	• "Children are naturally creative." (imaginative/ ability to think)
4b. Questioning/ Asking Questions/ Problem Finding	• "In science there is always scope to adding more information to an already existing fact. However, to get this new information, one has to think beyond what is already there. Questioning every existing fact and encouraging discussions leads to easy creative thinking." • "Children are naturally curious and want to explore practical science in a range of different ways. Starting off a topic with any wondering questions they may have makes their learning more meaningful and exciting to them." • Children are keen to "explore and be creative so providing problems in which they can ask questions and create can be fun." • "Science is the study of the world around us. Everywhere you look there is ample evidence of the creative God who created our world. As teachers we need to take the first simple step of thinking beyond our textbooks."

5. Teachers' Ability to Encourage Pupils	• "If a teacher has an ability to encourage pupils they will be interested in science."
6. Topic & Resources	• "I think the difficulty of encouraging creative thinking is dependent on which topic the children are learning about. Resources can help with this."

Table 6.8 summarising the responses to question 4b

Encouraging creative thought in science is hard because...	
Categories & Sub-categories	**Characteristic Responses**
1. Topic restraints	• "Not every topic in science involves experiments, data collection or practical activities." (Hands-on/ Do) • "Not all topics lend themselves to creative thinking. Lots of facts that need to be learnt."
2 Subject constraints	• "Not all scientific subjects lend themselves to this approach." • "I think it is hard because some subjects are more difficult, due to resource constraints."
3. Resource constraints	• "I think it is hard because some subjects are more difficult, due to resource constraints." • "Having the resources to make a lesson creative and the space is a difficulty."
4. Pressure on teachers to meet curriculum targets (time restraints)	• "Most teachers are very pushed for planning and teaching time. It is far easier to follow the science curriculum teaching subject matter, and often teaching from text books that do not encourage creative thought, than it is to plan activities that allow and encourage creativity." • "Because there is so much to learn and sometime only 35mins a week for

	science." • "It can be done but teachers are more controlled, have to make sure certain targets/ objectives are covered in 6/7 lessons."
5. Difficult to think independently (Think)	• "Because the children find thinking about more complex ideas tricky and therefore it is sometimes easy to think of simple activities." • "5 year olds struggle with independent thinking at the best of times!" • "Children often want a quick answer rather than an open ended question, so they will often be task orientated say: Yes I could observe all this 'stuff' but just tell me what the answer will be!"
6. Difficult to ask questions/ Need for Teacher Prompt (Think & Ask)	• "Sometimes the children find it difficult to ask questions and look for answers- they sometimes need prompts."
7. Need for Teacher Prompt	• "Sometimes the children find it difficult to ask questions and look for answers- they sometimes need prompts."

Table 6.9 summarise the responses to question 5a

Q 5a	Yes	No
Do you see problem-solving as related to creativity?	27 (93%)	2 (7%)

Table 6.10 summarise the responses to question 5b

Yes, problem-solving is related to creativity...	
Categories & Sub-categories	**Characteristic Responses**
1. Think Creatively	• Children need to think creatively to solve scientific problems. • It promotes resilience and they have to think about how to tackle a problem in different ways if a solution is not initially found. • creating an experiment that would prove a solution to a problem • Working out how to test for an effect, e.g. effects of different substances on teeth using eggs, or thermal qualities of different materials

2.Hands-on/ Do	• Science often involves an enquiry process and involves active learning. • When children investigate certain aspects they are solving problems • If they do something creative, they know how to execute it • Open ended investigations allow for alternative 'solutions' and creative thinking.
3. Think & Hands-on/ Do?	• "Again due to the link between assessing basic skills via application."

Table 6.11 summarise the responses to question 6

An example of a problem which children might solve in science	
Categories & Sub-categories	**Characteristic Responses**
1. Think (Question form, most responses.)	• "Which materials would be best to build a boat?" • "Why do some shoes slip more on certain surfaces than others?" • "How to change ice into water?" • "Having studied about environment and the effects of global warming on the it, students can be asked to explain how they would make their school or residential area a completely eco friendly space." • "Working out how different densities of fur change the thermal properties for animal adaptation." (Project) • "How can we identify different trees?" (Observe, Think?)
2.Hands-on/ Do	• "Mr Mole needs to provide some light in his house for when badger visits him. How can you make the light adjustable so that it doesn't hurt their eyes?" • "They can help a wounded person in an emergency, if they know how to administer First aid." • "If they are asked to prepare a vegetable

	garden in their house as part of their project, they can do it easily as they know how to do it."
3. Think & Hands-on/ Do?	• "during a materials topic, the children were given a scenario in which a number of items had been mixed up. they then had to find out a way of separating the materials using a range of apparatus." • "building a paper house that could withstand a storm. Students investigate different kinds of paper, maybe come up with laminated paper as a choice. " • "Again challenged to make a spinner fall at a slower or faster rate." • "Why does the bulb not light up in my circuit? They have to work out (think) like: Is it the bulb? Is it the wire? Is the circuit complete?" (Solving practical problems (issues) while doing a practical task in the class room.)
4. Finding Answers to Questions	• "Using classification keys - children have to answer the questions relevant to the subject, to determine which one it is." • "How can we eat a healthy, balanced diet?" • "Which conditions encourage the growth of plants?"

Table 6.12 summarise the responses to question 7b

If yes (encourage problem-solving), in what way	
Categories & Sub-categories	**Characteristic Responses**
1) Teacher sets/ provides problems in the form of investigations (experiments, tests), projects and discussions	• "Yes children are then challenged to link their scientific knowledge together. To for example investigate insulation and design a cup to keep a drink hot for a long time." • "Asking the children to lead the enquiry themselves think of their own questions and how they will answer them." • "Quite often give them a problem in the form of an experiment but not give them any equipment or help. They need to decide how they are going to solve the problem and choose their equipment." • "I encourage problem-solving through

	group/individual projects, tests, group discussions." • "I try to make the science concept relevant to real life and present problems for the children to solve when possible. I used to try to present them with a problem or a challenge."
2. By posing questions 2a. Teacher Posing Questions	• "by posing questions and giving children the resources but not the solution" • "By using a question as the initial stimulus for a topic." • "Asking 'why' questions."
2b. Pupils posing questions	• "problem-solving in taught sessions linked to topic/story. Children also create their own problems during challenge time. Resources are provided to encourage scientific thought." • "I encourage my students to seek ways to answer their own questions and not rely on the teacher for everything. We have a "wonder wall" where students write down their "wonderings" and we use our free time to research and find answers. "
3. Think (Encouraging pupils to think)	• "Children are encouraged to think outside the box and explore and challenge their prior scientific understanding." • "We always think about how to test hypothesis etc and how wrong and right answers are subjective."
4. Hands-on/ Do (Through Hands-on/ Do tasks where children are active (Physically active)	• "By encouraging pupils to work independently and actively find answers to questions."
5. Guiding Teachers (Head Teacher's response)	• "Suggesting ways for teachers to pursue the scientific process in their contextual topics"

Table 6.17 summarise the responses to question 10b

• Do you encourage problem finding in science lesson? If no, why do you think this is so?	
Categories & Sub-categories	**Characteristic Responses**

1. Lack of assessment	• "As I teach the curriculum, it can be more about teaching the children about each topic, than spending time looking at different areas that aren't assessed."
2. Lack of time	• "We always allow opportunities for the children to raise questions but I personally always feel under the pressure of time and the need to follow the plan. There have been times when I have been bold enough to explore children's ideas more fully." • "Because of large class sizes and short time."
3. Large class size (2)	• "Sometimes there might be too many problems developed by 31 children and so be hard to monitor, resource effectively, etc."
4. Contextual (not all topics good for CT)1	• "I give them a problem situation (last lesson) and they experience problems while doing it. Contextual, some lessons, time constraint."
5. Lack of awareness (teacher's) about this area (PF)1	• "I do not think it is something I have ever thought about, but will do now."

Table 6.18 summarise the responses to question 11b

Do you see problem finding as being related to creativity? If yes, in what way?	
Categories & Sub-categories	**Characteristic Responses**
1. Think (15 responses)	
1a.Thinking for both creativity and problem finding(3)	• "Through the thought process and lines of enquiry." • "They need to think of their answers. Think independently about their ideas." • "They think and imagine in both of them."
1b.Thinking creatively for problem finding (creativity for PF)(5)	• "The children are looking for solutions to problems which aren't given to them. They are using their creativity to think of problems which may require a solution." • "Problems won't occur unless they do something creative."

	• "One needs to think out of the box to go beyond what already exits. Therefore finding a problem with existent information requires creativity." • "Thinking creatively around an idea should raise questions and therefore how to answer the questions."
1c. Thinking from diff angles (4)	• "That the children are looking at different ways to approach a challenge or piece of work."
1d. Thinking outside the box (3)	• "One needs to think out of the box to go beyond what already exits. Therefore finding a problem with existent information requires creativity." • Thinking outside the box.
1e. Children engaged & interested (4)	• "Children are actively involved in finding their own problems." • "Creativity is about using your imagination and creating things. If a child is thinking of their own problems it is all part of the thinking and being interested and engaged process." • "I feel it is. they topics can then be child initiated and led." • "It involves an active learning process and enables pupils to explore and find an answer to problems posed."

Table 6.19 summarise the responses to question 11c

Do you see problem finding as being related to creativity? If no, why do you think so? (3) (one gave no reason)	
Categories	**Characteristic Responses**
1a. Artistic view of creativity (1)	• "Problem-solving is generally a logical process, creativity is more artistic."
1b. Not sure	• "Not sure. I think creativity just helps children to overcome/ solve problems."

Table 6.21 summarise the responses to question 12b

Problem Finding is easy or hard? Easy, because... 9 responses (31%)	
Categories & Sub-categories	**Characteristic Responses**
1. Open ended activities (1)	"open ended activities in challenge time. Resources available for children to explore."
2. Active & independent learning (1)	"Because Science is often active and can incorporate learning processes that encourage pupils to work independently."
3. Questions from real life (1)	"Most of the problems occur related to their life experiences."
4. Availability of resources (2)	"open ended activities in challenge time. Resources available for children to explore."
5. Easy to encourage children (3)	"All science is based on somebody who decided to investigate so children should also be encouraged to forward experiments with further research of their own." "It is always easy to encourage students to do something than asking them to learn from the text."

Table 6.22 summarise the responses to question 12b

Problem Finding is easy or hard? Hard, because... 20 responses (69%)	
Categories & Sub-categories	**Characteristic Responses**
1. Setting up the stage to find questions (1)	• "Because it is easier to tell kids what we need them to learn. It's harder to set the stage for them to find it for themselves."
2. Child factors - independent thinking ability, perseverance, observation, good understanding, reasoning & logic (7)	• "It requires the children to be independent learners and to think for themselves. This is a skill some children have and others do not." • "Children give up too easily and don't always have the perseverance needed to be problem finders or solvers." • "Children may not find a problem with what they have observed." • "Some children find it difficult to grasp- don't have the knowledge and understanding."

	• "Its easy to accept something as it is but to question it further is challenging. To encourage this type of thinking in young minds becomes hard." • "It is a way of looking at the world that many of our children have never been exposed to and requires reasoning and logic."
3. Time constraints and pressure on teachers (5)	• "When the time table is so full it is hard to make the time." • "Time restraints." • "Lack of time because we have lots of facts to learn." • "With a large class and often no support, it is hard to give time and space to creative thinking with such a pressured and full curriculum."
4. Availability of resources (2)	• "Having the resources and space can make it difficult." • "At primary level due to facilities and equipment."
5. Assessment system & teachers' thought process (1)	• "The natural thought process for teachers is to teach information. The testing system we use in science assesses understanding and subject knowledge. "
6. Class size (1)	• "With a large class and often no support, it is hard to give time and space to creative thinking with such a pressured and full curriculum."
7. Teacher prompts or scaffolding (1)	• "Contextual (some topics) Time is a problem. Not tried it. Some of them (more advanced) would be able to do it. May need guidance & help from the teacher."
8. Contextual (2)	• "Contextual (some topics) Time is a problem. Not tried it. Some of them (more advanced) would be able to do it. May need guidance & help from the teacher." • "Again dependant on topic."

Table 6.23 summarise the responses to question 13

Is there anything you want to add about problem finding in science?	
Categories & Sub-categories	**Characteristic Responses**
1. Time constraints (2)	• "It takes more time to pursue this approach to science than to simply impact knowledge or instruction." • "In theory, I know it is good to involve the children as much as possible in problem finding. In practise there is sometimes not time to do all that we aspire to."
2.Funds (1)	• "funding lacking in primary school."
3. Self reliance in children (1)(India) Children be made more self-reliant through PS & PF	• "We can encourage the students to be self reliant by identifying and solving the problems themselves."

Tables from Chapter 7-Student Teachers' Questionnaire Survey Results

Q3a: Give me an example of a science lesson which involves scientific creativity. (Topic and a brief discussion.)

Table 7.3 summarising the responses to Q3a in the questionnaire

Categories & Sub-categories	**Characteristic responses**
1.Hands-on/ Do (8)	
1a.Model Making (6)	• Digestion in H. beings-Creative part: Preparation of model of digestive system, innovative chart on the topic, Use of diff ICT.
1b. Practical Activity (Experiment)(1)	• Reaction of acid with carbonate (topic) can encourage scientific creativity among students. They can experiment the release of CO2 by using various creative techniques.
1c. Observation & data representation (1)	• Teaching the unit of 'Life Cycles', one lesson idea would be to bring in various types of fruits, fleshy and non-fleshy, and encourage the children to make observations about the fruit inside and looking at the seeds specifically. They must collate their data using a table provided. (Do/ Think & do) confirm?
2. Think & Hands-on/ Do (9)	
2a. Practical Problem-solving (testing materials to find the suitable one) (5)	• Insulation, Children design jackets to keep a frozen water bottle warm. See which materials best insulate it. • Investigating a range of materials to identify which ones float.
2b. Conducting experiments	• Have the children conduct experiments to either confirm

(3)	or disprove their ideas about the world. • Investigative experiment on insulation. • Gravitation-interesting topic, arouse curiosity. Lots of experiments and models that can be done by students. It will enhance their scientific creativity.
2c. Applying ideas in real life (1)	• Flowers (parts, seeds, pollination, germination etc) - It helps students to have a beautiful garden in their home.
3. Think (5) 3a. Mental Problem-solving (2)	• Description: Mars mission- what would you bring and why? • Real Life Problems: Phenomenon of Interference- petrol drop out on the road
3b. Demonstration of experiments/ activities (2)	• Force-demonstration of the contact and non-contact force and frictional force activities to the class. • Surface Tension-Floating of blade on the water surface, sinks when soap solution is added to it.
3c. Asking thought provoking questions (1)	• Cell Clusters- Creative teaching beginning with asking some provoking questions (topic related)
4. Creative Teaching/ Teacher's Creativity (3)	• States of matter introducing the children to frozen solids. Freeze bottles of water, using a ping pong frog head to make it more interesting to children. • Using a story book such as hungry caterpillar to introduce life cycles and asking children to write our life cycle. • Cell Clusters- Creative teaching beginning with asking some provoking questions (topic related) (THINK), Power point, Chart, materials can be shown.

Q3b: Which was the creative part?

Table 7.4 summarising the responses to sub question 3b

Categories & Sub-categories	**Characteristic Responses**
1. Hands-on/ Do (7)	
1a. Model making - finding suitable materials for the model (6)	• "Making the model using raw materials." • To make a beautiful model of human respiratory system.
1b. Observation (1)	• "There is a creative aspect to making observations as the children will need to articulate what they see …"
2. Think (5)	

2a. Thinking about properties of materials, choosing the suitable material and designing (2)	• "Designing the insulating jacket." • "Choosing the insulation."
2b. Demonstration of experiments encouraging thinking (2)	• "The experiments showing the diff between contact and non-contact force." • "The experiments to demonstrate soap reduces surface tension."
2c. Thinking of problems from every day life (1)	• "Daily life examples."
3. Think & Do (3)	
3a. Testing, thinking and finding out suitable materials (2)	• "Investigating a variety of materials." • "The children choose materials and investigate their own ideas."
3b. Applying ideas in real life (1)	• "To create a beautiful garden by knowing the nature of each plant including their flowering seasons." • "Construction & working of a fire extinguisher using baking soda and vinegar (acetic acid)."
4. Creative Lesson (2)	• "The troggs." • "Diagrams of cell shown through the power point or a chart."

- **3c: What was creative about it?**

Table 7.5 summarising the responses to sub question 3c

Categories & Sub-categories	**Characteristic Responses**
1. Hands-on/ Do (9)	
1a. Experiment demonstration/ practical activities (forces- contact, non contact, gravity)(1)	• "The experiments are creative."

1b. The process of preparation (2)	• "Preparation' process and the materials used in the preparation." • "Making model- creative and innovative activity, students will be encouraged to study."
1c. Children using different materials, designs to build a model (5)	• "Preparation process and the materials used in the preparation." • "To make human respiratory system using locally available materials."
1d. Interaction with nature (1)	• "Aesthetic beauty, new variety of flowers, creating an interactive nature with living creatures & plants."
2. Think (6)	
2a. Think to come up with own ideas (1)	• Designing outfits for them
2b. Decision making about materials to be used (2)	• The choice of floating materials. • Children need to think of what will be effective (insulation).
2c. Understanding? (3)	• Students could easily understand the concept of surface tension through the experiment.
3. Think & Hands-on/ Do (2)	• "Children could choose their materials and how they would arrange them." • "The children are questioning the properties of materials and designing ideal clothing."
4. Creative Lesson/ Teacher's Creativity (2)	• "Science lessons can be made creative through the introduction of everyday objects (like fruits -diff types) • "By showing the diagrams of the concerned topic students will remember its shape, colour etc than simply lecturing."

Table 7.7 summarising the responses to question 4b

Encouraging creative thought in science is easy because...	
Categories & Sub-categories	**Characteristic Responses**

1. Curious (4)	• "Children will be curious." • "Because children are natural experimenters." • "Pupils are curious to get knowledge."
2. Think- (Real life situations & different perspectives) (2)	• "By allowing students to think more about the theories and principles in connection with the practical life situations." • "The children should be encouraged to think about diff perspectives."
3. Think & Do (1)	• "Science exploration and investigation can lend itself to creativity."

Encouraging creative thought in science is hard because...

Categories & Sub-categories	**Characteristic Responses**
1. Topic restraints (contextual)(2)	• Some areas they already have interest in the area, so they will want to engage. Depends on content, plan and most importantly the children. • I think it is difficult to convey tricky concepts in a creative way without missing out imp bits of information.
2. Factual nature of science (4)	• "Because it's such a set subject, hard facts etc." • "Is often taught in schools in a more factual way (how something happens) as questioning and discussion (often seems more reserved for subjects like English)."
3. Curriculum and target constraints (2)	• Teachers are v. focussed on ticking off knowledge in the NC. Sometimes it can be easier * to tell children facts and give instructions for an experiment rather than letting them design an experiment themselves (*in terms of organisation, logistics, classroom management etc)
4. Independent thinking (4)	• Engaging pupils in all science topics, requires pupils to engage in a deeper level of thinking so must be engaged. • Pupils find difficult to think beyond a limited frame work. They always need more and more examples to develop a creative thinking in the field of science. • If children are stuck in one way of thought then difficult to get out of that way of thinking.

5. Lesson Planning and Implementation (4)	• It is difficult to plan into lessons. • I think it is hard as it is an area that I struggle with, therefore find it difficult to implement.
6. Teacher's subject knowledge (1)	• It may be difficulty to think both creatively and scientifically if knowledge on topic is not strong.
7. Children's interest (5)	• Each individual is unique. Every student may not be interested towards, this method. • Each pupil has diff interest.
8. Lack of books for some areas of science (1)	• "Children require a book to gain their enthusiasm for a topic, however this can be difficult to find for some subject areas without losing sight of the goals."
9. Big C view (Creativity for some) (1)	• "Creative thinking may not come from every one and every time. Few peoples may have excellence in it, others may not."
Ambiguous response (1)	

Table 7.9 summarising the responses to question 5b

Yes, problem-solving is related to creativity...	
Categories & Sub-categories	**Characteristic Responses**
1. Think (32)	
1a. Think Creatively to solve problems (29)	• Creativity is linked to thinking flexibly, which will help in critical thinking/ problem-solving • You can come up with creative ways to solve a problem. • It requires creativity to imagine various scenarios and ways of tackling a problem. It also requires knowledge and insight to correctly solve the problem.
1b. Think creatively to design experiments to solve problems	• Designing novel experiments to find the answers
1c. Generate understanding (2)	• A concept in science the children will have lots of questions on. A good way to guide understanding would be to solve a problem in lesson. • Explaining various ideas using various formats. Children are creative in their ideas.

2. Think & Do (10)	• Involves investigating and trial and improvement. • Children can be given things to experiment with which could be highly creative. • Can creatively test to prove/ disprove conceptions to solve a problem. • Problem-solving should be creative and children should be able to use "trial and improvement" when completing practical. • Problem-solving often includes practical activities and making observations, these two elements require an aspect of creativity. • Finding answers through experiment and investigation.
3. Do/ Hands-on (1)	• Practical activities can be creative.
4.Teacher as motivator (2)	Teacher should motivate to develop the creativity among them in the particular subject.

Table 7.12 summarising the responses to question 7b

Do you encourage problem-solving in science? If yes, in what way	
Categories & Sub-categories	**Characteristic Responses**
1) Teacher sets/ provides problems in the form of investigations (experiments, tests, practical activities), projects and discussions (2)	• Ask them to conduct the experiment when possible so they can solve the problem themselves. • Planning their own investigations.
2. By posing questions/ problems 2a. Teacher Posing Questions (10)	• Through questioning and problem based learning. • Posing a problem/ question and encouraging the children to develop a method for experimentation. • Giving them a question based on an event or topic and allowing them to discuss how to answer that question and what steps will be taking to arrive to the conclusion. • Give them various questions related to the problem and ask them to collect information related to the topic.

3. Helping children to think and come up with their own answers/ solutions (5)	• Encourage children to create their own situations to answer problems. • Get children to lead enquiries, how they can answer their own questions? • Using their prior knowledge and trying to apply it. • When I teach various concepts in the classroom, I try to relate the daily life examples of the particular concept. By analysing that pupils could try to find various solutions for the day to day observing problems. • Understanding of the lesson helps students to solve related problems
4. Helping students to identify the best solution (2)	• Identifying the best solution.

Table 7.16 summarising the responses to question 10b

Do you encourage problem finding in science lesson? If yes, give me an example of a problem which children might find in science	
Categories & Sub-categories	**Characteristic Responses**
1. Think (4)	• Why does a coat keep a snowman warm? • Students may ask the question how the nutrients become a part of our body. • Why convex mirror is used as the rear view mirror in vehicles?
2. Think & Hands-on/ Do (5)	• Waste disposal • Children might be surprised to discover that a tennis ball and bowling ball fall at the same speed. • Children might ask why a balloon doesn't float. • Teaching 'acids and carbonate' students realised the working principle of fire extinguisher.
Wrong interpretation of the term 'problem' finding in science in the above questions-Do you encourage problem finding in science lesson? **If yes, give me an example of a problem which children might find in science.** 4 responses (wrong interpretation of the term problems- scientific problems as problems faced by children in the learning of science) 2 responses-one not in a question form and the other don't seem to be a question asked by a child. Most respondents didn't answer the above question. It might be very unlikely that children are getting opportunity to find science problems/ questions in the classroom.	

Table 7.18 summarising the responses to question 11b

Do you see problem finding as being related to creativity? If yes, in what way?	
Categories & Sub-categories	**Characteristic Responses**
1. Think (responses)(25)	
1a.Thinking creatively/ flexibly/ alternative ways for problem finding (CT for PF)(9)	• Thinking in alternative ways • Again thinking flexibly- creatively will help discover situations. • If the student develop creative thinking only, they can point out or figure out problems in the science aspects • Because creative thinking helps to identify problems.
1b. PF leading to creative thinking (PF for CT)(3)	• Problem finding encourages students to think in a wider area and develops their creativity. • Problem finding will help the students to think creatively and critically. It helps them to develop a scientific attitude.
1c. Thinking for deeper understanding (1)	• Children are attempting to understand- finding problems helps to find a deeper knowledge.
1d. Student engagement (1)	• The children must be engaging to develop their own questions in a subject.
1e. Scientific attitude (2)	• Helps the students to develop a scientific attitude • Problem finding will help the students to think creatively and critically. It helps them to develop a scientific attitude.
1f. Seeking new information (1)	• Pupils try to collect new information and apply that.
1g. Solving problem creatively (7)	• Different individual ideas on how to solve • We can find creative ways to solve the problem. • Problem-solving links to creative thinking. • Can use creative tests to prove/ disprove problems and find solutions.
1h. Imaginative (art based view of CT) (1)	• You are required to be imaginative to some extent.

2. Think & Do/ Hands-on (1)	• Practical tasks to demonstrate.

Table 7.19 summarising the responses to question 11c

Do you see problem finding as being related to creativity? If no, why do you think so? (4)	
Code category	Characteristic Responses
1. Observant & being inquisitive (1)	• Finding problems is about being observant and inquisitive
2. Can see a relationship between PS and creativity, not PF (3)	• Children use creativity to solve problems. • They do not need to be creative to find a problem. • In a people does not with a creative mind, but can find their problems.

Table 7.21 summarising the responses to question 12b

Problem finding is easy, because... (12)	
Categories & Sub-categories	**Characteristic Responses**
1. Curious and inquisitive nature of the child (6)	• Children naturally ask questions • Ask questions and can investigate to answer them • It is often accidental.
2. Nature of science- explorative, interesting, inquisitive (4)	• Because there are lots of topics to explore and lots of possible outcomes and conclusions • Every concept could be explored to show .... • Being inquisitive is a key part of science. • Science is full of enthusiastic interrelated facts.
3. PF as a lesson starter activity (1)	• Problems could be posed as a lesson starter.
4. Thinking creatively (1)	• Because when we start thinking creatively, problems will be identified easily.

Table 7.22 summarising the responses to question 12b

Problem finding is hard, because..... (21)

Categories & Sub-categories	Characteristic Responses
1. Child factors- 1a. Ability to think independently & in-depth understanding (3)	• Requires a deeper level of thinking • It takes lot of time for students to understand certain topics in depth. Problem finding starts only when they try to find answers for questions, why, how etc. • Hard to find answers immediately.
1b. Interest (2)	• Individual differences and interest. Can be inculcated by a good teacher. • Every individual may not be interested.
2. Teacher factors - (3) 2a.Good subject knowledge	• Difficult task for the teacher, a teacher should update with her subject. • For this a teacher should be resourceful and competent. • Both finding out the problem and finding out the solution to the problem are difficult tasks for a teacher. A teacher should posses good sub knowledge.
3. Factual nature of science- (2)	• Is often taught in schools in a more factual way (how something happens) as questioning and discussion (often seems more reserved for subjects like English). • There are often misconceptions in science. • It can appear daunting but does make science real.
4. Curriculum Targets & Pressure (1)	• Directing the learning to meet objectives
5. Hard to encourage (5)	• Because the teacher can't try to and know each persons to solve problems. • It can appear daunting but does make science real. • Hard to encourage but may find their own without realising through misconceptions.
Ambiguous (1)	

Table 7.24 summarising the responses to question 13

Is there anything you want to add about problem finding in science? (3)	
Categories & Sub-categories	**Characteristic Responses**

1. Teacher support (1)	• If the students are provided with opportunity to get clarifications for their questions by the teacher, they will be interested to find more problems (Teacher support)
2. Real life problems (1)	• It should go in hand with the practical life.
3. Discovery learning	• Problem finding will be the first step of discovery learning and discovering skills.

12.8 APPENDIX 4a Check lists for classroom observations

1.	Informed consent form	
2.	Participant Information Sheet	
3.	Observation Schedule	
4.	Observation cue list	
5.	Questionnaire	
6.	Recording devices	

12.9 APPENDIX 4b Observation Behaviour Cue List

APPENDIX 4b Behaviour Cue List

Observation cue list for creative thinking, problem solving and problem finding in science

1. Observation statements to do with creative thinking

1a. Pupil giving tentative descriptions of situations, properties of substances and patterns or trends in a data

1b. Pupil finding and describing about analogies

1c. Pupil giving tentative explanations, reasons, causes and hypothesis

1d. Pupil constructing a test/procedure to collect descriptive information

1e. Pupil constructing an empirical or fair test of a tentative explanation

2. Observation statements to do with problem solving

2a. Teacher finding problems to solve

2b. Teacher defining problems to solve

2c. Teacher clarifying the problem

2d. Teacher using figures and diagrams to represent problems

2e. Teacher scaffolding pupils problem solving through focussed questioning

3. Observation statements to do with problem finding/ posing/ formulating/ sensing/ generating/ constructing/ framing

3a. Pupil finding problem

3b. Pupil defining the problem in terms of objectives and obstacles

3b. Pupil clarifying specific challenges and relating them

3c. Pupil using diagrams/figures to express the problem

3e.Teacher modelling problem finding by showing examples of problems

3f. Teacher scaffolding pupils' problem finding through focussed questioning

3g. Teacher giving pupils opportunity to ask questions

12.10 **APPENDIX 4c: Observation Schedule**

Observation schedule for CT, PS and PF														***Date:***						***Case No.***	
Who		**Time**	**Creative Learning**					**Problem Solving**				**Problem Finding**								**Other Contextual Factors**	**C**

12.11 APPENDIX 4d: Sheet to enter details of the textual resources used by teachers

Textual materials and web resources teachers use to plan	***Case No.***			

12.12 APPENDIX 5a Textual Analysis

Content Analysis of Textual Resources: Qualitative Analysis (Chapter 8)

Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Folens Science in Action -(507/FO) Y3 Jo Powell, Simon Smith, Anne Whitehead, Steve Sizmur, (Published by Folens, 2004)			
	Sc 2 Biology **Teeth and Eating**	**Sc 3 Chemistry** **Rocks and Soils**	**Sc 4 Physics** **Light and Shadows**
CT	1. Design a fair test to investigate the effect of cola , sugar and water on teeth (marble/ tooth/ egg) (acid dissolves teeth, microbes turn sugar to acids and leads to tooth decay) Think & Do	1. Investigation to find which sample of the soil holds more water. Predict. Investigate. Record. (soil with bigger particles =bigger air spaces) Think & Do	1. Investigating what happens to the size of a puppet's shadow when you change how far it is from a light source. How will you keep the test fair? (Photocopiable outline of a puppet is provided to cut out and paste it on a lolly stick) Record, distance and height of the shadow. Encourage pupils to explain why height of the puppet changed using the knowledge that light travels in straight lines. Think & Do 2. Recording length of shadows depending on the position of the shadow in the play ground. Investigate what happens to the length of the shadow over the day. When is the shortest? Longest? Why the length changes? Think & Do
PS	1. Food diary- Maintain a food diary for a week, group foods into 4 groups (table, p10). From your food diary choose a selection of foods to **plan a healthy meal** (should contain food from each of the groups). Think & Do 2. Plan a meal for someone in the hospital (balanced and tasty). Think	1. Group the rock samples into 3 groups (sedimentary rocks (with grains or layers), igneous rocks (crystals), metamorphic rocks (glassy and layers of crystals). Think & Do	
PF			

Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Folens Science in Action -(507/FO) Y4 Sue Harris, Simon Smith, Anne Whitehead, Steve Sizmur, (Published by Folens, 2004)			
	Sc 2 Bio Habitats	**Sc 3 Chem- Solids and Liquids, and How they can be Separated**	**Sc 4 Phy- Circuits and Conductors**
CT	1. Design a fair test to see if woodlice prefer light or dark conditions. Predictions about the habitat woodlice prefer. How to make a fair test? Observe and make conclusions. (Change in their original environment) Think & Do	1. Plan a fair test to find out if an ice cube or a piece of chocolate would melt first? Predict? Fair? Conclusion? Think & Do 2. Plan a fair test to find out whether butter and candle wax will melt at room temp? Think & Do 3. Plan a fair test to compare teabag paper with filter paper. Which do you think is better? Why? p50 Think & Do 4. Does the temperature of the water affect whether or not a solid dissolves? How could you find out? (p52) Think & Do	
PS	1. Make up a key to identify animals like tiger, lion leopard Think	1. Can a mixture of sugar and water can be separated using either filtering or sieving? Explain. (p54) Think	1. Use given objects to fill a gap in the circuit and see which ones light the bulb. Try completing the circuit with the 'lead' in your pencil by touching the two ends of the pencil with the wires. What happens? Research what is lead made from. (p70) Think & Do 2. Make a circuit Think & Do 3. Make a switch for your circuit, so that we can turn the bulb on and off. (P72) Think & Do
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Folens Science in Action -(507/FO) Y5 **Petheram, L. , Szczesniak, P., Anne Whitehead, Steve Sizmur, (Published by Folens, 2004)**			
	Sc 2 Biology **Unit B:Life Cycles**	**Sc 3 Chemistry** **Unit D:Changing State**	**Sc 4 Physics** **Unit F:Changing Sounds**
CT	1. Seed germination (investigation): a) Do seeds need water to germinate? b)light c)temperature/ warmth (Decide on what each group is going to find out, how to make it a fair test? how many seeds will you use? why?) Think & Do	1. Factors affecting evaporation: Choose a question and plan a fair test. Keep changing one factor while keeping others constant. (How spread out or folded a towel, how warm it is, windy or still days...(factors to vary) Think & Do 2. Someone tells you the water on the outside of the drinks can come from the ice inside the can. Plan an experiment to prove that it hasn't. Think	1. Design a fair test to find how the length of an elastic band affects the sound it produce. (putting a pencil under an elastic band around a match box changes the length of the band that can vibrate) P71. Think & Do 2. Plan a fair test to find out the factors that affects the sound produced by a wind instrument. (change? same? observe?...) p74 Think & Do
PS	1. How could plants living in small ponds spread their seeds to new ponds? (seed dispersal in water- find out) Think		
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Folens Science in Action -(507/FO) Y6 Petheram, L., Szczesniak, P., Anne Whitehead, Steve Sizmur, (Published by Folens, 2004)			
	Sc 2 Biology Unit B:Micro-organisms	**Sc 3 Chemistry Unit C:More about Dissolving**	**Sc 4 Physics Unit:E Forces in Action**
CT	1) Design an investigation to find if fresh strawberries go mouldy more quickly if they are: warm/ cold? Dry/ wet? Think & Do	1) Plan a fair test to find how long different solids take to dissolve in water. (Constant? Vary? Repeat?) Think & Do	
PS	1) Do all micro-organisms need air? Mix sugar and yeast with boiled water (boiling drives all the dissolved air out of the water). Fill this mixture in a bottle and put a balloon on top. Predict what will happen? Was your prediction right? Think & Do		1) Submarines sink and come to the surface. Find out How? Think
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Letts - 1. Teaching and Learning Science Teacher's Book , KS2, Y3 Alan Jarvis, Ian Baldry, Wendy Hart, Diane Lowton, William Merrick, Joan O'Sullivan			
	Sc 2 Biology **Unit: Helping plants to grow well**	**Sc 3 Chemistry** **Unit: Materials and their Properties**	**Sc 4 Physics** **Unit: Magnets and Springs**
CT	1. Design a fair test to investigate if a plant would suffer if given too much water. Think & Do 2.Plan an investigation to see if plant growth is affected by sun light. Think & Do	1. Design a fair test to find out the best material to cover the floor. (hard enough) Compare hardness and order materials accordingly. Think & Do 2. Design a fair test to find out the best kitchen towel based on their absorbency. Think & Do 3. Plan an investigation that shows which pair of tights is the most stretchy. Think & Do 4. If a new fabric material had just been invented how you would test it to see if it would be suitable for clothing. (Is it waterproof? thermal insulator? stretch? hard-wearing? absorbent? easily wash?) Think & Do	1. Plan an investigation to find out whether all magnets are equally strong. Plot a bar chart. Think & Do
PS	1. Investigate how crops fail and what can be done to relive famine.(oxfam.org.uk) Think	1. Discuss the materials used to make drinking cups and the positive and negative features of each. Think	
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Letts - Teaching and Learning Science Teacher's Book , KS 2, Y4 **Alan Jarvis, Ian Baldry, Wendy Hart, Diane Lowton, William Merrick, Joan O'Sullivan**			
	Sc 2 Biology **Unit: Bony Skeletons**	**Sc 3 Chemistry** **Unit:Keeping warm**	**Sc 4 Physics** **Unit:Circuits and Conductors**
CT		1. Investigate the best materials to keep drinks hot (container -diff or same materials, range of materials to wrap round them). Think & Do 2. Plan and carry out an investigation to find out which thermal insulators keep things cold for the longest time (cotton wool, bubble wrap, aluminium foil, sponge and polythene). Think & Do	1. Plan an investigation to find ways to make a bulb brighter. Think & Do
PS	1. Investigation into body measurements - E.g. Do taller kids weigh more? **Ask questions** that can be tested. Think & Do (Bridging problems)	1. Make a class display of thermal insulators and conductors? Think & Do	
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Letts - Teaching and Learning Science Teacher's Book , KS 2, Y5 Alan Jarvis, Ian Baldry, Wendy Hart, Diane Lowton, William Merrick, Joan O'Sullivan			
	Sc 2 Biology Unit: Keeping Healthy	**Sc 3 Chemistry Unit: Gases around us**	**Sc 4 Physics Unit: Changing Sounds**
CT	1. Plan a fair test to see how exercise affects the pulse rate of pupils in your class (before exercise, after 1minute on the spot running and after 3mts rest.) P17 (Pupils' Book p19) Think & Do	1. Plan a fair test to investigate how much air is trapped in 3 different types of soil samples. (Follow the method given in the Pupils' book, p57.) Think & Do	1. Plan a fair test to find which material is good for ear muffs or for sound insulation. What to keep the same?(pupil, sound generator) Change?(thickness & type of material) Measure? (distance at which sound can be heard)p 91 Think & Do
PS	1. An athlete has increased his training before taking part in a marathon. Write a menu for a meal that could give him enough energy for the race. (over weight person/ or a person with scurvy) Think 2. Group Work: Produce a handout/ poster on one of the topics: alcohol, smoking, becoming ill and hygiene. Deliver a talk and encourage the rest of the class to ***ask questions.*** Can also invite a guest speaker who could bring some real life examples or get a video about the effects of tobacco, alcohol and/ or other drugs. (p18) Think		1. Design and make an instrument that can make at least three notes of diff pitch and a way of changing the loudness of each. Draw the design. p93 Think & Do
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Letts - Teaching and Learning Science Teacher's Book , KS 2, Y6 **Alan Jarvis, Ian Baldry, Wendy Hart, Diane Lowton, William Merrick, Joan O'Sullivan**			
	Sc 2 Biology **Unit: Interdependence and adaptation**	**Sc 3 Chemistry** **Unit: Changing materials**	**Sc 4 Physics** **Unit: Electrical Circuits**
CT	1. Plan and investigate what plants need for healthy growth.(what to keep the same, what to change, what to measure / observe) Think & Do 2. Plan an investigation to see how fast water drains through different types of soil. Think & Do		1. Build a complete circuit with bulbs/ buzzers/ motors. Predict - what will happen if we add more batteries to each of the circuits. Try and see. Think & Do 2. Plan a fair test to see how changing the length of the wire changes the brightness of the bulb. Make predictions. Think & Do
PS	1. Develop your own keys to identify local organisms. Choose easily identifiable factors. Think		
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Letts - Teaching and Learning Science Activity Book , KS 2, Y3&4 Alan Jarvis, Ian Baldry, Wendy Hart, Diane Lowton, William Merrick, Joan O'Sullivan			
	Sc 2 Biology Unit: Keeping Animals Healthy	**Sc 3 Chemistry Unit: Materials and their Properties**	**Sc 4 Physics Unit: All about Forces**
CT		1. Daniel has three spoons : a metal one, a wooden one and a plastic one. He wants to find out which one would be the best for stirring a hot drink without burning his fingers. Design a fair test which he could carry out to find out the answer. ES Think & Do	1. Design and draw two cars: one that will move through the air quickly and one that will move slowly. Explain why you have designed the cars the way you have. Use the idea of air resistance to help make your answer more scientific. Think
PS	1. Measure the height of some of your friends. Do taller children also have longer arms? Think & Do 2. Tom's mother is ill so he is doing the shopping for the week. He wants to make sure he has the right kind of food for healthy meals. He has started his shopping list. Can you complete it for him? Think 3. Jelly fish living in the water have very soft bodies. Explain what problems they would have if they come out of water on to land. Think	1. Design a container that will stop ice lollies melting on a picnic. Draw and label the materials you would use. Explain how your container would work. Think 2. Make up a game to identify materials by describing their properties. Think	1. Research how magnets are used in everyday life. Make a poster. ? Think
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Letts - Teaching and Learning Science Activity Book , KS 2, Y5 & 6 Alan Jarvis, Ian Baldry, Wendy Hart, Diane Lowton, William Merrick, Joan O'Sullivan			
	Sc 2 Biology Unit: Living Together	**Sc 3 Chemistry Unit: Changes**	**Sc 4 Physics Unit: Changing Sounds**
CT	1. Design a fair test to find out what seeds need to germinate. P33 Think & Do 2. Clare's mum had two apple trees. Clare noticed that caterpillars were eating the leaves of one of the apple trees. The other tree had left alone. In the autumn, one tree had 50 large apples. The tree with leaves eaten by caterpillars had 20 small apples. Try to explain why the damaged tree had fewer apples. p 37 Think	1. How much air is trapped in the spaces between particles of soil? Design a fair test. P 57 Think & Do	1. Which material is good for sound insulation? Mitchelle turned on the radio kept on the table and pressed diff materials to her ears and listened. Make a list of ways to make it a fair test (improve). p105 Think & Do
PS	1. Grow a flowering plant (Marigold/ nasturtium)from seed. Keep a diary of changes that takes place from germination, to flowering and producing seed. Draw pictures of each stage. Think & Do 2. Design a poster to display in a doctor's room giving advice on how to avoid micro-organisms getting onto food. Think 3. Make a collection of as many different seeds as you can. Explain how each kind of seed is dispersed. Think 4. Imagine you have travelled to another planet rather like Earth. On this planet you have founded a habitat which is warm and damp with tall trees and ponds. Describe five animals living there and explain how they are adapted to this habitat. Think	1. Picture of a scene (weekend in the countryside). Find as many gases as you can from the picture. Where is it found? What is it used for? Useful or harmful. Think 2. You have just received a postcard from your friend Zoycletes of the planet Arcturan near Alpha Centuril. She plans to visit you soon. Her mother is worried about her washing and drying clothes whilst she is visiting you. She does not know the best conditions for getting the washing dry on Earth. Email her mother to explain scientifically the best conditions for drying washing. Think	
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Pearson Longman - Exploring Science, KS 2, Y3 Penny Johnson and Mark Levesley (507/EX)			
	Sc 2 Biology Unit :3B Helping plants to grow well	**Sc 3 Chemistry Unit: 3D Rocks and Soils**	**Sc 4 Physics Unit: 3Ea Magnets and Springs**
CT	1. What might happen if farmers put too much water on a field? Explain. Think	1. Plan a fair test to see which kind of soil lets water flow through easily. Think & Do	1. Plan a fair test to find which material a magnet will attract. Predict. Think & Do 2. Fair test to find out which magnet is the strongest. (paper clips, paper) Think & Do 3. Fair test to investigate what makes Mike's toy car move by stretching the elastic band. Think & Do
PS	1. Ben has grown some bean plants in the dark and they are yellow and thin. Ben wants to know if they will go green if he puts them in the light. ***Write a question for Ben to investigate.*** Make a prediction. (copy- P30) Think		
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Pearson Longman - Exploring Science, KS 2, Y4 **Penny Johnson and Mark Levesley (507/EX)**			
	Sc 2 Biology **Unit:4Aa Skeletons**	**Sc 3 Chemistry** **Unit: 4C Keeping Warm**	**Sc 4 Physics** **Unit: 4E Friction**
CT	1. Plan an investigation to compare the sizes of one part of people's bodies. Write down your prediction. (p9- very good example of starting from a question/ prediction to investigation) CT-HS/ES? Think & Do Copy 2. How could you find out how much exercise you have to do before you start to feel different? What exercise? What will you measure/ observe? What do you think you will find? Make a prediction. P14 Think	1. Plan a fair test to find out which material is the best at keeping water warm? What will you measure? How will you test the materials? How to make it fair? Predict what do you think the best material is going to be? (p36) Think & Do	1. Plan a fair test to find which surfaces allow objects to slide most easily? (p56) Think & Do 2. Plan a fair test to find out which shapes have the lowest water resistance? How can you find out? What apparatus you will need? (p61) Think & Do 3. How could you find the best material for clothes to wear on a slide? (p57) Think & Do
PS		1. How does the temperature change in your classroom? Draw a map of the classroom, mark two places where you will be measuring the temperature at different times of the day. How will you measure the temperature? How do you think the temperature will change? Predict.(p33) Think & Do 2. Three spoons made from three different materials (wood, steel, plastic) are put into hot water. How could you find out which spoons are good thermal insulators? (p38) Think & Do	
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Pearson Longman - Exploring Science, KS 2, Y5 Penny Johnson and Mark Levesley (507/EX)			
	Sc 2 Biology Unit: 5A Keeping Healthy	**Sc 3 Chemistry Unit:5C Gases Around us**	**Sc 4 Physics Unit: 5F Changing Sounds**
CT	1. Plan a fair test to see if exercise affects your pulse rate? Prediction? Think & Do	1. Plan a fair test to measure the amount of air in different soils. (p34) Think & Do	1. Plan a fair test to find out which materials sound travels through best? How can you measure the sound? How will you present the results? (p69) Think & Do 2. Plan a fair test to find out which materials are best at absorbing sound? How will you measure the sound? (p72) Think & Do
PS			
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Pearson Longman - Exploring Science, KS 2, Y6 Penny Johnson and Mark Levesley (507/EX)			
	Sc 2 Biology **Unit:6A Interdependence and Adaptation**	**Sc 3 Chemistry** **Unit: 6C More about Dissolving**	**Sc 4 Physics** **Unit: 6E Balanced and Unbalanced Forces**
CT	1. Plan an investigation to find whether a plant looks different when growing in short or long grass. What type of plant you will investigate? What differences will you look for? How many plants? Apparatus? Safety measures? (p9) Think & Do	1. Plan a fair test to find how you can dissolve a solid more quickly. Which factor you keep the same? Apparatus? How will you use the apparatus? How will you tell the sugar has dissolved fully? Safety? (p28) Think & Do 2. Plan a fair test to find if all solids (sugar, salt, bath salt, stock cubes, instant coffee)dissolve equally well in water? What solids will you compare? How much water will you use? Fair test? Present your results? (p32) Think & Do	1. Plan a fair test to find how long a spinner would take to fall. Which factor will you investigate? How will you make it fair? What apparatus will you need? How many times will you repeat each measurement? How will you present your results? (p49) Think & Do
PS			
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Teaching File 3 (507 SC) Collins, Science Directions			
	Sc 2Biology **Unit:3A Teeth and Eating**	**Sc 3Chemistry** **Unit :3D Rocks and Soils**	**Sc4Physics** **Unit: 3F Light and Shadows**
CT	1. Suggest a method of testing the effectiveness of two diff tooth pastes. (3A PM4 - Writing frame to plan their investigation) Think & Do	1. Provide pupils with 4 samples of rock. Ask them to choose the best rock to make a monument or grave stone. Ask them to test for hardness and permeability and produce an order of hardness and order of permeability and then choose the best rock. Think & Do	1. Which material would be the best to make a dark den? Which material would be the best for a window covered by a curtain? Devise a test for choosing the best material, how to make the test fair? (Torch and materials provided) Transparent, translucent and opaque materials (Opaque). (3F PM3- format for the investigation) Think & Do
PS	1. Design a menu for a 'Healthy Party'. (3A PM1- Blank Menu) Think 2. Produce a leaflet for teenagers to warn them about dental decay. (Format provided -3A PM2) Think	1. Ask the pupils to do a survey of the types of soil found in the school grounds. Flower borders (peat soil), sandy soil, clay soil etc. Pupils can be given a simple map of the school site and asked to mark the areas they find each type of soil. Think &Do	
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Teaching File Y4 Collins, Science Directions (507/SC)			
	Sc 2 Biology **Unit:4B Habitats**	**Sc 3 Chemistry** **Unit: Solids and Liquids**	**Sc3Physics** **Unit :4F Circuits and Conductors**
CT	1. Scenario - (can choose one from the local news) or converting a pond into a playground. What would happen to the organisms and plants that lived in and around the pond? What would happen to woodland if all the trees were felled? Debate and poster preparation - in favour and against? Think		
PS	1. Pictures of plants and invertebrates were provided and pupils were asked to sort them into groups (insect, spider, worms, trees, bushes, leaf shape). Encourage them to pose simple questions like *"is it possible for an organism to have wings and not have any legs"?* (PP) Think 2. Take a walk outside. Collect leaves, sort them on the basis of observable features like veins, number of lobes etc and try to identify the plant they are from. Think & Do 3. Identify the most common trees found around the school site using a simple key. Observe 4. Construct food chains for the organisms that they found around the school in a given habitat (Flower bed/ pond/ play ground). Think 5. Pond Diary - collect pond water and organisms (snail, fish...) and investigate the conditions in which they live for a week. (4B, PM3) format	1. Find out how temperature affects how quickly the ice melts?(Provided three ice cubes of same size, thermometer and stop watch. Also suggested 3 diff places where temp are significantly different - cool bag/ fridge, radiator top, window sill.) Think & Do 2. Separating the mixture of pea shingle (pebbles), sand and salt. What could be removed first? How to remove the pea shingle? How could you remove the sand from the salt? (group activity)(salt water) Think & Do 3. How much of a solid can you dissolve in 30 ml of water at room temperature? Does the amount that dissolves depend on which solid you use? (sugar, salt and alum, measuring cylinders, spoons, transparent containers) (4D PM3, pupil material with the format) Think & Do	1. Conductors and insulators - testing materials to see if they are conductors or insulators. Ask pupils to predict. (scissors, beer bottle tops, nails, milk bottle tops, paper clips, coins etc -metallic objects) (non-metallic objects- cork, plastic carton, paper bag, wooden spoon, fabric etc) (all metals are good conductors, don't use graphite) (not all metals are magnetic, only iron and steel)(4F PM1) Think & Do 2. Assign pupils (diff groups) different tasks (game /card/ light house) where they can use their understanding of circuits into action. Ask how does your game/card/light house work? How have you made your circuit? What **problems** did you have? (problems/ challenges pupils encountered while building their circuit) Think & Do 3. Exploring what happens to the brightness of the bulb when more cells are added to the circuit? (measure brightness by covering the bulb with tissue papers until no light can be seen)

	for pond diary. Encourage pupils to **pose questions** about what conditions the pond snails prefer: Do they live near the edge or near the middle? Do they live under leaves? What do they eat? What time of the day do they move? Are they near the top or the bottom first thing in the morning? (PP -pupils on conditions snails prefer in the pond)? Think & Do		Predict, use 4F PM3 format. Measure only one bulb. Think & Do
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Teaching File Y5 Collins, Science Directions (507/SC)			
	Sc 2 Biology **Unit:5B Life Cycles**	**Sc 3 Chemistry** **Unit:5C Gases all Around**	**Sc3 Physics** **Unit:5E Earth, Sun and Moon**
CT		1. Design an investigation to find out how quickly water evaporates in different places using the given format (5C PM2). Think & Do 2. Which material do you think would be the best insulator? Predict? How are you going to make the test fair? (use same amount of water, same thickness for the material) 5C PM3- format. Think & Do	1. Plan an investigation to find out which material makes the best track for a balloon rocket. Predict? How to make it a fair test? Format as in 5E PM3. Think & Do
PS	1. Classify seeds into groups according to how they are dispersed (e.g. wind, animal, self-dispersal, water) Think & Do	1. Sealed syringes full of air, water and sand. What happens to each when the plunger is pushed? Record your observations in a table. Notice the order for ease of compressibility? (gas-liquid-solid) (Constructing tentative descriptions/ PS?)Think & Do 2. Which of the three soil samples has the most trapped air and so would be better for worms to live in? (sandy soil, clay soil, peat soil) Predict? 5C PM1 - A format with procedure and questions to guide Think & Do 3. Investigate and explain which parts of the school grounds become waterlogged most easily. Think & Do	1. Stars and Planets: 1.Research a planet of your choice: How big it is? How far away it is from the Sun? What the planet is made of? How long it takes to orbit the Sun? Any other interesting facts? 5E PM2 -framework to record information about the planet Collecting facts/ information seeking 2. Produce an information card about the Moon. Collecting and presenting facts
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Teaching File 6(507 SC) Collins, Science Directions (Sunley, C., Bourne, J. and Norman, A.)			
	Sc 2 Biology **Unit: 6B Micro-organisms**	**Sc 3 Chemistry** **Unit:6C Reversible and Irreversible Changes**	**Sc4 Physics** **Unit: How We See Things**
CT	1. In what conditions do you think yeast will grow best? Plan an investigation. What are they going to control and what they will measure? (flour, sugar, warm water, yeast) Think & Do	1. Plan an investigation to find out how long a candle will burn in different-sized containers (small, medium and large) Predict? Writing frame (6D PM2) Think & Do	1. A torch is placed on a white sheet of paper in a dark room. What will happen if a mirror is placed in the path of light? Explore. (Tent descriptions/ hypotheses) Think & Do 2. Investigate if the distance from a light source affects the size of the shadow? (6F PM2 writing frame) (Here or under PS)? Think & Do
PS	1. Home food preservation survey -find out methods to preserve food. Any interesting methods that are not used today? (6B PM3 format) Survey	1. Graph showing the mass of a burning candle every 30 minutes is given (6D PM3). Look at the graph and say what happened to the mass of the candle while it was burning? (Interpreting graph -problem) Think	1.Predict whether you will be able to see an image of yourself in the materials provided?(plane mirrors, spoons, convex and concave mirrors, foil (aluminium and coloured)paper, fabric, plate, cutlery, perspex, scissors, bathroom tile) Test the materials and record your results. (6F PM1 format given) Which of them give a partial image? Those materials that gave an image, what features do they all have? (PS)? Think & Do 2. Shadow Puppets: From the graph given, describe how the height of the shadow has changed as the distance from the torch to the puppet changed. (6F PM3 frame work) Think
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Year 4	Collins -Science Directions , Pupils Book By: Chris Sunley, Jane Bourne, Alison Norman		
	Sc 2 Biology **Unit: 4B Habitats**	**Sc 3 Chemistry** **Unit:4D Solids and Liquids**	**Sc 4 Physics** **Unit:4F Electrical Circuits and Conductors**
CT	1. What would happen to this woodland habitat (pic provided) and all the animals that live there, if it was cleared to make way for a new road? (HS) p17 Think	-	
PS	1. Pond visit and survey to see water life (fish and other organisms). Draw a food chain to show what they found in the pond. (HS) p13 Think		
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Year 5	Collins -Science Directions, Pupils Book By:Chris Sunley, Jane Bourne,Alison Norman		
	Biology **Unit: Life Cycles**	**Chemistry** **Unit: Gases All Around**	**Physics** **Unit: Earth, Sun and Moon**
CT	1) Investigating plant growth - (p18) After leaving two squares of plastic on healthy grass for 5 days, what did they observe? Why grass yellow under the black plastic sheet? Think&Do	1. Hydrogen is lighter than helium. Why helium is used in balloons rather than hydrogen? Think	
PS		1) Three pots with 10 ml of water kept in 3 diff places. Table showing volume of water in the beginning and later is given. Answer the questions given (p 25). Fact finding	1) Use information sources to find what an eclipse is? Fact finding
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Year 6	Collins -Science Directions, Pupils Book By: Chris Sunley, Jane Bourne, Alison Norman		
	Biology **Unit: Micro-organisms**	**Chemistry** **Unit: Reversible and Irreversible Changes**	**Physics** **Unit: Forces in Action**
CT			1. Will the astronaut be able to pour a drink from a bottle into a glass? Will the drink stay in the glass? Think 2. In what ways do you think walking on the Moon would be different from walking on Earth? Think
PS			1. Ann and Jim investigate how a spring stretches when mass is added to it. Graph given. What was the amount of stretch.....? page 31 Think
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Scholastic 100 science lessons (CD) - Y3 Scottish Primary (507/ ON)- Malcolm Anderson (2007)			
	Sc 2 **Unit 3B:Helping Plants to Grow**	**Sc 3** **Unit 3C: Characteristics of Materials**	**Sc 4** **Unit 3 F:** **Light and Shadows**
CT	1) Plan an investigation to find out the ideal conditions for growing plants (Light, heat, water). Plan a fair test. How many diff combinations and how many samples needed? ES Think & Do 2) Ask children to predict if they expect to find any differences in the plants that grow in two diff habitats (e.g. plants under the tree and in the filed). Design an investigation to find this. Put a hoop under the tree and count the no. of daisies in the hoop. Also try this in the field and compare. Fair test? Same sized hoop or diff sized hoops? (same hoops for two areas) Think & Do	1) Design a fair test to find which material is the hardest/ strongest or most absorbent? (Which property to investigate (strength/ absorbency); what exactly they will test (how much force is needed to break something/ absorbs water); how the test will be carried out (adding weights/ dripping water); and which materials to test. Think & Do 2) Draw a labelled diagram to show how you would carry out an investigation to find out which was the best kitchen paper for mopping up spillages. This should be a fair test. Think & Do	1) Plan and carry out a test to find out how much light comes through the materials in their collection. (opaque, transparent, translucent) Think & Do
PS	1) Make a book about the two habitats they studied above (relationship between physical aspects and the plants living there). Factual		
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Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

<table>
<tr><td colspan="4">Scholastic 100 science lessons (CD) - Y4 Scottish Primary (507/ ON)- Kendra McMahon (2007)</td></tr>
<tr><td></td><td>Sc 2 Biology
Unit 4B:Habitats</td><td>Sc 3 Chemistry
Unit:4D Solids and Liquids</td><td>Sc 4 Physics
Unit:4 Circuits and Conductors</td></tr>
<tr><td>CT</td><td></td><td>1) Design a fair test to find out which of the given materials dissolve in water and which do not?
Think & Do
2) Devise a test for viscosity of liquids or to compare the runniness of different liquids.
Think & Do
3) Devise a fair test to find which sweet dissolves the best.
Think & Do</td><td>1) Explore a collection of items and predict whether or not electricity will flow through the different items. Design a circuit to test them and make generalisations from the results.
Think & Do
2) Investigate if changing the number of bulbs in a circuit affects the brightness of the bulbs?
(Question, prediction, drawing of the test, what will change, what will be the same, what I found out)
Fair test? Change only one factor at a time.
Think & Do</td></tr>
<tr><td>PS</td><td>1) How to investigate the behaviour of an animal? How to encourage pupils to pose their own questions about animal behaviour to investigate. (Bridging Problem)
2) Two containers with wet sand and dry sand, wood lice - add 1 wood louse and observe which soil it prefers? Add more no. of animal (by chance?-rule out)
Observe for more time (Fair test)
3) Snails prefer - to eat grass/ other leaves?
Think & Do</td><td></td><td>1) Design and make a model that uses a switch.
(A light for reading in the bed with a pressure switch in bed, a model of a man with eyes that light up, a wolf alert buzzer for the Three Little Pigs, or a quiz-show lights)
Think & Do
2) Given pupils a card picture of a clown. Make the clown's eyes light up using only the material s provided.
Think & Do</td></tr>
<tr><td>PF</td><td></td><td></td><td></td></tr>
</table>

Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Scholastic 100 science lessons (CD) - Y5 Scottish Primary (507/ ON)- David Glover, Ian Mitchell, Louise Petheram and Peter Riley (2007)			
	Sc 2 Biology **Unit 5A: Chapter 1Keeping Healthy**	**Sc 3 Chemistry** **Unit 5: Gases around us**	**Sc 4 Physics** **Unit 5F:Changing Sounds**
CT	1) Plan a fair test to find out if tall people have bigger lungs than short people? Think & Do 2) Predict how the pulse rate vary with exercise and then to plan an investigation. Think & Do	1) Plan a fair test to compare the volumes of air in three diff soil samples :gravel, sand and garden soil Fair? Think & Do	1) Choose the right material to make a string telephone. Make predictions about when the string telephone will work and when it won't and then test their predictions. Think & Do 2) Plan and carry out a fair test to find out which of the given materials is best at blocking the sound of a buzzer. Think & Do 3) Elastic band sonometer given to pupils. Test and suggest things that could be changed to make higher or lower notes. (Length of the band plucked, the thickness of the band used and the tension in the band (how stretched it is)). Think & Do
PS	1) What food do you recommend to someone who needed more food for activity (an athlete)? Think 2) Plan a regime for a healthy lifestyle (My Lifestyle circle) with exercise, a balanced diet and hygiene. Think 3) Group activity- how peer pressure can introduce young people to drugs. Role-play: Persuader, resister and observer - persuader should try to get the resister to take a drink of water (pretending alcohol). After 3 minutes, the group can reflect on the activity and ask each other questions such as :' When do you think I might take a drink?', 'If you had more time, could you have persuaded me to take a drink?', 'How would the observer have felt if they		1) Sound survey around the school and produce a report. Think & Do 2) Design a poster to advertise a sound proofing material (what the material is like? what it is made of? where it might be useful?) Think 3) Design and make a musical instrument from junk. Must make more than one sound. (D&T) Think & Do

	were a friend of the resister or the persuader?' The observer should be prepared to report back to the class. Think & Do		
PF			

Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Scholastic 100 science lessons (CD) - Y6Scottish Primary (507/ ON)- Clifford Hibbard, Karen Mallison-Yates and Tom Rugg (2007)			
	Sc 2 Biology Unit 6B:Micro-organisms	**Sc 3 Chemistry Unit 6C: More about Dissolving**	**Sc 4, Unit 6G:Changing Circuits**
CT	1) Plan a fair test to investigate what conditions are best for mould to grow in? (Temperature the bread is left at? Bread has been exposed to the air before the experiment? Bread is wet/ dry?)(Investigation sheet page 42 copy) Think & Do	1) Plan a fair test to find which place would be the best for the water to evaporate completely. Think & Do 2) Plan a fair test to show that sugar dissolves faster in hot water rather than in cold water. (Fridge water, cold tap water, hot tap water, same amount of water, sugar, stirs and same containers.) Think & Do 3) Plan a fair test to see if salt dissolves faster in hot water or cold water. Predict. Results (table). (Asked to repeat the test for same temp and find the average time at each temp) Think & Do 4) Plan an investigation to find out if particle size affects the speed at which sugar dissolves. How to make it a fair test? Think & Do	1) Plan a test to find the effect of changing the amount of wire in the circuit. Think & Do
PS	1) Explain: one bacterium can divide to make two bacteria every 20 minutes. If one bacterium causing sore throat lands in your throat at 10pm, how many could be there at 7am the next morning? (worksheet provided) Think 2) List 5 ways the world would be different without microbes. Think		
PF			

Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Hamilton Trust: Online science resources , KS2, Y3			
	Sc 2 Biology **Unit: Animals Including Humans**	**Sc 3 Chemistry** **Unit: Rocks**	**Sc 4 Physics** **Unit: Forces and Magnets**
CT	1) Testing whether physical activity has any effect on the pulse rate. (Measuring pulse before and after exercise - effect of exercise) (Recipe format) Think & Do	1) Plan a fair test to find out, which type of soil can water flow through more easily (most permeable)? Repeat investigations. Think & Do	1) Plan a fair test to find out how different surfaces affect the movement of the vehicle. Think & Do 2) Plan a fair test to find which is the strongest magnet among the given by looking at the no. of paper clips attracted to it. Think & Do
PS	1) A visit to a local supermarket can be arranged to look at the range of foods available. Challenge children to find foods from each group and create a 'shopping list' of ten items with prices of what they would buy (including items from each food group) – (see *session resources for two shopping list frames*). Think & Do 2) Design & label a healthy balanced meal for a vegetarian (*session resource*). Think		1) Give each child a bar magnet and ask them to investigate objects found around the room to see if they are magnetic or non-magnetic. Think & Do
PF			

Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Hamilton Trust online science resources , KS2, Y4			
	Sc 2 Biology **Unit: Animals Including Humans**	**Sc 3 Chemistry** **Unit: States of Matter**	**Sc 4 Physics** **Unit: Electricity**
CT	1) Investigate which liquid does the least damage to egg shells? (How to make it a fair test? - hard boiled egg, vinegar, cola, milk, water, orange juice...) Think & Do	1) Enquire factors that speed up evaporation (wind, warmth, puddle, scrunched up washing/ spread out). Measure the time taken to dry completely. Fair test? Think & Do	1) Plan a fair test to see what will happen to a bulb/motor when more components are added to a simple circuit. Predict and test. Think & Do
PS	1) Make a model of the human digestive system Do 2) Children as zoo keepers - prepare a food order for a range of animals in the zoo. Think	1) An ice cube made from fresh water and salt water is given to kids. Which one melts more quickly? Think & Do	
PF			

Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Hamilton Trust online science resources , KS2, Y5			
	Sc 2 Biology **Unit: Living things and their habitats**	**Sc 3 Chemistry** **Unit: Properties and change of materials**	**Sc 4, Physics** **Unit: Forces**
CT		1) Plan a fair test to find which material is the best to use for mopping up spills? Think & Do 2) Plan a fair test to find which of the given materials good conductors of electricity are. (Electric circuit with a bulb or buzzer). Think & Do 3) Plan a fair test to find the time taken for the salt to dissolve all the crystals : 1. Same volume of water, same mass of salt, but vary the temp of water; 2. Same mass of salt, but different volumes of water at same temp. Think & Do 4) Predict which of these liquids (tap water, sea w, puddle w, coloured inks, distilled w, mineral w) is pure and which have material dissolved in them? Test? Results? (Evaporate) Think & Do 5) Plan a fair test to find the best material for a thermal insulator to wrap a container with warm water and compare it with an unwrapped container to see the temp diff. Think & Do 6) Plan a fair test to find the best insulator to keep ice-cream/ ice blocks warm. Wrap the blocks of ice cream and place them separately in petri dishes. (Measure -size, temp and time it takes to melt completely). Think & Do 7)Rusting nail enquiry: Enquire about what causes the nails to go rusty. (Choose a question for each group and	1) Plan a fair test to find on which surfaces their sports shoe works the best (hardest to pull, most friction). Think & Do 2) Plan a fair test to find how does the number of paper clips affect the time the spinner takes to fall? How does the size of the spinner affect the time it takes to fall? Think & Do

		plan a fair test. Can discuss with children what they know and what they want to answer and plan accordingly -**strategy?)** Which liquids will cause the nails go rusty?(place nails on sponge lying in the liquid to ensure nails are partially in the liquid but also exposed to air). Think & Do 8) Plan a fair test to find which coatings would prevent rust (paint, varnish, oil, petroleum jelly etc). Think & Do	
PS	1) Find a spot in the school grounds where you can sit and observe nature. See? Smell? Hear? Take notes on everything they see, hear and smell. (Birds, ants carrying food...) Think & Do		1) Investigate the centre of gravity of a ruler at www.askaboutireland.ie/learning-zone/primary-students/5th-+6-class/science/gravity/some-ideas-about-gravity/. Think & Do 2) Create a paper boat (A4 paper) that can float with most paper clips in it and record how many were in it before it sank. Think & Do 3) Launch 4 paper boats (made in the same way, same amount and type of materials) one in tap water, salted water, carbonated water and water having bubbles slowly blown in through a straw. Slowly load paper clips to each and what do they notice? Present results and conclusion. Think & Do 4) Design and make a simple artefact using at least one mechanical device. (D&T)??? Think & Do
PF			

Opportunities for creative thinking, problem solving and problem finding in the areas of National Curriculum

Hamilton Trust online science resources , KS2, Y6			
	Sc 2 Biology **Unit: Living things and their habitats**	**Sc 3 Chemistry**	**Sc 4 Physics** **Unit: Light**
CT			1) Investigate a question about shadows. What happens to the size of the shadow when you move the shape nearer to the light? (Predict, plan and conduct a fair test and present the results and conclusion). Think & Do
PS	1) Create a classification key to identify: common insects and birds, tree leaves/ wild flower leaves Think		1) Create shadow puppets and devise a puppet show using some of their findings from the above test. How to make shadows appear larger and give some special effects like using coloured shadows/ faint (ghostly) by using some translucent materials like tracing paper or tissue paper. Think & Do 2) Make a rainbow with a glass of water, a sheet of white paper and a sunny day. Think & Do
PF			

12.13 APPENDIX 5b Textual Analysis

Content Analysis of Textual Resources - Quantitative

Opportunities for Creative Thinking, Problem Solving and Problem Finding (Chapter 8)

Teaching File (3) 1. Collins Science Directions (Series: 1, 507/SC) Authors: Chris Sunley, Jane Bourne and Alison Norman Content Pages: 7-54, Pages analysed : 10, 22, 34, 47					
Page	Unit Title	Topic Title	CT	PS	PF
10	3A Teeth and Eating	Pet-food survey	1		
22	3B Helping Plants Grow Well	Green House Investigation Continued			
34	3D Rocks and Soils	Comparing the Hardness and Permeability of Rocks	1	1	
47	3F Light and Shadows	Key Ideas for Teachers			
Additional Information: choose a rock for making a monument.					

Teaching File (4) **Collins Science Directions (**Series: 1, 507/SC) Authors: Chris Sunley, Jane Bourne and Alison Norman Content Pages: 7-53, Pages analysed : 15, 27, 39, 51					
Page No.	Unit Title	Topic Title	CT	PS	PF
15	4B Habitats	Key Ideas for Teachers			
27	4C Keeping Warm	Thermal Insulators		2	
39	4E Friction	Key Ideas for Teachers			
51	4F Circuits and Conductors	Making Use of Electricity		2	
Page 51- problems faced during the development of a circuit. Additional Information: There are opportunities for creative thinking during problem solving situatior Therefore, they overlap and counting them separately seems difficult.					

Teaching File: 5, Collins Science Directions (Series: 1, 507/SC) Authors: Chris Sunley, Jane Bourne and Alison Norman Content pages: 7- 55					
Page	Unit Title	Topic Title	CT	PS	PF
12	5B Keeping Healthy	Muscles and Movements		1	
24	5C Gases All Around	Solids, Liquids and Gases	2	1	
36	5D Changing State	Purifying Water			
48	5F Sound All Around	Sound Review			
Additional Information: P12 - designing health education leaflets -explains beneficial aspects of one ty of exercise P 24 PS -names of some gases, uses?					

Teaching File:6 Collins Science Directions (Series: 1, 507/SC) Authors: Chris Sunley, Jane Bourne and Alison Norman Content pages: 7-53					
Page	Unit Title	Topic Title	CT	PS	PF
10	6A Interdependence and Adaptation	Food Chains			
22	6C More About Dissolving	Dissolving			
35	6E Forces in Action	Key Ideas for Teachers		1	
46	6H How We See Things	Reflecting Light			
Additional Information: P10 -think of some food chains (PS) P35 -describe situations -2 forces acting on an object P46-activity - what happens if a mirror placed in the path of light? (PS) -How to make light beam travel around maize? (PS)					

2. Scholastic 100 science lessons (Y3) Author: Malcolm Anderson Content Pages:7 to 191					
Page	Unit Title	Topic Title	CT	PS	PF
10	3A Teeth and Eating	2Sorting Foods			
56	3 The Environment	Scientific Enquiry: Hiding from th Sun	1	1	
103	3D Rocks and Soils	Scientific Enquiry: Which soil dra the best?	1	1	
147	3E Magnets and Springs	Assessment 2		1	
P10, 103A good example of CT, PS.					

Scholastic 100 Science Lessons(Y4) Author : Kendra McMahon Content Pages: P7 to 191					
Page	Unit Title	Topic Title	CT	PS	PF
12	4A Moving and Growing	3 A bag of bones	1	1	
58	4B Habitats	Collecting Animals		1	
104	4D Solids and Liquids	Dissolving (Which material dissolve and which do not?)	1	1	
150	6 Exploring Forces	Assessment activity on pagee155.			
P12 Children were allowed to ask questions but those didn't lead to investigations or research. P104-good activity.					

Scholastic 100 Science Lessons Y5 Author: David Glover, I am Mitchell, Louise Petheram and Peter Riley Content pages :7 to 201					
Page	Unit Title	Topic Title	CT	PS	PF
14	5A Keeping Healthy	Breathing	1	1	
63	5B Life Cycles	Changes in the body			
112	5D Changing State	Materials and Heat		1	
161	5E Earth, Sun and Moon	Solar Eclipse			
P14 How could we measure how often we breathe?					

Scholastic 100 Science LessonsY6 Authors: Clifford Hibbard, Karen Mallinson-Yates and Tom Rugg Content Pages:7-201					
Page	Unit Title	Topic Title	CT	PS	PF
16	6A Interdependence and Adaptation	Healthy Plants			
64	6BMicro-organisms	Assessment			
114	6D Reversible and Irreversible Changes	Power Generation (work sheet)		1	
163	6F How we see things	How does distance affect shadow size (enquiry) (Group activity)?	1		

3. Folens Science in Action (Series: 507/FO) Y3 Authors: Jo Powell, Simon Smith, Annie Whitehead, Steve Sizmur Content Pages : 6- 80, Pages Analysed : 8, 28, 47, 66					
Page	Unit Title	Topic Title	CT	PS	PF
8	A Teeth and Eating	Living or What? (Pupil worksheet)			
28	C Characteristics of Materials	What Materials are?	1	1	
47	D Rocks and Soils	The Wormery		1	
66	F Light and Shadows	What is Light?			

3. Folens Science in Action (Series: 507/FO) Y4 Authors: Sue Harris, Simon Smith, Annie Whitehead, Steve Sizmur Content Pages : 6- 80, Pages Analysed : 10, 30, 50, 69					
Page	Unit Title	Topic Title	CT	PS	PF
10	A Moving and Growing	At Arm's Length		1	
30	C Keeping Warm	How Hot or Cold are Things?	1		
50	D How do materials Change State	Making Tea	1	1	
69	Circuits and Conductors	What Makes a Circuit Work?	1	1	

3.Folens Science in Action,507/ FO, Y5 Authors: Louise Petheram, Pat Szczesniak, Annie Whitehead, Steve Sizmur Content Pages : 6- 80,Pages Analysed : 12, 31,50, 69					
Page	Unit Title	Topic Title	CT	PS	PF
12	A Keeping Healthy	Exercise and Pulse Rate	1	1	
31	C Gases Around Us	Solids and Liquids			
50	D Changing State	Make a Model Water Cycle			
69	F Changing Sounds	Musical Instruments			

3.Folens Science in Action 50/ FO, Y6 Authors: Louise Petheram, Pat Szczesniak, Annie Whitehead, Steve Sizmur Content Pages : 6- 80Pages Analysed : 15,34, 53, 70					
Page	Unit Title	Topic Title	CT	PS	PF
15	A Interdependence and Adaptation	Food Chains		1	
34	C More About Dissolving	Investigating How Quickly Different Things Dissolve		1	
53	E Forces in Action	Forces Making Things Stretch	1	1	
70	F How We See Things	Test 6F Continued		1	

4. Letts Teaching & Learning Science Activity Book :KS2 Years 3&4, 507LE Authors: Alan Jarvis, Joan O'Sullivan, Wendy Hart, Diane Lowton, Heather Monaghan, Judith Willis, 20					
Page	Unit Title	Topic Title	CT	PS	PF
10	Keeping Animals Healthy	Living Animals			
38	Growing and Living Together	Food Chains			
66	Solids Liquids and Mixtur	Mixing Materials			
94	Light and Shadows	Shadows			
Additional Information: Text book with few questions at the end of the chapters.P10 - Group animals?					

4. Letts Teaching & Learning Science Activity Book,Years 5&6 (507/LE) Authors: Alan Jarvis, Joan O'Sullivan, Ian Baldry, Andrew Hodges, William Merrick, Pat Szczesniak					
Page	Unit Title	Topic Title	CT	PS	PF
25	Keeping Healthy	Disease (How do micro-organism get into our bodies?		3	
57	Gases and Changing State	What's in the gaps? (How much a is trapped in the soil?)		3	
91	Our Earth and the Solar System	The Earth, the Sun and the Moon	1	3	
125	How We See Things	Reflections (How do you see objects?)		4	
Add Inf. P91- draw a diagram, what the Sun, Moon and Earth would look like from a spaceship? (CT)F1?					

5. Letts Teaching & Learning Science Teachers' Book (507/LE) KS2, Y3 Alan Jarvis, Ian Baldry, Wendy Hart, Diane Lowton, William Merrick, Joan O' Sullivan					
Page	Unit Title	Topic Title	CT	PS	PF
20	Teeth and Eating	Carnivore or Herbivore?		1	
42	Materials and their Properties	A Survey of Materials		1	
64	Rocks and Soils	Investigating Soil Drainage	1(F2)	1	
86	Light and Shadows	Movements of the Sun	1	1	
F2- Creative thinking in the experimental space					

5. LettsTeaching & Learning Science Teachers' Book KS2, Y4 Alan Jarvis, Ian Baldry, Wendy Hart, Diane Lowton, William Merrick, Joan O' Sullivan					
Page	Unit Title	Topic Title	CT	PS	PF
15	Moving and Growing	Investigate Patterns in Body Measurements	1		
39	Habitats	Worksheet		2	
65	Solids and Liquids	Sorting with sieves		2	
90	The Force of Friction	The force of friction 1 (WS)		3	
Additional Information: P15 - suggest questions - do taller children weigh more? Predicting and testir (CT F2)?					

5. Letts Teaching & Learning Science Teachers' Book KS2, Y5 (507/LE) Alan Jarvis, Pat Szczesniak, Ian Baldry, Wendy Hart, Diane Lowton, William Merrick, Joan O'Sullivan					
Page	Unit Title-	Topic Title-	CT	PS	PF
15	Keeping Healthy	How much oxygen do we use? (IC activity)			
37	Life Cycles	Life cycles (End of the unit questions)			
59	Changing State	Changing temperature - Written work -predict what the next readings of temp in the table and construct a graph			
82	Changing Sounds	Making sounds- introductory top (understanding what sound make have in common -vibrations)			
81+1==82, p81 didn't have enough content					

5. Letts Teaching & Learning Science Teachers' Book KS2, Y6 Alan Jarvis, Pat Szczesniak, Ian Baldry, Wendy Hart, Diane Lowton, William Merrick, Joan O'Sullivan					
Page	Unit Title	Topic Title	CT	PS	PF
10	Interdependence and Adaptation	Using Keys		2	
32	More about Dissolving	Do all solids dissolve equally well (investigation)		1	
54	Micro-organisms	Investigating Decay		2	
76	Electrical Circuits	Investigating Bulb Brightness		2	
Additional Information: P76- does the length of the wire affects the brightness of the bulb in the circuit? PS					

6. Pearson Longman Exploring Science Y3, 507EX Authors: Penny Johnson, Mark Levesley (Matches QCA scheme of work)					
Page	Unit Title	Topic Title	CT	PS	PF
8	3A Teeth and Eating	3Aa)Food Groups			
26	3B Helping Plants Grow V	3Bb) Leaves Roots and Stems		1	
44	3D Rocks and Soil	3Da) Using Rocks			
62	3E Magnets and Springs	3Ed) Springs			

6. Pearson Longman Exploring Science, Y 4, 507EX Authors: Penny Johnon, Mark Levesley Content pages analysed:10, 29,48, 67					
Page	Unit Title	Topic Title	CT	PS	PF
10	4A Moving and Growing	4Ac) Support and Protection			
29	4C Keeping warm	4Ca) Hot and Cold		1	
48	4D Solids Liquids and How they can be Separated	4Dc) Mixtures of Solids		1	
67	4F Circuits and Conductor	4Fa) Circuits and Switches		2	

6. Pearson Longman Exploring Science Y5, 507EX Content pages 4 to 77					
Page	Unit Title	Topic Title	CT	PS	PF
12	5A) Keeping Healthy	5Ac Changing Pulse Rates		1	
31	5C) Gases Around Us	5CaSolids, Liquids and Gases	1	1	
50	5C) Changing states	5De) The Water Cycle			
69	5F) Changing Sounds	5Fb) Moving Sounds	1	1	
69) How could u find out which materials sound travels through best? How can u make your test fair ...					

6. Pearson Longman Exploring Science Y6, 507EX					
Page	Unit Title	Topic Title	CT	PS	PF
6	6A Interdependence and Adaptation	6Aa Focus on: How Plants Grow			
28	6C More about Dissolving	6Cb Investigating Dissolving	1	1	
50	6E Balanced and Unbalan Forces	6Ed Air Resistance		1	
72	6R Revision	6Rc Stopping for Lunch			
P28 Good example. (Copy please) P50- Why a hammer falls faster than a feather if dropped on Earth? (PS?)					

7. Hamilton Trust Online Resource Y3(Biology:6pages, Chemistry: 8pages, Physics:7pages) (21pages total)					
Page	Unit Title	Topic Title	CT	PS	PF
2	Sc2 Animals Including Humans	Keeping Healthy		1	
8	Sc3 Rocks	Under our Feet			
14	Sc3 Rocks	Soil Investigation	1		
20	Sc4 Forces and Magnets	Uses of Magnets		1	

7. Hamilton Trust Online Resource- Y4					
Page	Unit Title	Topic Title	CT	PS	PF
4	Sc2 Animals Including Humans	Teeth			
10	Sc3 States of Matter	Temperature			
16	Sc 4 Electricity	Mains Electricity vs Batteries		1	
22	Sc4 Electricity	Scientists			

7. Hamilton Trust Online Resource-Y5 Content pages(1-24)					
Page	Unit Title	Topic Title	CT	PS	PF
6	Sc2 Living Things and theHabitats	Scientists			
12	Sc3 Properties and Changof Materials	Irreversible Changes	1		
18	Sc4 Forces	Air resistance	1		
24	Sc 4 Forces	Working Scientifically		1	
P12 Plan a rusting nail enquiry. P18 Plan an enquiry to test how the no. of paper clips affects the time the spinner takes to fall? P24 Design and make a simple artefact using a mechanical device.					

7. Hamilton Trust Online Resource (No Chemistry unit) (Pages 1-13)					
Page	Unit Title	Topic Title	CT	PS	PF
5	Sc2 Living Things and the Habitats	Identification		1	
8	Sc4 Light	Light travels in straight lines		1	
P8 plan a demo to show light travels in straight lines.					

12.14 APPENDIX 6a Filed Notes Template for Strategy Trials

School details:

Name:

Class size:

Age range:

Ability groups:

Pupil ratio:

Other:

Teacher details:

Name:

Experience:

Curriculum details:

Scheme of work if any:

Other web/ text resources used for teaching:

Willing to allow observation of a lesson?

Willing to do the online survey?

Willing to allow a short interview at a later stage?

Additional information:

Task Sheet: (Strategy)

Task:

Start time:

Finish time:

General Response:

Additional Information:

Additional Information Sheet:

12.15 APPENDIX 6b Chapter 9: Strategies Trialled, Tables and Examples of Children's' Questions

I. Summary Tables with Question Starters and Examples of Children's Questions

1. Question Starters on Giant Dice

Summary of Type of Questions, Question Starters and their Percentages

Question Type	Question Starters	No	% of total
Factual (559) 85%	Which…	191	29.03%
	Which is best for…	56	8.51%
	How would you…	125	18.10%
	What happens when…	116	17.63%
	Will it…. If we…	71	10.79%
Explanatory (99) 15%	What would happen if…	99	15.05%
	Grand Total	**658**	

Questions below are the exact copy of the child's version (including the spellings).

Examples of Factual Questions

What happens when a egg doesn't hatch does it get eaten by the bird?
What happens when a mother bird fees on another birds eggs?
what happens when you cook a egg?
What happens when a paper bag is thrown into the sea
What happens when a papper bag gets wet?
What happens when a plast bag was in the sea and got stuck on a turtles head.
How would you test which bag is the strongest?
How would you find out witch egg has the weakest shell without breaking them.
how would you know that a hen's egg was boiled?
Which bag is the most water proof.
Which bag is the best for the environment
Which bag lasts the longest and why?
Will a peper bag desolve if you put it in the water.
Will egg sink if we put in cola?

Examples of Explanatory Questions

What would happen if you drop a boiled egg in cider vinegar?
What would happen if you left a leather bag outside and it rained?
What would happen if you left a plastic bag outside for 2 weeks?
What would happen if you left a quil egg in a cup of coke for a week?
What would happen if a bag flies away and it goes in the water does fish die? (plastic bag)

Examples of Generic or Borderline Questions (i.e. not clear science or not clear non-science)

What would happen if an egg was dropped out of an aeroplane into a river? Would it smash or sink?
What happens when you drop a ostrach egg?
Will a boiled egg smash if we drop it?

Examples of RODIN Questions (RODIN- Research, Observation, Demonstration, Investigation and None of these)
R

What would happen if a Chic dieas inside a egg?
What happens when a plastic bag goes into the ocean?
Which egg is faster to hatch of
Will it the plastic bag or the papper bag fly farther?
Which does hatches faster a hens egg or a ducks egg?
Which bag is the moust polutive bag?
How would you know if the baby bird in the egg is alive?

Examples of Observation Questions (O)

How would you tell what kind of egg it is
How would you know if it is a duck or hen egg?

Examples of Investigative Questions (I)

What would happen if you left a jute bag in the rain for a month
What would happen if you dropped an egg in water, would it float?
which egg is the strongest
Will it sink if we fill a plastic bag full of ice?
How would you find out witch egg has the weakest shell without breaking them.
How would you test which bag is the strongest?
How would you see if what bag would dry from water the quickest?
Which bag lasts the longest and why?
Which bags are biodegradable

Example of None (N)
Which egg is the best to cook
Which bag is the bag to shop with?

2. 'The Elephant' Strategy

Summary of Type of Questions, Question Starters and their Percentages

Question Type	Question Starters	Number	Percentage
Factual Question(400)	How	195	48.75%
	What	64	16.00%
	Can	29	7.25%
	Do	28	7.00%
	Is	25	6.25%
	Does	15	3.75%
	I wonder	14	3.50%
	Where	10	2.50%
	Are	7	1.75%
	When	5	1.25%
	Would	3	0.75%
	Which	1	0.25%
	Who	1	0.25%
	Will	1	0.25%
	If	1	0.25%
	It	1	0.25%
Explanatory Question(133)	Why	120	90.23%
	What if	10	7.52%
	I wonder why	2	1.50%
	How…and why	1	0.75%
Total Science (533)		533	

Type of Questions, Question Starters and their Percentages

Question Type	Question Starters	Number of Questions	Sub-starters	Number	Percentage
Factual (400/75%)	How	195	How are	3	1.54%
			How big	25	12.82%
			How can	6	3.08%
			How do	54	27.69%
			How does	28	14.36%
			How doesn't	1	0.51%
			How far	1	0.51%
			How has	1	0.51%
			How is	4	2.05%
			How much	14	7.18%
			How will	2	1.03%

			How long	22	11.28%
			How small	1	0.51%
			How strong	7	3.59%
			How tall	5	2.56%
			How thick	2	1.03%
			How many	9	4.62%
			How old	5	2.56%
			How heavy	4	2.05%
			How hot	1	0.51%
	What	64	What (food, age, size, parts…)	7	10.94%
			What are	5	7.81%
			What do	29	45.31%
			What does	2	3.13%
			What happens	2	3.13%
			What is	9	14.06%
			What kind	2	3.13%
			What makes	2	3.13%
			What sort	2	3.13%
			What type/ types	2	3.13%
			What will	1	1.56%
			What would	1	1.56%
	Can	29	Can	26	89.66%
			Can it	1	3.45%
			Can a	1	3.45%
			Can the	1	3.45%
	Do	28	Do (people)	1	3.57%
			Do elephants/ male elephants	8	28.57%
			Do they	15	53.57%
			Do all	1	3.57%
			Do different	1	3.57%
			Do you	1	3.57%
			Do the	1	3.57%
	Is	25	Is it	16	64.00%
			Is the	3	12.00%
			Is there	4	16.00%
			Is this	2	8.00%
	Does	15	Does it	7	46.67%

			Does the	5	33.33%
			Does their	1	6.67%
			Does elephant	1	6.67%
			Does	1	6.67%
	I wonder	14	I wonder how	8	57.14%
			I wonder what	4	28.57%
			I wonder if	2	14.29%
	Where	10	Where do	6	60.00%
			Where does	3	30.00%
			Where will	1	10.00%
	Are	7	Are their	3	42.86%
			Are they	2	28.57%
			Are all	1	14.29%
			Are	1	14.29%
	When	5	When does	2	40.00%
			When the	1	20.00%
			When would	1	20.00%
			When…, does it…	1	20.00%
	Would	3	Would the	1	33.33%
			Would it	1	33.33%
			Would an	1	33.33%
	Which	1	Which has	1	100%
	Who	1	Who would	1	100%
	Will	1	Will it	1	100%
	If	1	If the	1	100%
	It	1	It needs	1	100%
Explanatory 133/25%	Why	120	Why do	60	50.00%
			Why are	25	20.83%
			Why does	17	14.17%
			Why is	9	7.50%
			Why don't	4	3.33%
			Why can't	1	0.83%
			Why did	1	0.83%
			Why doesn't	1	0.83%
			Why have	1	0.83%
			Why shall	1	0.83%
	What …if	10	What would happen if	5	50.00%
			What happens if	3	30.00%

			What will happen if	1	10.00%
			What do…if..	1	10.00%
	I wonder why	2	I wonder why	2	100%
	How…why	1	How are…why?	1	100%
Total Science Questions(533)		533		533	

Examples of Explanatory Questions:

Why do females don't have tusks but males do?
Why do elephents and humans have water in the womb?
Why does the elephant need to be in a bag of water?
Why do they have thick skin?
Why does they have little eyes but the rest of the body is really big.
What would happen if the chord was broken?
What would happen if elephants were extinct?
What would happen if the elephant had sharp tusks in the mums belly?

Factual questions demonstrating extension of children's thinking (Higher level factual questions)
E.g. *Would an elaphent live if the trunk got cut of?*
I wonder if the little elephant is a boy or a girl?
I wonder how the baby elephant eat food in the mum's tummy?
I wonder how the baby elephant eat food in the mum's tummy?
I wonder how many times does elephant flap their ears?
I wonder how big the baby elephant can be when it is in it's mum's tummy?
How will the mammy elephant feed when the doctor cuts the mam's umbilical cord?)
Do all elephants weigh around the same amount if they are the same age?
Do elephants use their trunks like snorkels to breathe under water?
Do they have good eyesight even though they have small eyes?
What is the differences between an baby elephant (embryo) and a human baby (embryo)
Does tusks grow on the baby when in the elephants?
Where do elephants sleep?
Wich has a bigger trunk male or female.
If the mum died with the embryo inside it,…? (incomplete

Factual questions asking for confirmation of specific facts

Examples: Do elephants use their trunks like snorkels to breathe under water?
are african elephants bigger than elephants?
and are their ancester's mamoth's?

Examples of How..? questions looking for **quantitative** factual information *(How long..? How big...? How far...? How much...? How small....? How strong...? How tall...? How thick...? How many...? How old...? How heavy...? How hot...? I wonder how...?).*

Examples: *"How long can elephants live for?"*
"How long dose the Elephant stay inside the babies womb?"
"How long does the umbilical cord grow up to?"
"How big are they compared to human?"

"how strong are the males tusck?"
"How many years can Elephants live for"
"How much does a baby elephant weigh?"
I wonder how many times does elephant flap their ears?
I wonder how big the baby elephant can be when it is in it's mum's tummy?

Questions asking for **procedural** information (How...? How are...? How can...? How do...? How does...? How doesn't...? How has...? How is...? How will...? I wonder how....? Do...? Does...? Can...? Would...if...?)
Examples: *How will the mammy elephant feed when the doctor cuts the mam's umbilical cord?)*
How does the baby elephant breathe?
How do the elephants make their trunks pick stuff up?
hawe dos the elifent get exrayd bay the docter.
How doesn't the baby drowned?
Can elephants swim under water?
Do elephants use their trunks like snorkels to breathe under water?
Do all elephants weigh around the same amount if they are the same age?
Do they have good eyesight even though they have small eyes?
Does the cord just come of by its self for an elephant?
Does tusks grow on the baby when in the elephants?
I wonder if the little elephant is a boy or a girl?
I wonder how the baby elephant eat food in the mum's tummy?
Would the baby die if the mother died?
Would an elaphent live if the trunk got cut of?

Examples of factual questions asking for descriptive information: What..?. Where...? When..? Which...? Who...? Are...? Is...? *What do elephants eat? Where do elephants sleep?*

Wich has a bigger trunk male or female.
What happens when an elephant tuscs get took off them?
What is the differences between an baby elephant (embryo) and a human baby (embryo)
What is the ivory made out of?
I wonder what they eat except grass?
Are their brain really small?
are african elephants bigger than elephants?
and are their ancester's mamoth's?

Example of RODIN Questions(RODIN- Research, Observation, Demonstration, Investigation and None of these)
R

How does the baby elephant breathe?
Why does it have big ears?
What do elephants eat?
What happens to the elephants when they are getting tamed?
How long will it take for a baby elephant to be born?
How does the air get from the tip of their trunk in to their lungs?
Do they have good eyesight even though they have small eyes?
Why do only male elephants have tusks?
How will the mammy elephant feed when the doctor cuts the mam's umbilical cord?
How much does a baby elephant weigh?
Why is the embryo surrounded by water?
Why do they have large toe nails?
How long can elephants live?

How many elephants are in the wild
Why do they drink through the trunks?
What is their natural habbitat?
Do elephants use their trunks for snorkelling?

Examples of 'None of these' or 'N' Questions
What's the line behind the baby?
What would you call them?
Where does the baby come out of?
Is this actually a baby elephant?

3: Question Generation Workshop Using Real Eggs & Bags

Table Showing Question Type, Question Starters and their Percentages

Question Type	Question Starter	Number of Questions	Percentage
Factual Questions (682)	Are	29	4.25%
	Can	26	3.81%
	Could	3	0.43%
	Do	33	4.83%
	Does	10	1.46%
	Has	1	0.14%
	Have	2	0.29%
	How	195	28.59%
	If	9	1.31%
	In	1	0.14%
	Is	41	6.01%
	What	141	20.67%
	When	6	0.87%
	Where	32	4.69%
	Which	146	21.40%
	Who	3	0.43%
	Will	1	0.14%
	Would	3	0.43%
Explanatory Questions (276)	Do....Why?	1	0.36%
	If....why?	2	0.72%
	The....why?	1	0.36%
	Which.....and why?	1	0.36%
	What happens when....?	1	0.36%
	What.....if.....?	8	2.89%
	Why.....?	262	94.92%
Total Science Questions (958)			

Type of Questions, Question Starters and their Percentages

Question Type	Question Starter	Number of Questions	Sub-starters	Number	Percentage
Factual Questions (682)	Are	29			
			Are…	13	44.82%
			Are all…	4	13.79%
			Are some…	2	6.89%
			Are the….	10	34.48%
	Can	26			
			Can…	10	38.46%
			Can a….	3	11.53%
			Can the…	2	7.69%
			Can there….	1	3.84%
			Can you….	9	34.61%
			Can we….	1	3.84%
	Could	3			
			Could…	3	100.00%
	Do	33			
			Do…	10	30.30%
			Do all….	5	15.15%
			Do some….	1	3.03%
			Do the….	4	12.12%
			Do they….	11	33.33%
			Do we…	1	3.03%
			Do you….	1	3.03%
	Does	10			
			Does…	3	30.00%
			Does a…..	1	10.00%
			Does it…..	2	20.00%
			Does the….	4	40%
	How	195			
			How…	2	1.02%
			How and which…	1	0.51%
			How are….	14	7.17%
			How big…	13	6.66%
			How can…	5	2.56%
			How come….	1	0.51%

			How could….	1	0.51%
			How did….	2	1.02%
			How do…..	54	27.69%
			How does…..	14	7.17%
			How fast….	1	0.51%
			How hard….	3	1.53%
			How heavy…..	6	3.07%
			How ill….	1	0.51%
			How is…..	9	4.61%
			How little…..	1	0.51%
			How long….	24	12.30%
			How many…..	25	12.82%
			How much…..	5	2.56%
			How old….	1	0.51%
			How quick…..	1	0.51%
			How small…..	2	1.02%
			How soft…..	1	0.51%
			How strong…..	1	0.51%
			How thick…..	4	2.05%
			How to…..	1	0.51%
			How were…..	1	0.51%
			How wide…..	1	0.51%
	Has	1			
			Has…	1	100.00%
	Have	2			
			Have…	2	100%
	If	9			
			If…….does it….?	1	11.11%
			If……how big will be?	1	11.11%
			If….will….?	4	44.44%
			If……would they…..?	1	11.11%
			If……could it…..?	1	11.11%
			If…..would it…..?	1	11.11%
	In	1			
			In…	1	100.00%
	Is	41			
			Is…..	7	17.07%

			Is a…..	2	4.87%
			Is an….	1	2.43%
			Is every…..	1	2.43%
			Is it……	6	14.63%
			Is the…..	15	36.58%
			Is there…..	9	21.95%
	What	141			
			What…..	53	37.58%
			What are…..	9	6.38%
			What do….	4	2.83%
			What does….	3	2.12%
			What else…..	1	0.07%
			What is….	48	34.04%
			What happens….	14	9.92%
			What would be….	3	2.12%
			What…..would be the….?	2	1.41%
			What would happen to….?	1	0.07%
			What….will be the….?	1	0.07%
			What …is most…..?	1	0.07%
			What comes….	1	0.07%
	When	6			
			When do…	1	16.66%
			When you…	1	16.66%
			When….does it….?	2	33.33%
			When….is it…..?	1	16.66%
			When….are they….?	1	16.66%
	Where	32			
			Where do….	16	50.00%
			Where are….	3	9.37%
			Where did…..	4	12.50%
			Where does….	5	15.62%
			Where is….	1	3.12%
			Where was….	1	3.12%
			Where were…..	2	6.25%
	Which	146			
			Which…?	64	43.83%
			Which is…?	29	19.86%

			Which is not….?	1	0.68%
			Which…..is the…?	2	1.36%
			Which does not….?	1	0.68%
			Which of the…..?	1	0.68%
			Which one…..?	14	9.58%
			Which would….?	7	4.79%
			Which….would….?	11	7.53%
			Which….is the….?	11	7.53%
			Which….is….?	2	1.36%
			Which….has the….?	1	0.68%
			Which…..the most…?	1	0.68%
			Which….will be….?	1	0.68%
	Who	3			
			Who….?	3	100.00%
	Will	1			
			Will the….?	1	100.00%
	Would	3			
			Would…..?	3	100%
Explanatory Questions (276)	Do…..Why?	1			
			Do…..Why?	1	100%
	If……why?	2			
			If……why?	1	100%
	What happens when….?	1			
			What happens when….?	1	100%
	What….if….?	8			
			What happens to….if….?	2	25.00%
			What will happen if….?	2	25.00%
			What would happen to…..if….?	2	25.00%
			What happens if…..?	1	12.50%
			What would happen if….?	1	12.50%
	Which…..and why?	1			
			Which...and why?	1	100.00%

	The.....why?	1			
			The....why?	1	100%
	Why....?	262			
			Why....?	7	2.67%
			Why are.....?	91	34.73%
			Why aren't.....?	2	0.73%
			Why can.....?	2	0.73%
			Why can't.....?	1	0.38%
			Why did.....?	2	0.73%
			Why do....?	65	24.80%
			Why does....?	26	9.92%
			Why don't.....?	5	1.90%
			Why has....?	2	0.73%
			Why have....?	1	0.38%
			Why is.....?	53	20.22%
			Why not.....?	4	1.52%
			Why the.....?	1	0.38%
			Why was.....?	1	0.38%
Total Science Questions (958)				958	

Examples of Explanatory Questions Generated by Children

What happens if a person left a silk cloth in the rain?
What happens to the sea animals if the thin plastic bag goes in the sea?
What will happen to leather bags and paper bags if you put them together outside in rain?
What happens when a plastic bag gets thrown in the sea?
The shell is different than the other eggs?
Which bag wighs more and why?
What would happen to an bag made out of animal skin if it was left out in the sun for long?
goose egg is white and shiny? (why?)
The shell is different than the other eggs?
Why are the eggs different coulors?
Why do Quail eggs have patterns on.
Why does the ostrich egg have little dents
Why have some eggs got babies in but others don't?
Why duse the Quail Egg have spots?
Way did he was bigger.Way did the ostrich eggs?
Why do they lay eggs, not have birth?
Why do animals get killed for there skin?
Why dous paper bags rip off the rain
Which bag wighs more and why?
Why do we need to pay for bags?
Why do shops mainly sell plastic bags?
What happens when a plastic bag gets thrown in the sea?
Why don't we make more cotton bags?

Why not make skin bags?
Why do plastic bags not disintergrate
Why not use dead animals skin

Examples of Factual Questions Asking for Confirmation of Specific Facts
Does it matter about the sise to how nutritias it is
Do the bigger eggs need more incubation
Is the eggs colour depend on who's laying it?
Is the biggest egg always the hardest?
Is the smallest egg always the most fragile?
Is it based on the colour of the bird what colour the egg was.
Does the colour of the egg afect the colur of it. (bird)
If the bird is ill/ weak/ not fed enough , will that affect the size of its egg and the bird inside it?
Are thicker bags heayer?
Are Ostreges when they are born are they big because the shell is big?
If they have a different diet will all the eggs taste different?

Examples of Factual Questions on Ethical Issues
Do people kill the silkworm to make the bags?
do they take the skin of and let it live or kill and then take the skin
Do they kill snakes to make bags?
are animals killed in a painful way or a good way?
Do they have to kill animals for leather or does it have surgery and live?

Examples of Factual Questions Asking for Procedural Information
What happens to the paper bags when it rains?
What happens inside of the egg?
What happens inside of an egg before it is laid by the mother?
What happens in the eggs?
What happens to the paper bags when it rains?
How are different eggs different colours?
How are the shells formed before they are hatched?
How did Quail have coluers on it.
How do the animals keep them walm? (Research Qstn- Can visit local farms and see how)
Can birds have twins?
Can there be twins and how does it happen?
How do they make cotton bags?
haw do silk bag made from silk worm?
How do the plastic bags get coloured.

Examples of Factual Questions Asking for Quantitative Information
How long does an Ostrich egg take to hatch?
How many bird or chick do you get in one egg?
How long dose a Ostrich spend in it's egg.
How thick are all of the eggs.
how big are silk worm
How many coulors egg dose a hen lay?
How long does each egg tak to hatch?
How much does the goose egg way?
How small is a quail wen it haches
how big is the youlk inside the egg's?
Howe hevy are they?

Examples of Factual Questions Asking for Descriptive Information
What does the inside of the Quail egg look like?
What bird lays the smallest egg in the world?
Where do they nest?
Which egg is the heaviest?
What is in a Ostrich egg befor they turn into a baby Ostriches
Where does an ostrich lay its egg at.
What is an egg shell made of?
Where are cotton plants grown?
Which plat (plant) makes Jute?
Is the Quil egg black or not, inside?
Which bag is best for the environment?
Which bag would last the longest?
Which bag has the worst affect on nature?
Which bag would last for the longest outside?
Which is the best bag for the environment.
Are all the eggs got the same things inside or different?
Is there a yolk inside an ostrich egg?

Examples of Mis-conceptions
Is yoke a ducks blood?

Examples of Children's Queries but not in Question Form
goose egg is white and shiny?
The shell is different than the other eggs?
Way they different colls?
Way did he was bigger. Way did the ostrich eggs?
I don't understand why do people kill animals just to get posh leather stuff?

Examples of RODIN Questions Children Asked (RODIN- Research, Observation, Demonstration, Investigation and None of these)
R
how do the baby Ostrich get out of the egg.
What is the inside the egg when it hatches?
How long does it take for an ostrich egg to hatch?
Why does the Quail egg have brown spots on it?
Why aren't all eggs the same size?
Where do the birds lay eggs?
how do you get different colour on silk bag?
Why is lether made from animal skin.
What mitteriels would bebest for shopping (bag)?
How do they make bags out of animal skin?
O

Are all birds nest the same?
how big is a goos?
how big is a Quail egg.
wat shape is the quail egg.

D
What is inside the eggs?
How thick is the shell?
How many coulors egg dose a hen lay?

I
Wich egg is the heviest
Which egg is the smoothest?
Is the smallest egg always the most fragile?
Wich bag is the strongest.
Which egg weighs the most?
Which is the worst bag for our environment?
if you leave a plastice bag and a paper bag out in the rain will the paper bag disolve?
What will happen to leather bags and paper bags if you put them together outside in rain?
Which is better to use plastic bags or paper bags to help the environments

N
have you saw a dodo egg
Why (what) is your favroit egg out of them all?

4: Science Stories

Summary of the Question Type, Question Starters and Percentage

Question Type	Question Starters	Number	Percentage
Factual (392) 63%	Are	15	3.83%
	Can	53	13.52%
	Can't	9	2.30%
	Could	7	1.79%
	Couldn't	1	0.26%
	Did	9	2.30%
	Do	18	4.59%
	Does	10	2.55%
	Has	2	0.51%
	Have	1	0.26%
	How	157	40.05%
	If	14	3.57%
	Instead	1	0.26%
	Is	31	7.91%
	It is…,how is..	1	0.26%
	Should	2	0.51%
	Since…does..	1	0.26%
	Was	7	1.79%
	What	20	5.10%
	When	3	0.77%
	Where	3	0.77%
	Which	1	0.26%
	Who	2	0.51%
	Will	4	1.02%
	Would	20	5.10%
Explanatory (233) 37%	If…why..	4	1.72%
	Is this why…	1	0.43%
	Why	196	84.12%
	What…if…/ What if…..	30	12.88%
	How and why	2	0.86%
	Grand Total	**625**	

Summary Question Type, Question Starters and Sub-starters

Question Type	Starter	No.	Sub-starter	No	% of starters
Factual Questions (392)	**Are**	**15**			
			Are there…	2	13.33%
			Are they…	3	20.00%
			Are…	10	66.67%
	Can	**53**			
			Can it…	2	3.77%
			Can the…	1	1.89%
			Can there…	1	1.89%
			Can they…	13	24.53%
			Can we….	11	20.75%
			Can you…	14	26.42%
			Can…	11	20.75%
	Can't	**9**			
			Can't there…	1	11.11%
			Can't they..	4	44.44%
			Can't we…	2	22.22%
			Can't you…	2	22.22%
	Could	**7**			
			Could it….	3	42.86%
			Could we…	1	14.29%
			Could you…	1	14.29%
			Could…	2	28.57%
	Couldn't	**1**			
			Couldn't…	1	100.00%
	Did	**9**			
			Did it…	1	11.11%
			Did the…	1	11.11%
			Did they…	4	44.44%
			Did this…	1	11.11%
			Did…	2	22.22%
	Do	**18**			
			Do they….	8	44.44%
			Do we…	1	5.56%

			Do you…	3	16.67%
			Do…	6	33.33%
	Does	**10**			
			Does it…	2	20.00%
			Does the..	1	10.00%
			Does..	7	70.00%
	Has	**2**			
			Has….	2	100.00%
	Have	**1**			
			Have…	1	100.00%
	How	**157**			
			How are…	4	2.55%
			How big…	6	3.82%
			How can…	25	15.92%
			How could…	1	0.64%
			How did..	33	21.02%
			How do..	25	15.92%
			How does…	25	15.92%
			How has…	2	1.27%
			How is…	9	5.73%
			How many…	11	7.01%
			How much…	4	2.55%
			How often…	1	0.64%
			How rare…	1	0.64%
			How to..	1	0.64%
			How would…	4	2.55%
			How..	5	3.18%
	If	**14**			
			If it…	1	7.14%
			If they…	2	14.29%
			If you…	2	14.29%
			If….	1	7.14%
			If…..don't they…?	1	7.14%
			If…could we..	1	7.14%
			If…would…	6	42.86%
	Instead	**1**			

			Instead…	1	100.00%
	Is	**31**			
			Is it…	16	51.61%
			Is the…	4	12.90%
			Is there…	3	9.68%
			Is this..	3	9.68%
			Is..	5	16.13%
	It is…,how is..	**1**			
			It is…,how is..	1	100.00%
	Should	**2**			
			Should…	2	100.00%
	Since…does..	**1**			
			Since…does..	1	100.00%
	Was	**7**			
			Was it…	4	57.14%
			Was there…	3	42.86%
	What	**20**			
			What are..	1	5.00%
			What causes…	1	5.00%
			What could…	1	5.00%
			What else…	1	5.00%
			What is…	2	10.00%
			What should..	1	5.00%
			What will happen…	3	15.00%
			What would happen…	1	5.00%
			What would have happened…	1	5.00%
			What would…	1	5.00%
			What…	7	35.00%
	When	**3**			
			When…	3	100.00%
	Where	**3**			
			Where…	3	100.00%
	Which	**1**			
			Which…	1	100.00%
	Who	**2**			
			Who…	2	100.00%

	Will	**4**			
			Will…	4	100.00%
	Would	**20**			
			Would a…	1	5.00%
			Would it..	3	15.00%
			Would there…	1	5.00%
			Would they..	5	25.00%
			Would you..	2	10.00%
			Would..	5	25.00%
			Would the..	3	15.00%
			Grand Total	**392**	
Explanatory questions (172)	**If…why..**	**4**			
			If…why don't…	2	50.00%
			If…why...	2	50.00%
	Is this why…	**1**			
			Is this why…	1	100.00%
	Why	**196**			
			Cows… .Why…	1	0.51%
			Why are...	13	6.63%
			Why aren't...	2	1.02%
			Why can...	1	0.51%
			Why couldn't...	1	0.51%
			Why can't...	12	6.12%
			Why did...	25	12.76%
			Why didn't...	8	4.08%
			Why do...	53	27.04%
			Why does...	9	4.59%
			Why doesn't...	2	1.02%
			Why don't...	27	13.78%
			Why hasn't...	1	0.51%
			Why is…	22	11.22%
			Why might...	1	0.51%
			Why not...	5	2.55%
			Why was...	3	1.53%
			Why wasn't...	1	0.51%
			Why won't...	1	0.51%

			Why would...	1	0.51%
			Why...	7	3.57%
	What…if…/ What if…..	**30**			
			What could have happened if..	1	3.33%
			What happens if..	1	3.33%
			What if…	4	13.33%
			What will happen if..	1	3.33%
			What would happen if..	18	60.00%
			What would happen…if..	4	13.33%
			What would have happened if…	1	3.33%
	How and why	**2**			
			How…and why	2	100.00%
			Grand Total	**233**	
Total Science Questions (625)					

Explanatory Questions

Why did they cut open her stomach?
Why don't they recycle the bags?
Why don't they use paper bags?
What would happen to the two yolks if they hatch?
Why do people be more careful with plastic bags?
Why don’t we stop making plastic bags?
What would happen if bothe the yolks turned into chicks?
Why dosent every egg have 2 yokes?
What would happen if you put it in an incubater
Why didn't the acid in the cows stomache burn the bag?
What would happen if you put it in the incuvator
Why cant we make bags out of a different safer material?
Why can't we reuse the plastic bag?
Why did it have two yolk?
Examples of Factual Questions
Are double yolk eggs bigger than a single yolk egg.
Will the cow sufficate if it gets a bag on its head?
Can cows eventually digest plastic.
Can we recycle these plastic bags?
Can chicks be twins and be born out of the same egg?
Can you tell if the egg is a twin egg?
Can they produce a collar to stop it from eating litter?
Do they have more protien in?
Does the egg have more protein if there is 2 yolks?
How did the cow die?
How you degrade plastic bags?

How is it possible for the cow to have so much plastic inside of it?
How did the two yolks form?
How is it different to one yolk egg?
How do the two babies fit in one egg?
If a bird gave birth to a double yolk would they be twins?
Is it fair that people throw bags and it makes some animals die?
Was there 2 chicks inside the egg?
What percent of cows die off eating plastic bags?
What is the plastic bags doing to the earth?
What will happen to the chicks when they hatch?
Would one chick be smaller and would the other be big

Examples of Factual Questions Asking for Confirmation of Specific Facts
Would one chick be smaller and would the other be big
If a bird gave birth to a double yolk would they be twins?
Does the egg have more protein if there is 2 yolks?
Are double yolk eggs bigger than a single yolk egg.

Examples of Factual Questions on Ethical Issues/ Ethical Questions
Is it possible for us to help these stray cows in any way?
Is it fair that people throw bags and it makes some animals die?
Can we give cows shelter and food?
Couldn't you just ffed them than just let them suffer
Can we prevent this
Can we give stray cows to farmers so they can look after them?
Is it fair for Gowri?
Can they provide more bins?
Are their any animal shelters in India?

Examples of Factual Questions Asking for Procedural Information
Can cows eventually digest plastic.
Can we recycle these plastic bags?
How did the cow die?
How you degrade plastic bags?
How is it possible for the cow to have so much plastic inside of it?
What will happen to the chicks when they hatch?
How did the double egg form?

Examples of Factual Questions Asking for Quantitative Information
How many plastic bags is 88 pounds?
how much liter from cows (cows tummy?)
how many eggs have two yocks.
how manry die a year?
How many bags were eaten.
How big are the eggs?

Examples of Factual Questions Asking for Descriptive Information
Does the egg have more protein if there is 2 yolks?
Was there 2 chicks inside the egg?
is it rare for a egg to have a egg to be dobble yoak?
What could have caused the egg to have two yolks.
What causes a double-yolked egg?
What coulor was the egg yolkes?
Would the egg split into 2 geezes

Examples of Misconceptions
Do we eat the beginning of a chick?

Examples of Children's Queries but not in Question Form
tidd it up and put in bin?(Can't they..)
We should invent bin with lock? (Should we..?)
people should adopt them and keep care of them? (can people…)
We could make a bag that waists away after a week? (Could we?)

Examples of RODIN Questions (Research, Observation, Demonstration, Investigation, None of these)

R

Why do they Have 2 yokes?
Why cant the open a cow sanctuary if the worship them so much?
Why do people be more careful with plastic bags?
Why was the cow stray and not cared for?
how can you get a double youker.
Why are there 2 yokes.
how can you get 2 yokes in a egg?
Can we recycle these plastic bags?
Why did Gowri eat the plastic bags?
Why don't the people recycle the bags?
Why cant we make bags out of a different safer material?
if they is a doble yolk are they twins?
Why don't you make bags which are editable (edible)?
Why wasn't this animal kept in a farm?
doo the cow's choke on the bag's?
Are plastic bags a danger for nature?
Can you get triplits?
Why does it have two yolks?
is it a conjoined twin?
is this why they charge 5p for bags?
Is it possible for us to help these stray cows in any way?
Why didn't the acid in the cows stomache burn the bag?
If you eat a cow that has eaten plastic bags what would happen?
How does the cow eat so much litter?
Was there 2 chicks inside the egg?
Would you get ones that are atached by there feet?
What if the egg had 4 yolkes?
What would happen if bothe the yolks turned into chicks?
How is it different to one yolk egg?
What causes a double-yolked egg?
What would happen if you put it in an incubater
What would happen inIndia if they charge?

N- None of These

How Do They wership The poor Gowri.
Who drops the plaastic bags?
If you see a plastic bag can you pick it up?

5: Science Scenarios

Summary - Question Type, Question Starters and Percentage

Question Type	Question Starters	Number	Percentage
Factual Questions (380 or 63%)	How	166	43.68%
	What	49	12.89%
	Is	48	12.63%
	Can	33	8.68%
	Does	16	4.21%
	Do	10	2.63%
	Will	9	2.37%
	Where	8	2.10%
	When	7	1.84%
	Would	7	1.84%
	Could	7	1.84%
	Did	6	1.58%
	If	3	0.79%
	Was	3	0.79%
	Are	2	0.53%
	Can't	2	0.53%
	Which	1	0.26%
	Should	1	0.26%
	Couldn't	1	0.26%
	In….how would….	1	0.26%
Explanatory Questions (219 or 37%)	Why	197	89.95%
	What….if../ What if…	22	10.04%
Total Science Questions		599	

Summary- Question Type, Question Starters, Sub-starters and Percentages

Question Type	Question Starter	Number of Questions	Sub-starters	Number	Percentage
Factual (380 or 63%)	How	166			
			How are	4	1.66%
			How big	11	6.63%
			How can	10	6.02%
			How could	1	0.60%
			How did	7	4.22%
			How do	45	27.11%
			How does	21	12.65%
			How hard	2	1.20%
			How heavy	1	0.60%
			How high	1	0.60%
			How is	9	5.42%
			How large	1	0.60%
			How light	2	1.20%
			How long	19	11.45%
			How many	9	5.42%
			How much	3	1.81%
			How old	3	1.81%
			How small	3	1.81%
			How thick	1	0.60%
			How was	2	1.20%
			How will	1	0.60%
			How would	10	6.02%
	What	49			
			What are	5	10.20%
			What can	1	2.04%
			What	6	12.24%
			What is	18	36.73%
			What other	3	6.12%
			What happens to	7	14.29%
			What else	1	2.04%
			What does	2	4.08%
			What will	1	2.04%
			What would	3	6.12%
			What would happen to	1	2.04%
			What happened when	1	2.04%
	Is	48			
			Is it	30	62.50%

			Is it not	1	2.08%
			Is the	5	10.42%
			Is there	10	20.83%
			Is	2	4.17%
	Can	33			
			Can the	4	12.12%
			Can they	4	12.12%
			Can we	17	51.52%
			Can you	8	24.24%
	Does	16			
			Does the	12	75%
			Does it	4	25%
	Do	10			
			Do they	4	40%
			Do we	2	20%
			Do you	1	10%
			Do the	1	10%
			Do	2	20%
	Will	9			
			Will the	2	22.22%
			Will it	4	44.44%
			Will this	2	22.22%
			Will they	1	11.11%
	Where	8			
			Where do	5	62.50%
			Where does	2	25%
			Where is	1	12.50%
	When	7			
			When will	2	28.57%
			When would	1	14.29%
			When does	1	14.29%
			When	3	42.86%
	Would	7			
			Would the	4	57.14%
			Would it	3	42.86%
	Could	7			
			Could we	3	42.86%
			Could you	1	14.29%
			Could they	2	28.57%
			Could it	1	14.29%
	Did	6			
			Did it	4	57.14%
			Did the	2	28.57%
	If	3			

			If	3	100%
	Was	3			
			Was	3	100%
	Are	2			
			Are…	2	100%
	Can't	2			
			Can't	2	100%
	Which	1			
			Which would	1	100%
	Should	1			
			Should	1	100%
	Couldn't	1			
			Couldn't	1	100%
	In….how would…	1			
			In…how would…	1	100%
Explanatory (219 or 37%)	Why	197			
			Why do	56	28.43%
			Why does	46	23.35%
			Why are	31	15.74%
			Why is	30	15.23%
			Why can't	9	4.57%
			Why don't	7	3.55%
			Why	5	2.54%
			Why not	2	1.02%
			Why would	2	1.02%
			Why has	2	1.02%
			Why doesn't	2	1.02%
			Why isn't	1	0.51%
			Why it is	1	0.51%
			Why can't	1	0.51%
			Why can't	1	0.51%
			Why couldn't	1	0.51%
	What…if…/ What if…..	22			
			What happens if	7	31.82%
			What would happen if	6	27.27%
			What will happen if	4	18.18%
			What if	2	9.09%
			What happens….if…	1	4.55%
			What would happen….if..	1	4.55%

			What would….if….	1	4.55%
Total Science Questions (599)				599	

Examples of Explanatory Questions Generated by Children

Why do they have very big eyes.
What would happen if the chick couldn't break the shell to get out.
Why do they have massive eyes?
Why do they come out without feathers?
What will happenn if you opened the chicks egg 3 or 2 weeks erly?
Why are the vains in the yolk
Why do they have to eat the yoke to get bigger?
Why does it have tiny beak?
Why are the chicks eyes huge and the body small
Why do we kill cows when we can wait intil its diys and then yose it
Why dosen't it have any feathers.
Why are animals killed to make leather?
Why don't humans wait untill the co's are dead then use their leather (skin)
Why do they have to kill it instead of make fake leather
Why don't they use fake leather or Jude bags
Why do people like to kill animals just for fashion?
Why isn't this classed as animal cruilty?
Why do they kill wildlife for bags when you can use jute bags or other bags?
Why could we wait until the animal is dead to use the skin?
What would it have looked like if you opened the egg when it was 3 day old.
Why are the eyes big as a baby but small when an adult?
Why would someone wear an animal
What happens if the Embryo runs out of yolk?
What would happen if the chick was ready to come out but it wasn't taken care of?
How would you feel if you had a cow and it was killed for leather?

Examples of Factual Questions Asking for Confirmation of Specific Facts
is 1 week baby chick be the same size as 3 day baby chick
is it dead.
is it a male or a female
If the egg was damaged would the chick stop growing?
Does the youk disapear wanu the hen is fuly grown.

Examples of Factual Questions on Ethical Issues

Is it cruilety to animals?
how would you kill the cow?
Is it not animal cruelty?
Is it fair to kill cows?
Can you test different mateariel not animal skin?
culdn't they wate for the cow to have a young one first?
What can we do to stop this?
Which would the cow rather? Be pealled, or die?
Is it fair for nature?
Do we just have to kill cows for leather?
Is there another alternative product that doesn't kill animals?

How cude we have lether with no killing
Can't you Just wait until the cows die normaly?
how do you help save the cows.
Can we stop using leather for clothes etc?
it is naughty to kil cow? (Is it...)
Is it fair on the baby cow?
Can you recycle leather?

Examples of Factual Questions Asking for Procedural Information

How does the beak grow
How dose the chick breate inside the egg?
How is it born?
how do they eat in the egg?
Can a embryo survive with out wonth (warmth) for a couple of mins
how did you know that it was an egg with an ebryo?
How did you make the skin feel a bag?
how do you know there is a chick in the egg?
how do they survive in the egg?
Which would the cow rather? Be pealled, or die?
How do we make the cows skin into proper leather?
How do they kill the animals?
Will it bring an exstinction to cows on earth.
Could we recycle leather and if so how?

Examples of Factual Questions Asking for Quantitative Information

How much will one week old chic whey?
how much dose the chik grow in the egg?
How much will one week old chic whey?
How long would it take to make a leather bag?
how long does it take to fully form like an ordinary chick?
How long does it take for a chick embryo to grow properly?
how high will the chick grow every day
What is the temprcher in the egg?
How old is the chick when it hatches?
How long does it take for the chick to form?
How heavy is the chick and how tall is it?
How many animals does it take to make leather bag?

Examples of Factual Questions Asking for Descriptive Information

What is the diffrence between a chick embryo and a chicken
What coulor are they when there older.
What does the chick look like when the egg is first laid?
is it a boy chick or a girl chick
Dose the chick in the egg have a umbilecord?
Where does the cows body go once it is skinned?
What other materials could you use to make bags?
Can we make bags and clothes out of different materials instead of using animal skins?
Could we use rubber instead of leather?
Can we use lether without killing cows?
What country uses this method the most?
does it have all the bones of an adult

Do they use baby cows or adult cows

Examples of Misconceptions
In an egg you would eat (,) how would you get the chick out then eat or is it a diffirent type of egg?
I's the chicks wings yellow because the yolk yellow.

Examples of Children's Queries but not in Question Form

We should wait until someone dosent want it any more then they can re-use it? (Should we..?)
Is it painfull when a chicken egg. (in the egg?)
you could chos a different metterial
Cant the cows just not be killed for leather We can just have no bags!
it is naughty to kil cow? (Is it...)

Examples of RODIN Questions Children Asked ((*RODIN: Research, Observation, Demonstration, Investigation and None of these)*

R or Research Questions
Why do they have very big eyes.
How much will one week old chic whey?
Why does it grow large eyes first?
What would happen if the chick couldn't break the shell to get out.
Why does it have big eyes?
how can it breathe in the egg
Why do embryo not have feathers.
Was it hard to get the baby chick out of the egg?
What would it look like in 2 weeks time?
What would it look like in 2 weeks time?
How long does it take for the chick to develop?
Why are people allowed to kill animals for fashion?
Can they use alternative materials like rubber, plastic?
What would happen to the bag if it was put under water?
How do you know it's gender?
is there another way to make leter?
Why Do they use Alive cows not Dead
Why cant we make a fake leather alternative that isn't hurting animals and the environment?
How can it survive with out oxoyn? (oxygen)
Why don't humans wait untill the co's are dead then use their leather (skin)
How is the bag made?
Can you make a bag with a different matireel.
How can it breathe in the yoak?
How do you get the leather from the cow?
Why do people kill cows for leather when you can use jute bags?
What other materials could you use to make bags?
Could we recycle leather and if so how?
how do they make the skin into lether.
What types of animals do people take the skin from?
Can we make fake cows skin?
Why can't we wait until the animals have died naturaly?
How do you put detale on? (detail)

N Questions/ None of these
How did you open the egg?
How can you cut an egg opan?

Why is it shaped like a cow?
Why does it look like an alien
Is the head a real one?
How much does the leather cost to buy?
Why would the people want to buy a cow? (bag with cow)
how wood you stick the head off
How is the hed still on.

6:'I Wonder' Board
Summary Question Type, Question Starters, Number and Percentages

Question Type	Question Starter	Number	Percentage
Factual Question (131)	Are	2	1.52%
	Can	4	3.05%
	Do	11	8.39%
	Does	4	3.05%
	Has	1	0.76%
	Have	1	0.76%
	How	57	43.51%
	what	18	13.74%
	Is	15	11.45%
	I wonder	5	3.81%
	I would	2	1.52%
	If	1	0.76%
	When	2	1.52%
	Where	2	1.52%
	Which	1	0.76%
	Who	3	2.29%
	Why	1	0.76%
	Would	1	0.76%
Explanatory Questions (63)	Why	52	82.53%
	What if	6	9.52%
	If….why	1	1.58%
	In…if….would…why?	1	1.58%
	I wonder why…	3	4.76%
Total Science Questions (194)			

Summary of Question Type, Question Starters, Sub-starters, Number and Percentages

Question Type	Question Starter	Number of Questions	Sub-starters	Number	Percentage
Factual Questions (131)	How	57	How	2	3.50%
			How are	1	1.75%
			How big	2	3.50%
			How small	1	1.75%
			How long	5	8.77%
			How high	1	1.75%
			How far	1	1.75%
			How many	12	21.05%
			How is	3	5.26%
			How was	1	1.75%
			How can	7	12.28%
			How can't	1	1.75%
			How did	3	5.26%
			How do	8	14.03%
			How does	9	15.78%
	What	18	What	3	16.60%
			What could	1	5.55%
			What do	2	11.11%
			What does	1	5.55%
			What happens in	1	5.55%
			What is	9	50%
			What was	1	5.55%
	Is	15	Is	6	40.00%
			Is there	9	60%
	Do	11	Do	8	72.72%
			Do you think	3	27.27%
	I wonder	5	I wonder how	1	20.00%
			I wonder what	4	80%
	Does	4	Does	4	100%
	Can	4	Can	4	100%
	Are	2	Are	2	100%
	I would	1	I would like to	2	100%
	Who	3	Who	3	100%
	Where	2	Where	2	100%
	When	2	When	2	100%
	Which	1	Which	1	100%
	Why	1	Why	1	100%
	Would	1	Would	1	100%
	If....would it...	1	If.... Would it...	1	100%
	Has	1	Has	1	100%
	Have	1	Have	1	100%
Explanatory	Why	52	Why are	4	7.69%

Questions (63)					
			Why can	1	1.92%
			Why did	5	9.61%
			Why do	29	55.76%
			Why does	9	17.30%
			Why don't	1	1.92%
			Why is	2	3.84%
			Why there is	1	1.92%
	What..if	6	What will happen if..	1	16.66%
			What would happen if..	5	83.33%
	If…why…	1	If….why…	1	100%
	In…if….would….why?	1	In…if…would…why?	1	100%
	I wonder why…	3	I wonder why….	3	100%
Total Science Questions (194)				194	

Examples of questions

Explanatory
In the food chain if a plant was a producer would it be able to eat anything?why?
What would happen if two things were both predators and prey to each other?
I wonder why they have stems.
What would happen if one of the animals in the food chain died out?
I wonder why they have flowers
What would happen if plants didn't get eny water?
if there is no life on otere plantes why do we need theme?
What would happen if the Moon didn't exist?
What would happen if you changed the habitat of the food chains?
I wonder why they have polen
What will happenif There wer no plants in the world?
Why don't birds die on pylon wires?
Why do animals eat the same animal like a big fish eating a small fish?
Why do big animals eat smaller animals.
why does plants always start food chains?
Why does the food chain always end with a big animal?
Why does the food chain always start with a plant?
Why do things die of old age?

Factual Descriptive Questions
What does a zebra eat?
What is the main type of science ?
Where does serten plants come from like rainforest plants.
I wonder what plants are in the rainforest
I wonder what the inside of a plant looks like.
if the sun got biger would it beume super nove?
Is there life on different planets
is there life in space?
Is there any animals on space and if there is what animals?
What could you find in space?

What is the farest planet you can see from earth?
What is a battery made of
Who created electricity?
When was electricity invented?
Is a fish a producer?
What is the cleverest animal in the world?
I would like to learn more about the different animals but what other animals do they eat?
Is there water in any other planets.
is the Sun hoter in space?
I would like to ask if there was an alien invation what would the governmant do?
Is gravity a power, a force or something elase?
When was electricity invented?
Who invented electrisity?
Is plankton poisonus to catterpillars?
Is there any other planets undiscovered.
Would plankton feed a human?

Factual Procedural
Do artik animals travel in to normal playses for food
Do Birds eat slugs.
Does plankton feed on bacteria?
How do animals die and make new plants?
How do plants live without water?
How does the plant absorbs the Sun?
Do plants ever stop growing?
How do flowers opn
How is there no gravity in space?
How did the galaxy get made?
How does electrisity not kill us if we toch the wooden post on pillons?
How does electricity work?
how can you tell the difference between a female shark and a male?
How can you tell the difference to a male and a female plant.
How do cars work?

Factual Quantitative
How many plants and animals are there in the biggest food chain?
How many types of plants are there in the world?
How many stars are there in the galaxy?
How many volts flow through a wire?
How long does a battery last for?
How many wires does a earth net cable have?
How far away is the space station from earth?
How long does battery energy last.
How many volts can kill someone?
How many stars are they?

Examples of RODIN Questions((*RODIN Research, Observation, Demonstration, Investigations and Noneof these)*

R

why does plants always start food chains?
Why do we have food chains?
In the food chain if a plant was a producer would it be able to eat anything? why?

how we are the only planet that we have found that can sustain life and has life on it
How is there no gravity in space?
How does electrisity not kill us if we toch the wooden post on pillons?
Why do we need different colour wires for different wires?
What would happen if one of the animals in the food chain died out?
I wonder why they have flowers
Why don't birds die on pylon wires?

Examples of Observation (O) Questions

Do Birds eat slugs.
How can flowers live in a verse without water?
I wonder what the inside of a plant looks like

Examples of Investigation (I) Questions

How long does battery energy last.
What would happen if plants didn't get eny water
Examples of None of these (N) Questions

What is the main type of science ?

II. Tables of Data Whose Graphs Summarises them in the Text (Chapter 9)

1. Question Starters on the Giant Dice

Whole KS2: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	2	97	99
Q2	113	2	115
Q3	121	0	121
Q4	129	0	129
Q5	116	0	116
Q6	67	0	67
Q7	7	0	7
Q8	3	0	3
Q9	1	0	1
Q10	0	0	0
	559	99	658

Whole KS2 Males: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	2	38	40
Q2	50	0	50
Q3	53	0	53
Q4	59	0	59
Q5	49	0	49
Q6	24	0	24
Q7	1	0	1
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	238	38	276

Whole KS2 Females: Showing the Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	0	59	59
Q2	63	2	65
Q3	68	0	68
Q4	70	0	70
Q5	67	0	67
Q6	43	0	43
Q7	7	0	7
Q8	2	0	2
Q9	1	0	1
Q10	0	0	0
	321	61	382

Upper KS2: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	**Factual Questions**	**Explanatory Questions**	**Science Questions**
Q1	1	48	49
Q2	57	0	57
Q3	63	0	63
Q4	63	0	63
Q5	49	0	49
Q6	35	0	35
Q7	0	0	0
Q8	1	0	1
Q9	0	0	0
Q10	0	0	0
	269	48	317

Upper KS2 Males: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	1	17	18
Q2	23	0	23
Q3	24	0	24
Q4	24	0	24
Q5	18	0	18
Q6	13	0	13
Q7	0	0	0
Q8	1	0	1
Q9	0	0	0
Q10	0	0	0
	104	17	121

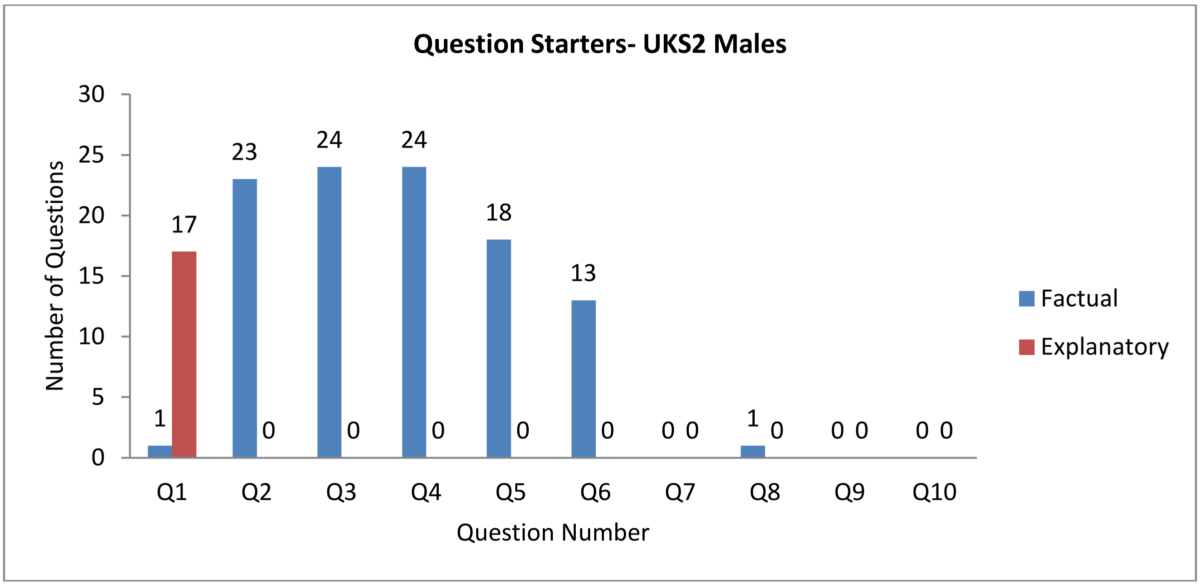

Figure 9.6 Upper KS2 Males: Pattern of Factual and Explanatory Questions

Upper KS2 Females: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	0	31	31
Q2	34	0	34
Q3	39	0	39
Q4	39	0	39
Q5	31	0	31
Q6	22	0	22
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	165	31	196

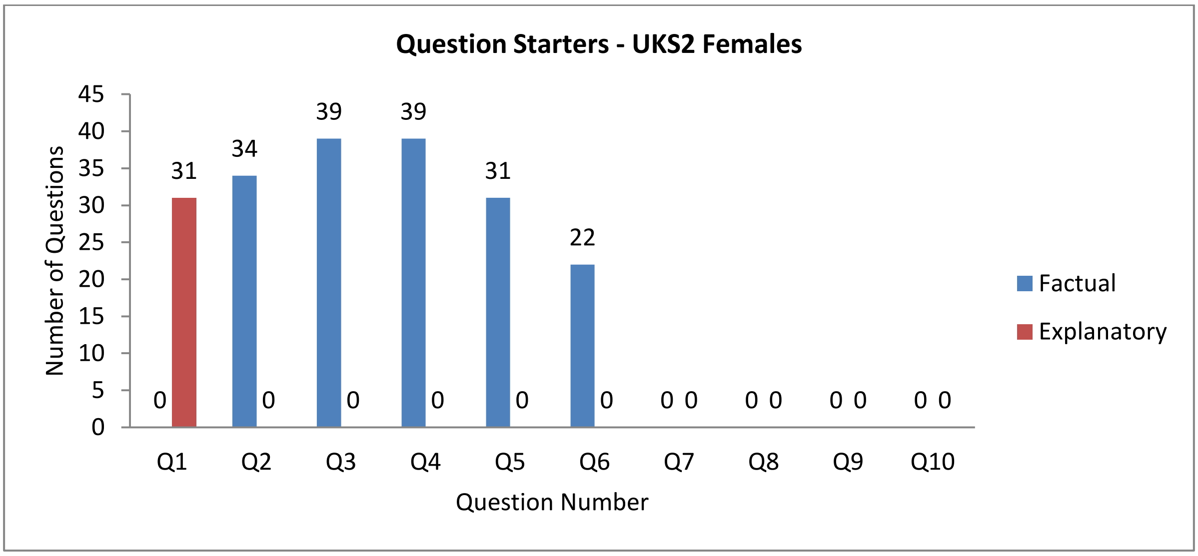

Figure 9.7 Upper KS2 Females: Pattern of Factual and Explanatory Questions

Lower KS2: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	1	49	50
Q2	56	2	58
Q3	58	0	58
Q4	66	0	66
Q5	67	0	67
Q6	32	0	32
Q7	7	0	7
Q8	2	0	2
Q9	1	0	1
Q10	0	0	0
	290	51	341

Lower KS2 Males: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	1	21	22
Q2	27	0	27
Q3	29	0	29
Q4	35	0	35
Q5	31	0	31
Q6	11	0	11
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	134	21	155

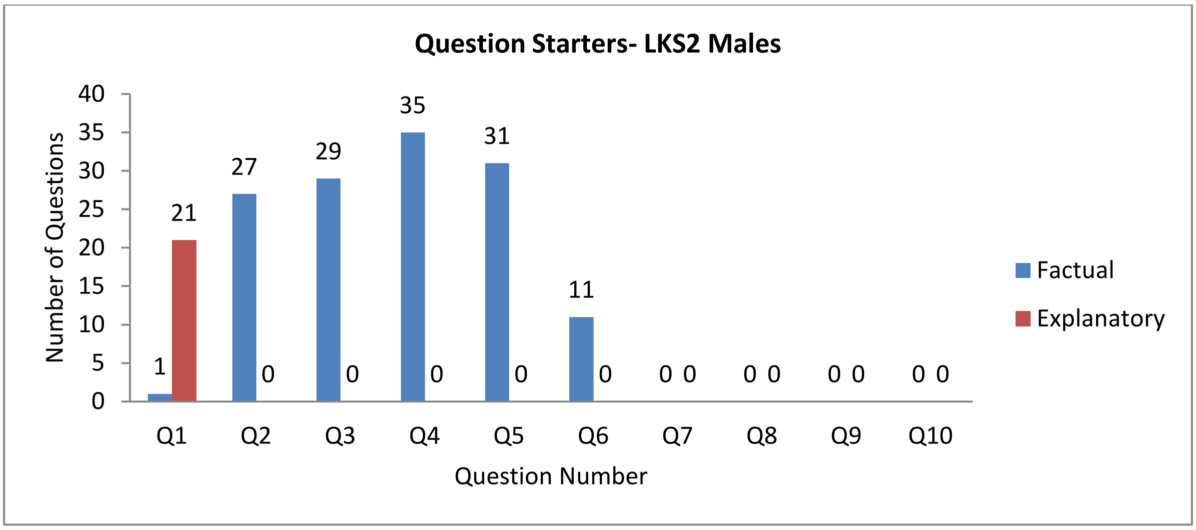

Figure 9.9 Lower KS2 Males: Pattern of Factual and Explanatory Questions

Lower KS2 Females: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	0	28	28
Q2	29	2	31
Q3	29	0	29
Q4	31	0	31
Q5	36	0	36
Q6	21	0	21
Q7	7	0	7
Q8	2	0	2
Q9	1	0	1
Q10	0	0	0
	156	30	186

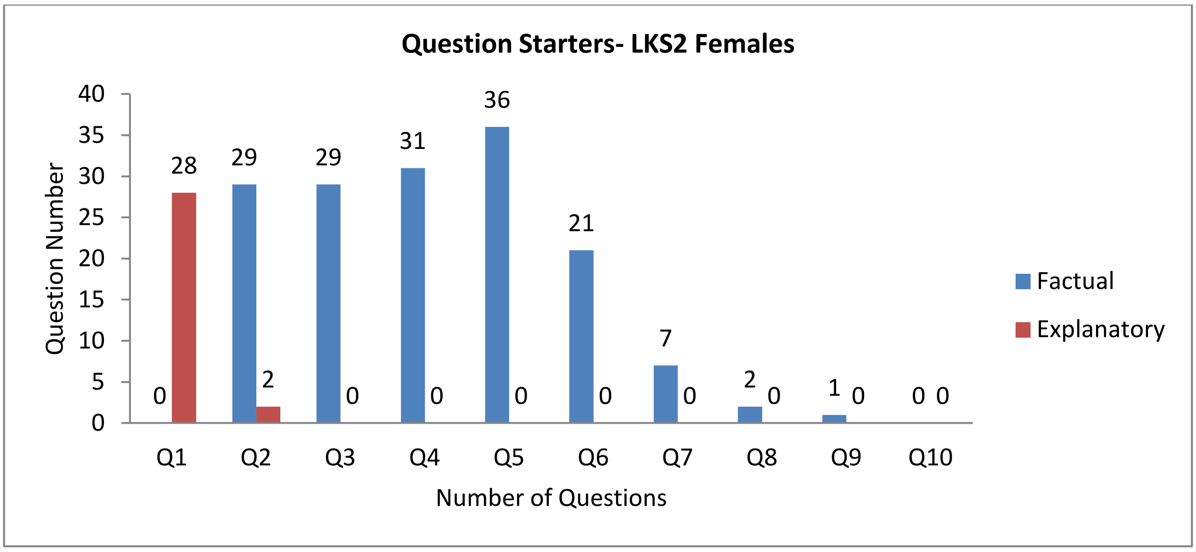

Figure 9.10 Lower KS2 Females: Pattern of Factual and Explanatory Questions

Whole KS2 Topic 'Eggs': Showing the Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	1	71	72
Q2	61	2	63
Q3	77	0	77
Q4	64	0	64
Q5	63	0	63
Q6	42	0	42
Q7	5	0	5
Q8	3	0	3
Q9	0	0	0
Q10	0	0	0
	316	73	389

Whole KS2 Topic 'Bags': Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	103	26	129
Q2	88	0	88
Q3	40	0	40
Q4	11	0	11
Q5	3	0	3
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	245	26	271

Table Showing the Number and Pattern of Occurrence of Factual and Explanatory Questions in the Upper KS2 'Eggs'

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	0	40	40
Q2	29	0	29
Q3	46	0	46
Q4	31	0	31
Q5	26	0	26
Q6	21	0	21
Q7	0	0	0
Q8	1	0	1
Q9	0	0	0
Q10	0	0	0
	154	40	194

Upper KS2 Topic 'Bags': Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	53	8	61
Q2	42	0	42
Q3	18	0	18
Q4	3	0	3
Q5	1	0	1
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	117	8	125

Lower KS2 Topic 'Eggs': Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	1	31	32
Q2	32	2	34
Q3	31	0	31
Q4	33	0	33
Q5	37	0	37
Q6	21	0	21
Q7	5	0	5
Q8	2	0	2
Q9	0	0	0
Q10	0	0	0
	162	33	195

Lower KS2Topics 'Bags': Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	50	18	68
Q2	46	0	46
Q3	22	0	22
Q4	8	0	8
Q5	2	0	2
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	128	18	146

Strategy 2: The 'Elephant Strategy'

Whole KS2: Showing the Number and Pattern of Occurrence of Factual and Explanatory Questions

Question Number	Factual Questions	Explanatory Questions	Science Questions
Q1	89	23	112
Q2	81	31	112
Q3	76	27	103
Q4	65	23	88
Q5	40	18	58
Q6	21	6	27
Q7	12	4	16
Q8	8	0	8
Q9	5	1	6
Q10	2	0	2
Q11	1	0	1
	400	133	533

KS2 Whole Group Males: Pattern of Factual and Explanatory Questions

Question Number	Factual Questions	Explanatory Question	Science Question
Q1	47	8	55
Q2	40	14	54
Q3	35	13	48
Q4	32	7	39
Q5	19	6	25
Q6	6	0	6
Q7	5	1	6
Q8	3	0	3
Q9	3	0	3
	190	49	239

KS2 Whole Group Females: Pattern of Factual and Explanatory Questions

Question Number	Factual Questions	Explanatory Questions	Science Questions
Q1	42	15	57
Q2	41	17	58
Q3	41	14	55
Q4	33	16	49
Q5	21	12	33
Q6	15	6	21
Q7	7	3	10
Q8	5	0	5
Q9	2	1	3
Q10	2	0	2
Q11	1	0	1
	210	84	294

Upper KS2: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	43	13	56
Q2	31	25	56
Q3	31	17	48
Q4	26	14	40
Q5	16	6	22
Q6	7	2	9
Q7	2	3	5
Q8	2	0	2
Q9	2	0	2
Q10	1	0	1
	161	80	241

UKS2Males: Pattern of Factual and Explanatory Questions

Question Number	Factual Questions	Explanatory Questions	Science Questions
Q1	22	5	27
Q2	14	13	27
Q3	14	8	22
Q4	14	3	17
Q5	5	2	7
Q6	2	0	2
Q7	0	1	1
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	71	32	103

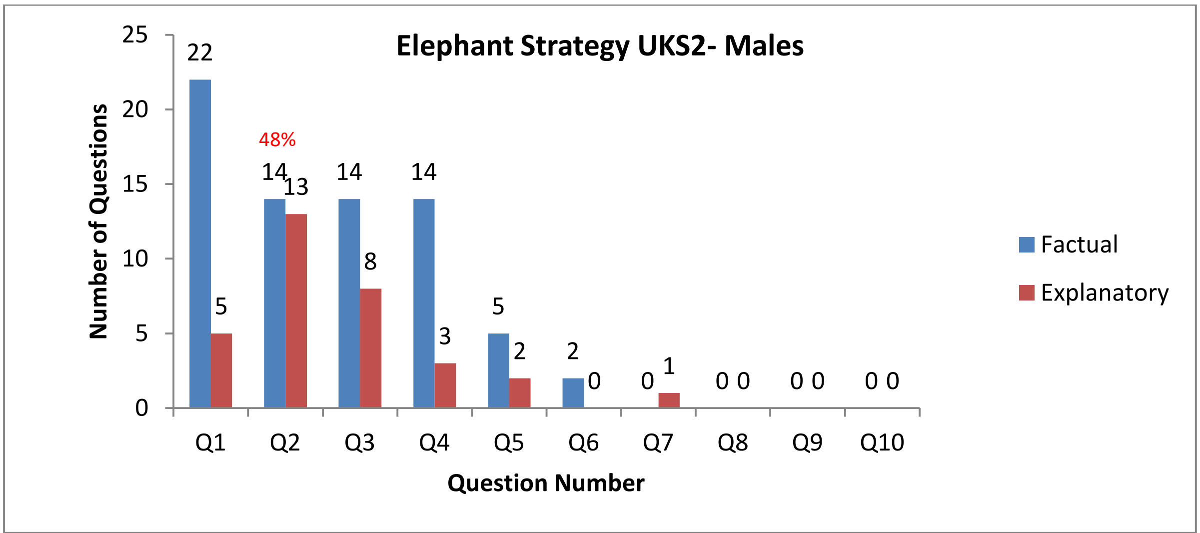

Figure 9.21 Upper KS2 Males: Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the number of science questions i.e. both factual and explanatory questions at each question.)

UKS2 Females: Pattern of Factual and Explanatory Questions

Questions Number	Factual Questions	Explanatory Questions	Science Questions
Q1	21	8	29
Q2	17	12	29
Q3	17	9	26
Q4	12	11	23
Q5	11	4	15
Q6	5	2	7
Q7	2	2	4
Q8	2	0	2
Q9	2	0	2
Q10	1	0	1
	90	48	138

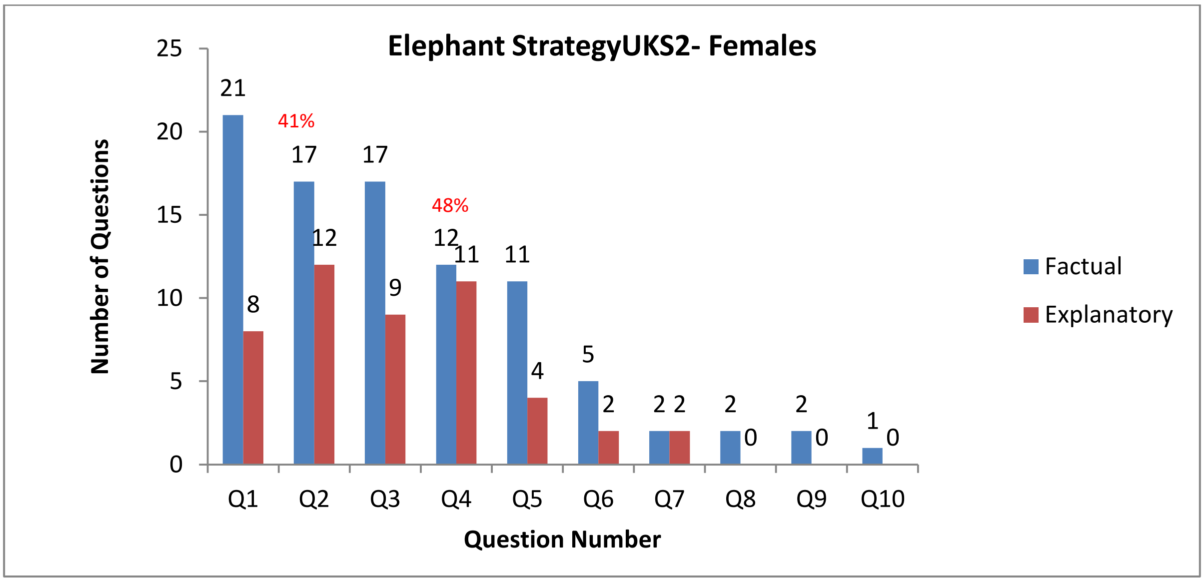

Figure 9.22 Upper KS2Females: Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the number of science questions i.e. both factual and explanatory questions at each question.)

Lower KS2: Number and Pattern of Occurrence of Factual and Explanatory Questions

Question Number	Factual Questions	Explanatory Questions	Science Questions
Q1	46	10	56
Q2	50	6	56
Q3	45	10	55
Q4	39	9	48
Q5	24	12	36
Q6	14	4	18
Q7	10	1	11
Q8	6	0	6
Q9	3	1	4
Q10	1	0	1
Q11	1	0	1
	239	53	292

Lower KS2 Males: Number and Pattern of Factual and Explanatory Questions

Question Number	Factual Questions	Explanatory Questions	Science Questions
Q1	25	3	28
Q2	26	1	27
Q3	21	5	26
Q4	18	4	22
Q5	14	4	18
Q6	4	0	4
Q7	5	0	5
Q8	3	0	3
Q9	3	0	3
Q10	0	0	0
Q11	0	0	0
	119	17	136

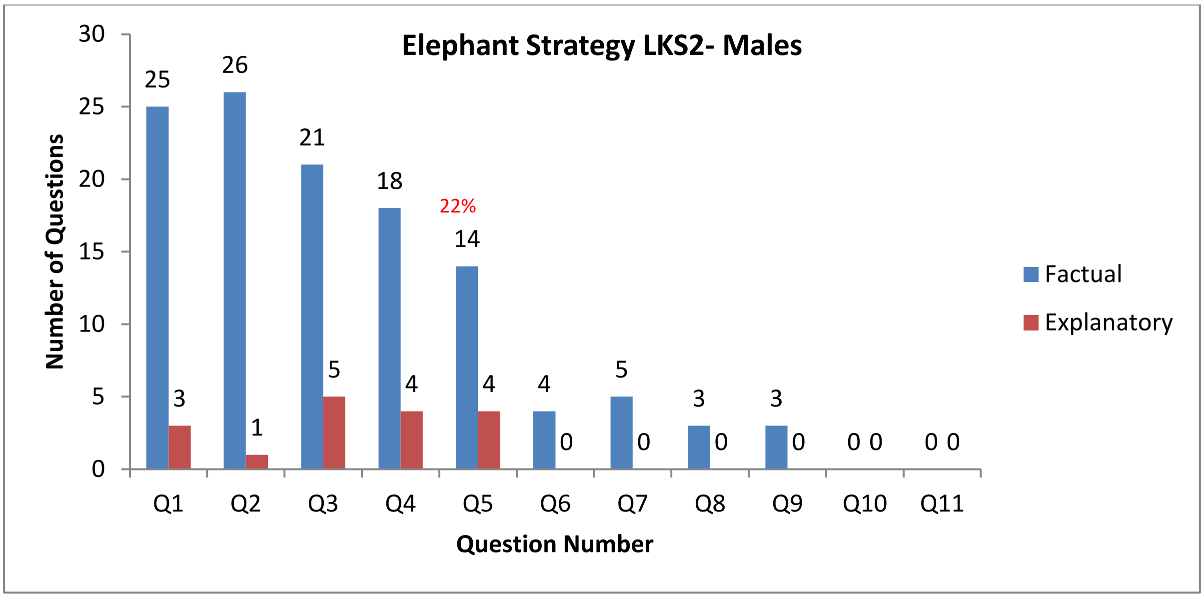

Figure 9.24 Lower KS2 Males: Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the number of science questions i.e. both factual and explanatory questions at each question.)

Lower KS2 Females: Number and Pattern of Factual and Explanatory Questions

Question Number	Factual Questions	Explanatory Questions	Science Questions
Q1	21	7	28
Q2	24	5	29
Q3	24	5	29
Q4	21	5	26
Q5	10	8	18
Q6	10	4	14
Q7	5	1	6
Q8	3	0	3
Q9	0	1	1
Q10	1	0	1
Q11	1	0	1
	120	36	156

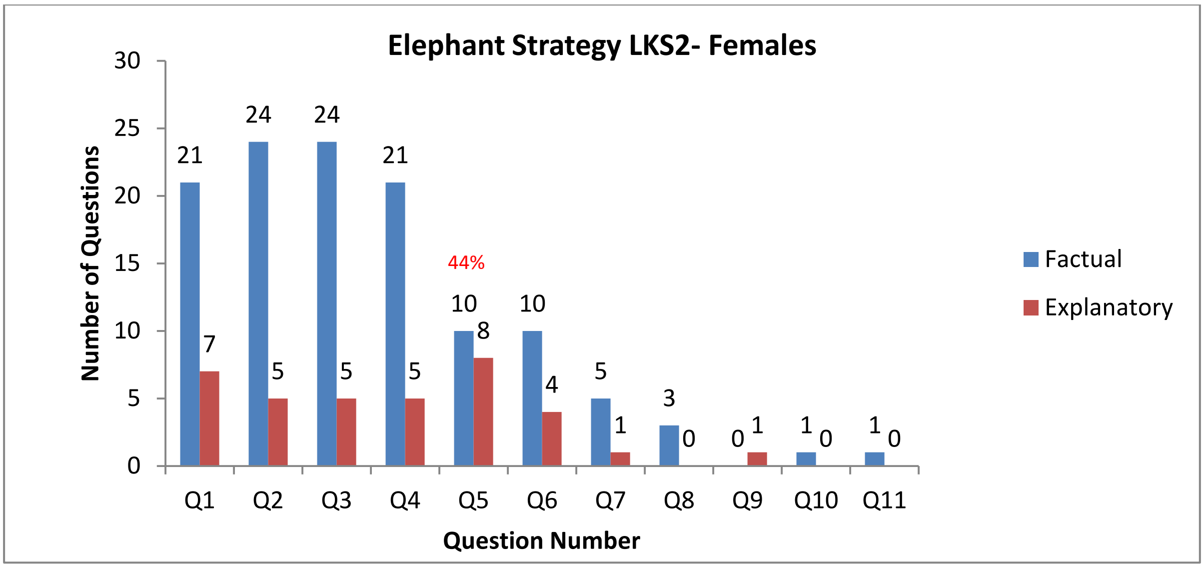

Figure 9.25 Lower KS2 Females: Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the number of science questions i.e. both factual and explanatory questions at each question.)

Analysis of the Number and Patterns of Factual and Explanatory Questions Based on the Topic: Comparison between Elephant in Captivity, Elephant in the Wild and Elephant Embryo in the Womb

Whole KS2'Elephant in the Wild': Number and Pattern of Occurrence of Factual and Explanatory Questions

Photograph	Factual Questions	Explanatory Questions	Science Questions
Q1	30	7	37
Q2	28	9	37
Q3	26	10	36
Q4	19	13	32
Q5	13	9	22
Q6	4	2	6
Q7	3	0	3
Q8	1	0	1
Q9	1	0	1
Q10	0	0	0
Q11	0	0	0
	125	50	175

Whole KS2 'Elephant in Captivity': Number and Pattern of Occurrence of Factual and Explanatory Questions

Question Number	Factual Questions	Explanatory Questions	Science Questions
Q1	28	10	38
Q2	24	15	39
Q3	22	13	35
Q4	24	4	28
Q5	12	8	20
Q6	8	4	12
Q7	6	4	10
Q8	5	0	5
Q9	3	1	4
Q10	2	0	2
Q11	1	0	1
	135	59	194

Whole KS2 'Elephant Embryo in the Womb': Number and Pattern of Occurrence of Factual and Explanatory Questions

Question Number	Factual Questions	Explanatory Questions	Science Questions
Q1	31	6	37
Q2	29	7	36
Q3	28	4	32
Q4	22	6	28
Q5	15	1	16
Q6	9	0	9
Q7	3	0	3
Q8	2	0	2
Q9	1	0	1
Q10	0	0	0
Q11	0	0	0
	140	24	164

Strategy3: Question Generation Workshop Using Real Eggs & Bags

Analysis of the Pattern of Factual and Explanatory Questions in Whole KS2, Upper KS2 and Lower KS2

Whole KS2: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	108	51	159
Q2	105	52	157
Q3	101	51	152
Q4	96	46	142
Q5	94	32	126
Q6	76	17	93
Q7	54	15	69
Q8	30	9	39
Q9	10	1	11
Q10	6	1	7
Q11	2	0	2
Q12	0	1	1
	682	276	958

Whole KS2 Males: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual	Explanatory	Science Questions
Q1	53	24	77
Q2	52	22	74
Q3	47	26	73
Q4	45	21	66
Q5	39	14	53
Q6	27	12	39
Q7	24	6	30
Q8	11	3	14
Q9	1	0	1
Q10	0	0	0
Q11	0	0	0
Q12	0	0	0
	299	128	427

Whole KS2 Females: Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	55	27	82
Q2	53	30	83
Q3	54	25	79
Q4	51	25	76
Q5	55	18	73
Q6	49	5	54
Q7	30	9	39
Q8	19	6	25
Q9	9	1	10
Q10	6	1	7
Q11	2	0	2
Q12	0	1	1
	383	148	531

Upper KS2: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual	Explanatory	Science Questions
Q1	55	29	84
Q2	59	24	83
Q3	53	26	79
Q4	53	24	77
Q5	59	10	69
Q6	46	8	54
Q7	29	7	36
Q8	17	5	22
Q9	3	0	3
Q10	2	0	2
Q11	1	0	1
Q12	0	1	1
	377	134	511

Table 8.60 UKS2 Males: Number and Patterns of Factual and Explanatory Questions

Question Number	Factual Questions	Explanatory Questions	Science Questions
Q1	22	5	27
Q2	14	13	27
Q3	14	8	22
Q4	14	3	17
Q5	5	2	7
Q6	2	0	2
Q7	0	1	1
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	71	32	103

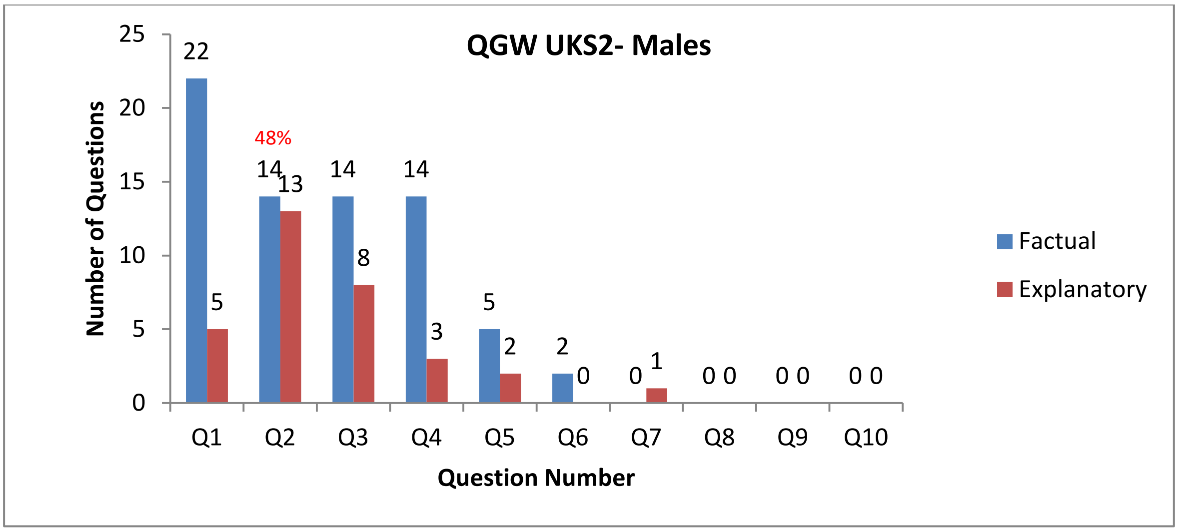

Figure 9.33 Upper KS2 Males: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

Upper KS2 Females: Number and Patterns of Factual and Explanatory Questions

Questions Number	Factual Questions	Explanatory Questions	Science Questions
Q1	21	8	29
Q2	17	12	29
Q3	17	9	26
Q4	12	11	23
Q5	11	4	15
Q6	5	2	7
Q7	2	2	4
Q8	2	0	2
Q9	2	0	2
Q10	1	0	1
	90	48	138

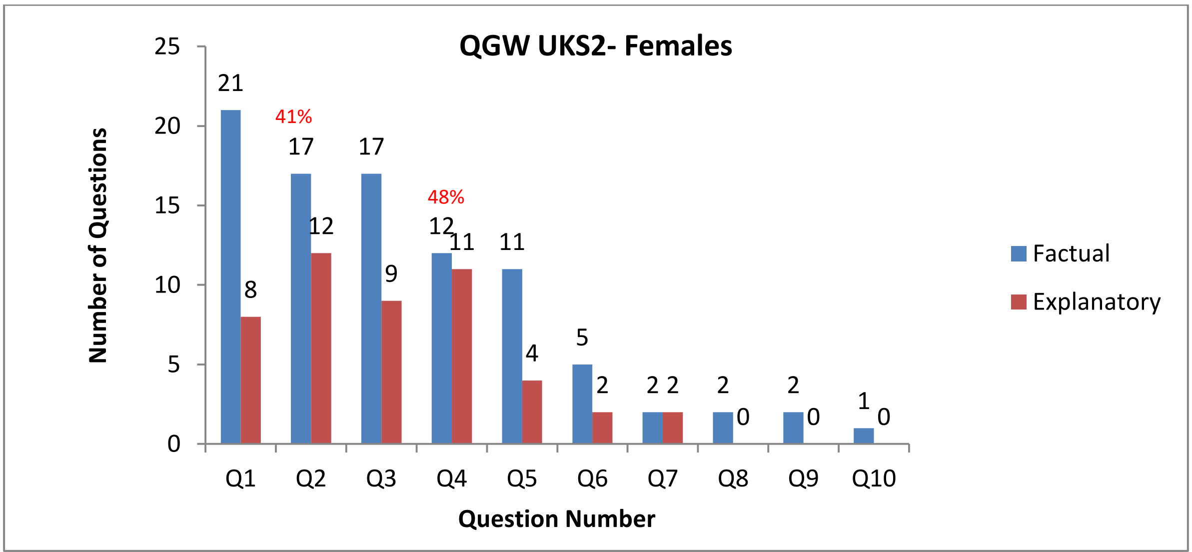

Figure 9.34 Upper KS2 Females: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

Lower KS2: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	53	22	75
Q2	46	28	74
Q3	48	25	73
Q4	43	22	65
Q5	35	22	57
Q6	30	9	39
Q7	25	8	33
Q8	13	4	17
Q9	7	1	8
Q10	4	1	5
Q11	1	0	1
Q12	0	0	0
	305	142	447

Lower KS2 Males: Number and Patterns of Factual and Explanatory Questions

Question Number	Factual Questions	Explanatory Questions	Science Questions
Q1	25	3	28
Q2	26	1	27
Q3	21	5	26
Q4	18	4	22
Q5	14	4	18
Q6	4	0	4
Q7	5	0	5
Q8	3	0	3
Q9	3	0	3
Q10	0	0	0
Q11	0	0	0
	119	17	136

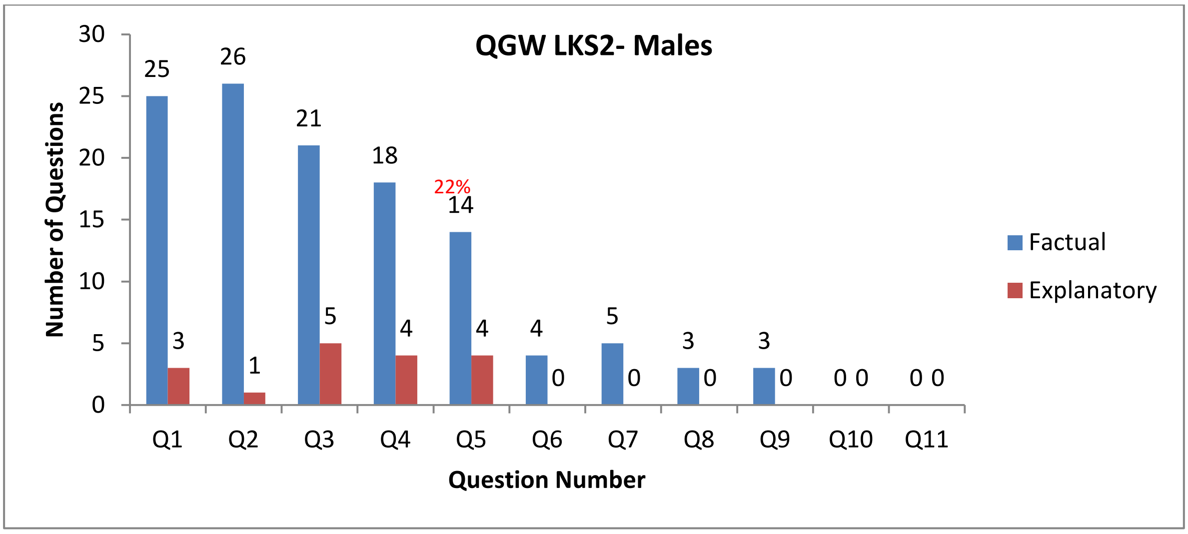

Figure 9.36 Lower KS2 Males: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

Lower KS2 Females: Number and Patterns of Factual and Explanatory Questions

Question Number	Factual Questions	Explanatory Questions	Science Questions
Q1	21	7	28
Q2	24	5	29
Q3	24	5	29
Q4	21	5	26
Q5	10	8	18
Q6	10	4	14
Q7	5	1	6
Q8	3	0	3
Q9	0	1	1
Q10	1	0	1
Q11	1	0	1
	120	36	156

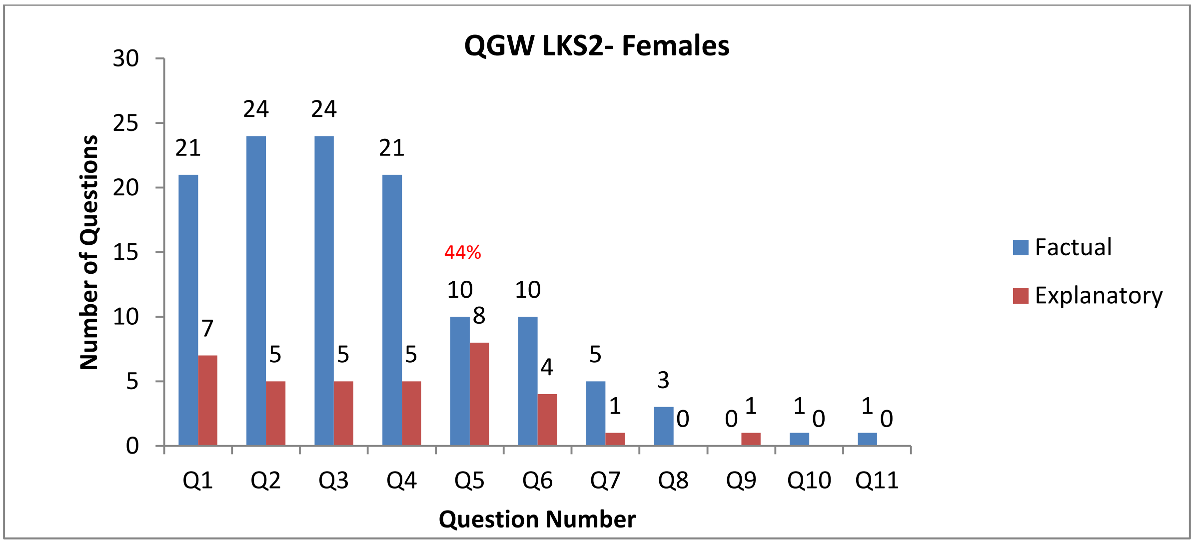

Figure 9.37 Lower KS2 Females: Number and Patterns of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

Analysis of the Pattern of Factual and Explanatory Questions Based on the Topics 'Eggs' and 'Bags'

Whole KS2'Eggs': Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	108	51	159
Q2	103	51	154
Q3	85	45	130
Q4	53	24	77
Q5	11	6	17
Q6	1	1	2
Q7	1	0	1
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
Q11	0	0	0
Q12	0	0	0
	362	178	540

Whole KS2 'Bags': Number and Patterns of Factual and Explanatory Questions

Questions	**Factual Questions**	**Explanatory Questions**	**Total Science Questions**
Q1	108	45	153
Q2	104	25	129
Q3	65	20	85
Q4	35	7	42
Q5	7	0	7
Q6	1	1	2
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	320	98	418

UpperKS2'Eggs': Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	55	29	84
Q2	57	23	80
Q3	44	23	67
Q4	29	12	41
Q5	4	2	6
Q6	0	0	0
Q7	1	0	1
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
Q11	0	0	0
Q12	0	0	0
	190	89	279

Upper KS2 'Bags': Number and Patterns of Factual and Explanatory Questions

Questions	**Factual Questions**	**Explanatory Questions**	**Science Questions**
Q1	65	18	83
Q2	60	12	72
Q3	40	9	49
Q4	19	5	24
Q5	3	0	3
Q6	0	1	1
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	187	45	232

Lower KS2 'Eggs': Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Total Science Questions
Q1	53	22	75
Q2	46	28	74
Q3	41	22	63
Q4	24	12	36
Q5	7	4	11
Q6	1	1	2
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
Q11	0	0	0
Q12	0	0	0
	172	89	261

Lower KS2 'Bags': Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Total Questions
Q1	43	27	70
Q2	44	13	57
Q3	25	10	36
Q4	15	2	18
Q5	4	0	4
Q6	1	0	1
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
Q11	0	0	0
	132	52	186

Strategy 4: Science Stories

Analysis of the Number and Pattern of Occurrence of Factual and Explanatory Questions

Whole KS2: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual	Explanatory	Science Questions
Q1	73	88	161
Q2	90	56	146
Q3	73	48	121
Q4	73	21	94
Q5	49	11	60
Q6	26	9	35
Q7	5	0	5
Q8	3	0	3
Q9	0	0	0
Q10	0	0	0
	392	233	625

Whole KS2 Males: Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	41	41	82
Q2	43	27	70
Q3	31	24	55
Q4	37	6	43
Q5	19	5	24
Q6	11	3	14
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	182	106	288

Whole KS2 Females: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	32	47	79
Q2	47	29	76
Q3	42	24	66
Q4	36	15	51
Q5	30	6	36
Q6	15	6	21
Q7	5	0	5
Q8	3	0	3
Q9	0	0	0
Q10	0	0	0
	210	127	337

Upper KS2: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	41	41	82
Q2	45	31	76
Q3	43	27	70
Q4	44	9	53
Q5	31	7	38
Q6	16	6	22
Q7	3	0	3
Q8	2	0	2
Q9	0	0	0
Q10	0	0	0
Q11	225	121	346

Upper KS2 Males: Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	24	18	42
Q2	22	13	35
Q3	19	14	33
Q4	23	2	25
Q5	12	4	16
Q6	6	3	9
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	106	54	160

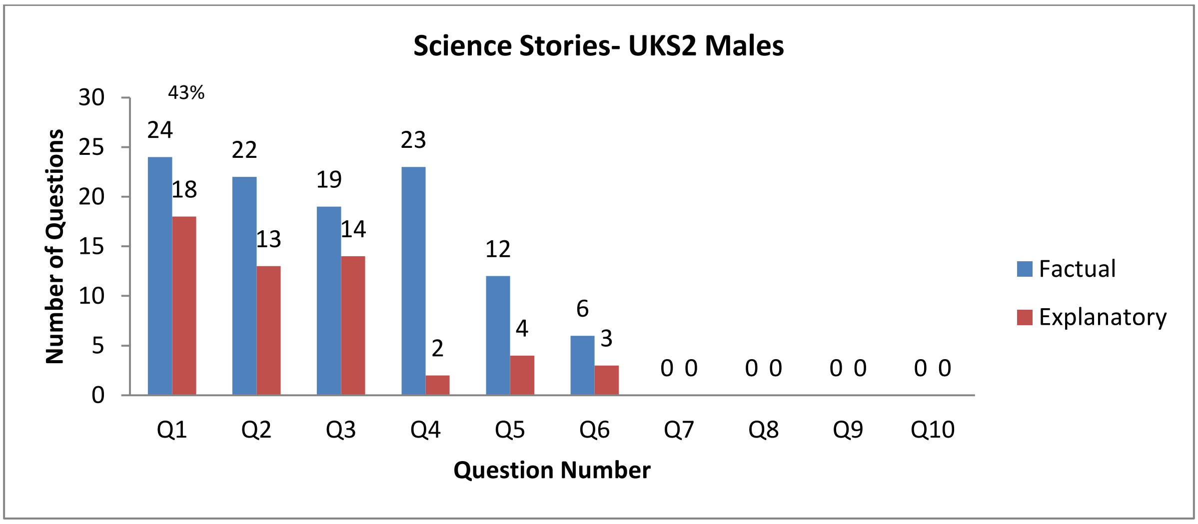

Figure 9.48 Upper KS2 Males: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

Upper KS2 Females: Number and Patterns of Occurrence of Factual and Explanatory Questions

Questions	Factual	Explanatory	Science Questions
Q1	17	23	40
Q2	23	18	41
Q3	24	13	37
Q4	21	7	28
Q5	19	3	22
Q6	10	3	13
Q7	3	0	3
Q8	2	0	2
Q9	0	0	0
Q10	0	0	0
	119	67	186

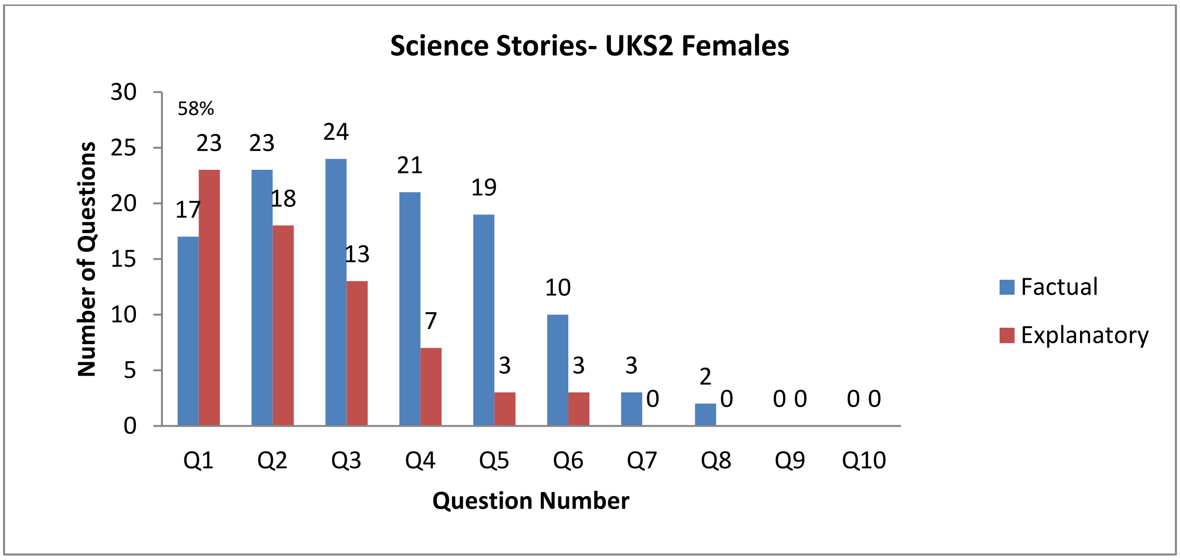

Figure 9.49 Upper KS2 Females- Females: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

Lower KS2: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual	Explanatory	Science Questions
Q1	32	47	79
Q2	45	25	70
Q3	30	21	51
Q4	29	12	41
Q5	18	4	22
Q6	10	3	13
Q7	2	0	2
Q8	1	0	1
Q9	0	0	0
Q10	0	0	0
Q11	167	112	279

Lower KS2Males: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual	Explanatory	Science Questions
Q1	17	23	40
Q2	21	14	35
Q3	12	10	22
Q4	14	4	18
Q5	7	1	8
Q6	5	0	5
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	76	52	128

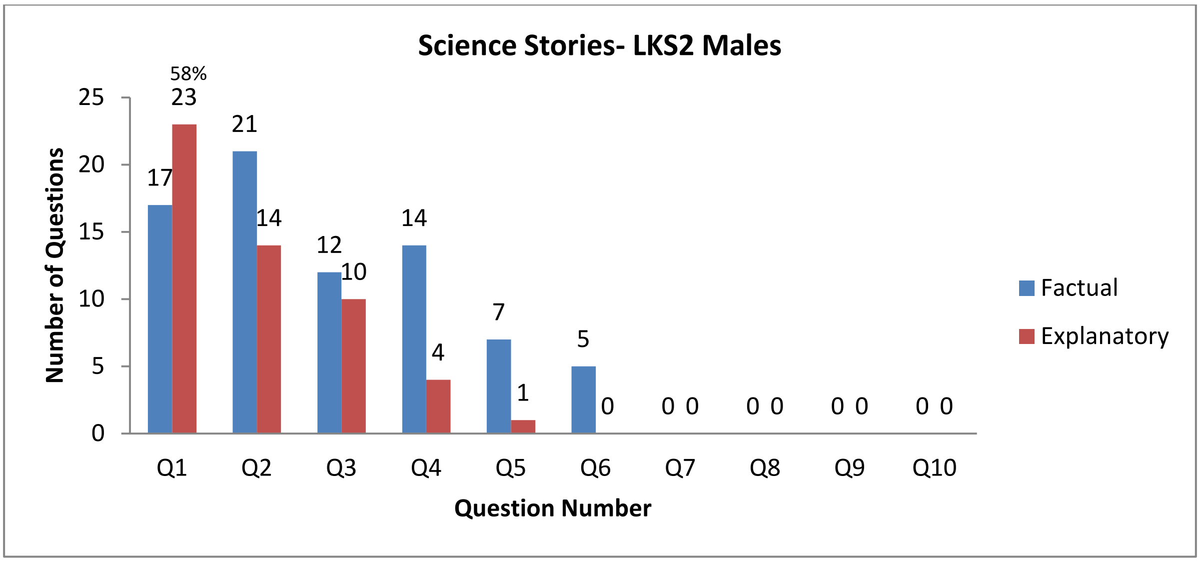

Figure 9.51 Lower KS2 Males: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of questions (both factual and explanatory questions.)

Lower KS2 Females: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual	Explanatory	Science Questions
Q1	15	24	39
Q2	24	11	35
Q3	18	11	29
Q4	15	8	23
Q5	11	3	14
Q6	5	3	8
Q7	2	0	2
Q8	1	0	1
Q9	0	0	0
Q10	0	0	0
	91	60	151

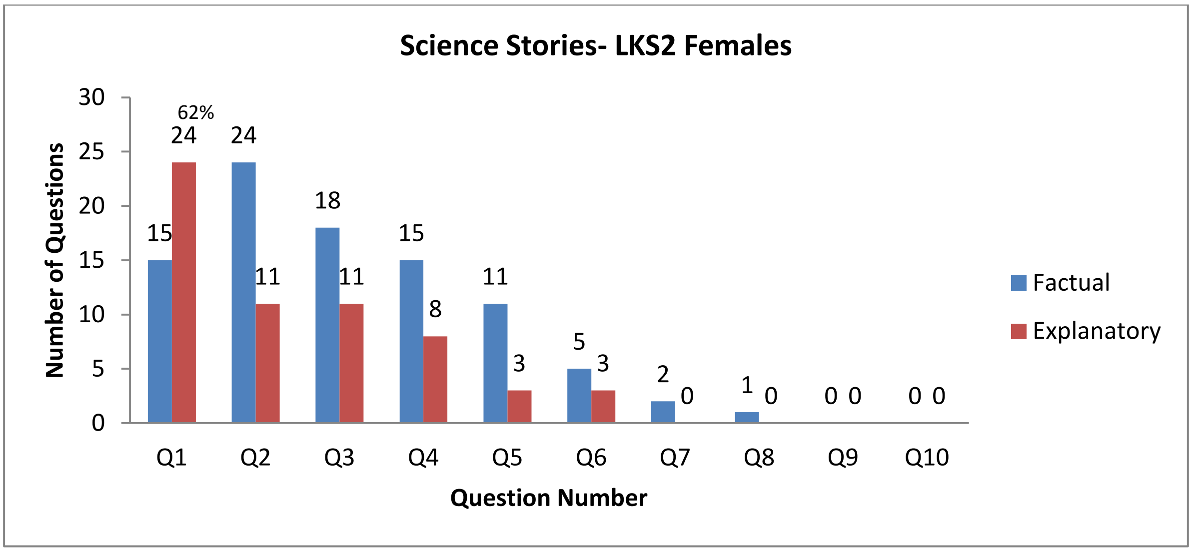

Figure 9.52 Lower KS2 Females: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

Analysis of the Number and Pattern of Occurrence of Factual and Explanatory Questions in the Whole KS2 Based on the Topics

Whole KS2Topic Eggs: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual	Explanatory	Total Eggs
Q1	123	38	161
Q2	69	23	92
Q3	40	10	50
Q4	5	0	5
Q5	0	0	0
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	237	71	308

Table Showing the Number and Pattern of Occurrence of Factual and Explanatory Questions in the Whole KS2 Based on the Bags Topic

Whole KS2 Bags: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual	Explanatory	Total Eggs
Q1	74	87	161
Q2	55	52	107
Q3	24	23	47
Q4	2	0	2
Q5	0	0	0
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	155	162	317

Upper KS2 Females: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	66	17	83
Q2	40	11	51
Q3	24	8	32
Q4	5	0	5
Q5	0	0	0
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	135	36	171

Upper KS2 Bags: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	42	41	83
Q2	32	30	62
Q3	14	14	28
Q4	2	0	2
Q5	0	0	0
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	90	85	175

Lower KS2Topic Eggs: Number and Pattern of Occurrence of Factual and Explanatory Question

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	57	21	78
Q2	29	12	41
Q3	16	2	18
Q4	0	0	0
Q5	0	0	0
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	102	35	137

Lower KS2 Bags: Number and Pattern of Occurrence of Factual and Explanatory Question

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	32	46	78
Q2	23	22	45
Q3	10	9	19
Q4	0	0	0
Q5	0	0	0
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	65	77	142

Strategy 5: Science Scenarios

Analysis of the Pattern of Factual and Explanatory Questions in the Whole KS2, Upper KS2 and Lower KS2

Whole KS2:Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	84	61	145
Q2	81	53	134
Q3	73	41	114
Q4	64	27	91
Q5	42	21	63
Q6	29	15	44
Q7	5	1	6
Q8	1	0	1
Q9	1	0	1
Q10	0	0	0
Q11	380	219	599

Whole KS2 Males: Number and Pattern of Occurrence of Factual and Explanatory Questions

Questions	Factual	Explanatory	Science Questions
Q1	45	26	71
Q2	45	25	70
Q3	43	16	59
Q4	29	16	45
Q5	21	10	31
Q6	13	6	19
Q7	2	1	3
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	198	100	298

Whole KS2 Females: Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	39	35	74
Q2	36	28	64
Q3	30	25	55
Q4	35	11	46
Q5	21	11	32
Q6	16	9	25
Q7	3	0	3
Q8	1	0	1
Q9	1	0	1
Q10	0	0	0
	182	119	301

Upper KS2: Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	45	31	76
Q2	42	27	69
Q3	36	23	59
Q4	33	17	50
Q5	25	10	35
Q6	14	7	21
Q7	2	1	3
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
Q11	197	116	313

Upper KS2 Males: Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	25	13	38
Q2	27	9	36
Q3	22	10	32
Q4	15	10	25
Q5	11	6	17
Q6	7	2	9
Q7	0	1	1
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	107	51	158

Table 8.117 Upper KS2Females: Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	20	18	38
Q2	15	18	33
Q3	14	13	27
Q4	18	7	25
Q5	14	4	18
Q6	7	5	12
Q7	2	0	2
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	90	65	155

Lower KS2:Number and Patterns of Factual and Explanatory Questions

Questions	Factual	Explanatory	Science Questions
Q1	39	30	69
Q2	39	26	65
Q3	37	18	55
Q4	31	10	41
Q5	17	11	28
Q6	15	8	23
Q7	3	0	3
Q8	1	0	1
Q9	1	0	1
Q10	0	0	0
	183	103	286

Lower KS2 Males: Number and Patterns of Factual and Explanatory Questions

Questions	Factual	Explanatory	Science Questions
Q1	20	13	33
Q2	18	16	34
Q3	21	6	27
Q4	14	6	20
Q5	10	4	14
Q6	6	4	10
Q7	2	0	2
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	91	49	140

Lower KS2 Females: Number and Patterns of Factual and Explanatory Questions

Questions	Factual	Explanatory Questions	Science Questions
Q1	19	17	36
Q2	21	10	31
Q3	16	12	28
Q4	17	4	21
Q5	7	7	14
Q6	9	4	13
Q7	1	0	1
Q8	1	0	1
Q9	1	0	1
Q10	0	0	0
	92	54	146

Analysis of the Pattern of Factual and Explanatory Questions Based on the Topics 'Chick Embryo' and 'Cow Bag'

Whole KS2 Chick Embryo: Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	83	61	144
Q2	71	44	115
Q3	52	26	78
Q4	16	3	19
Q5	0	1	1
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	222	135	357

Whole KS2 Cow Bag: Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	89	48	137
Q2	50	23	73
Q3	19	13	32
Q4	0	0	0
Q5	0	0	0
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	158	84	242

Upper KS2 Chick Embryo: Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	44	31	75
Q2	36	22	58
Q3	27	12	39
Q4	7	2	9
Q5	0	1	1
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	114	68	182

Upper KS2 Cow Bag: Number and Patterns of Factual and Explanatory Questions

Questions	Factual	Explanatory	Total Bags
Q1	47	28	75
Q2	27	12	39
Q3	9	8	17
Q4	0	0	0
Q5	0	0	0
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	83	48	131

Lower KS2 Chick Embryo: Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	39	30	69
Q2	35	22	57
Q3	25	14	39
Q4	9	1	10
Q5	0	0	0
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	108	67	175

LowerKS2CowBag: Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	42	21	63
Q2	23	11	34
Q3	10	4	14
Q4	0	0	0
Q5	0	0	0
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
Q9	0	0	0
Q10	0	0	0
	75	36	111

Strategy 6:'I Wonder' Board

Analysis of the Number and Patterns of Factual and Explanatory Questions in the Whole KS2, Upper KS2 and Lower KS2

Whole KS2: Number and Patterns of Science Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	55	23	78
Q2	38	24	62
Q3	20	8	28
Q4	7	5	12
Q5	5	2	7
Q6	4	0	4
Q7	1	1	2
Q8	1	0	1
	131	63	194

Whole KS2 Males:Number and Pattern of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	22	7	29
Q2	16	7	23
Q3	6	1	7
Q4	2	0	2
Q5	1	1	2
Q6	1	0	1
Q7	0	0	0
Q8	0	0	0
	48	16	64

Whole KS2 Females: Number and Patterns of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	33	16	49
Q2	22	17	39
Q3	14	7	21
Q4	5	5	10
Q5	4	1	5
Q6	3	0	3
Q7	1	1	2
Q8	1	0	1
	83	47	130

Upper KS2: Number and Patterns of Factual and Explanatory Questions(Physical Science Topics)

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	30	6	36
Q2	20	8	28
Q3	10	1	11
Q4	2	2	4
Q5	2	1	3
Q6	2	0	2
Q7	1	0	1
	67	18	85

Upper KS2Males: Number and Pattern of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	12	1	13
Q2	9	2	11
Q3	2	0	2
Q4	0	0	0
Q5	0	0	0
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
	23	3	26

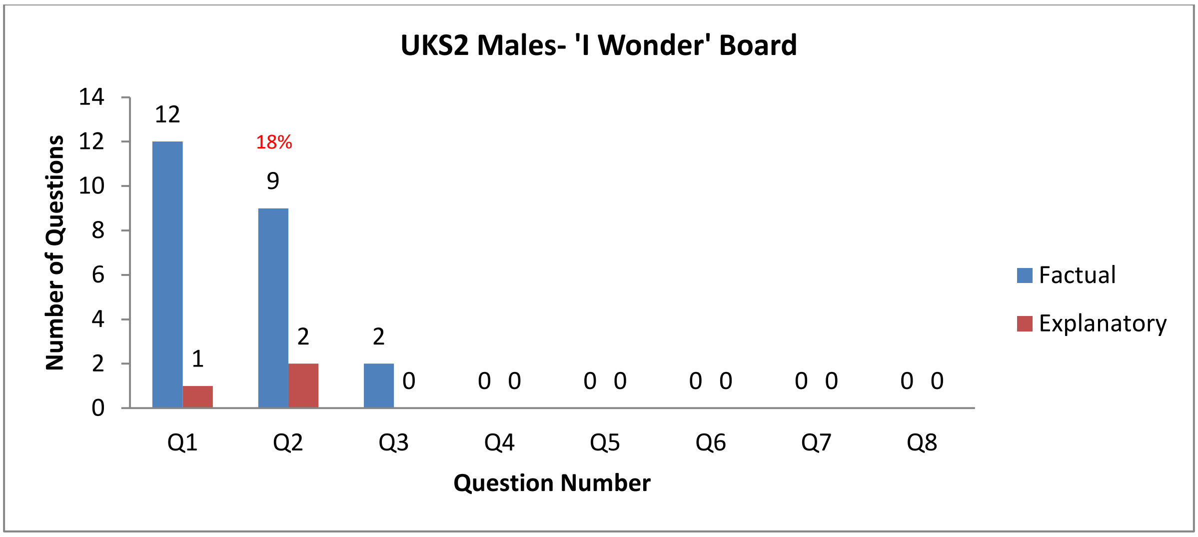

Figure 9.63 Upper KS2 Males- Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

Upper KS2 Females: Number and Pattern of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	18	5	23
Q2	11	6	17
Q3	8	1	9
Q4	2	2	4
Q5	2	1	3
Q6	2	0	2
Q7	1	0	1
Q8	0	0	0
	44	15	59

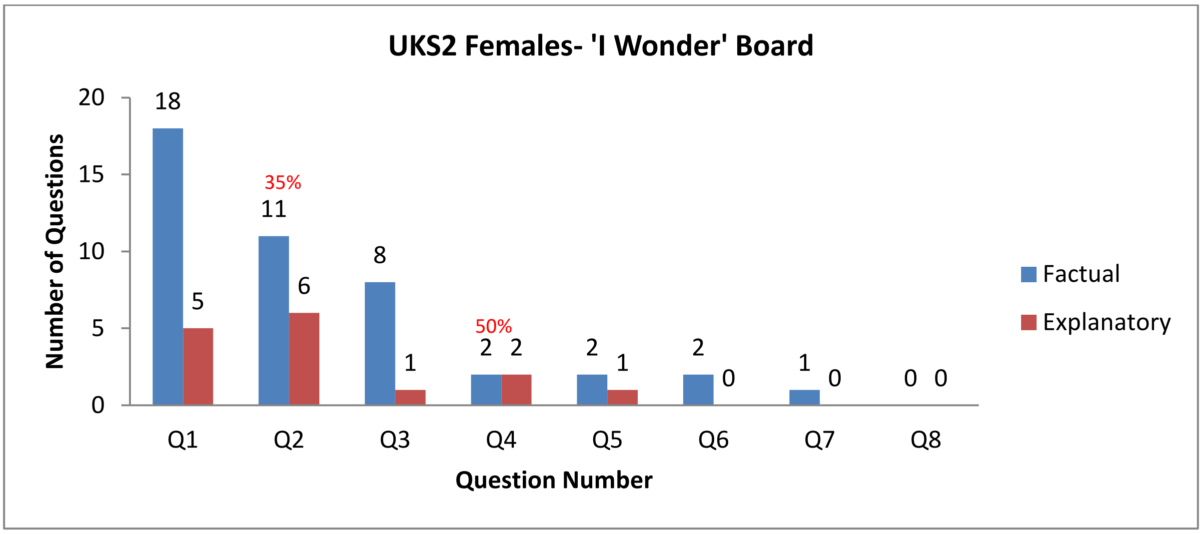

Figure 9.64 Upper KS2 Females- Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

Lower KS2: Number and Pattern of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	25	17	42
Q2	18	16	34
Q3	10	7	17
Q4	5	3	8
Q5	3	1	4
Q6	2	0	2
Q7	0	1	1
Q8	1	0	1
	64	45	109

Lower KS2 Males: Number and Pattern of Factual and Explanatory Questions

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	10	6	16
Q2	7	5	12
Q3	4	1	5
Q4	2	0	2
Q5	1	1	2
Q6	1	0	1
Q7	0	0	0
Q8	0	0	0
	25	13	38

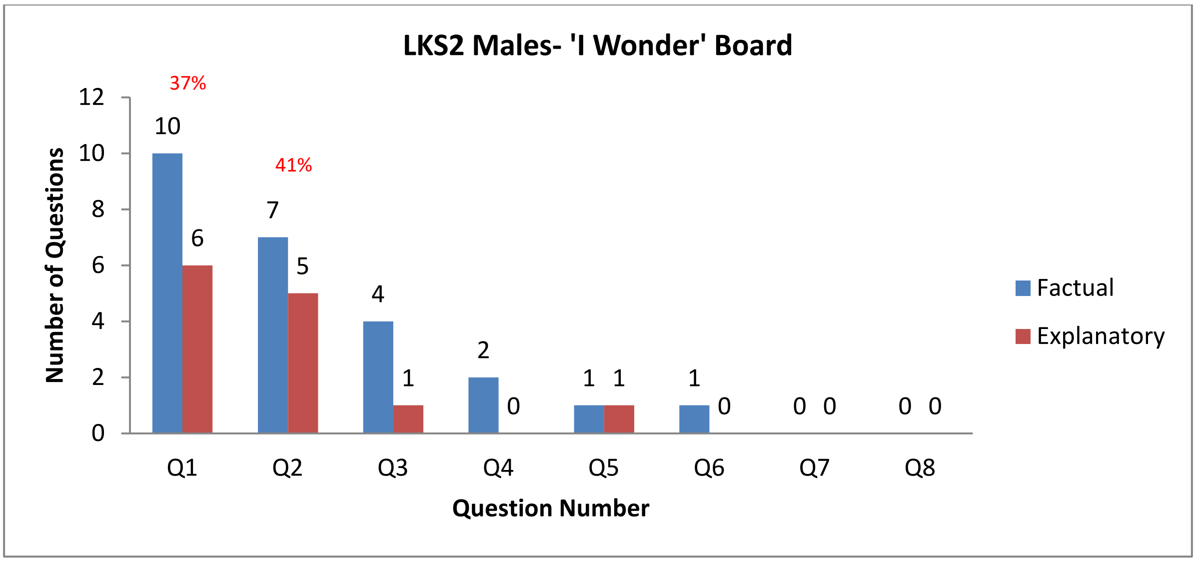

Figure 9.66 Lower KS2 Males- Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

Lower KS2 Females: Number and Patterns of Science Questions

Questions	Factual Questions	Explanatory Questions	Total Science Questions
Q1	15	11	26
Q2	11	11	22
Q3	6	6	12
Q4	3	3	6
Q5	2	0	2
Q6	1	0	1
Q7	0	1	1
Q8	1	0	1
	39	32	71

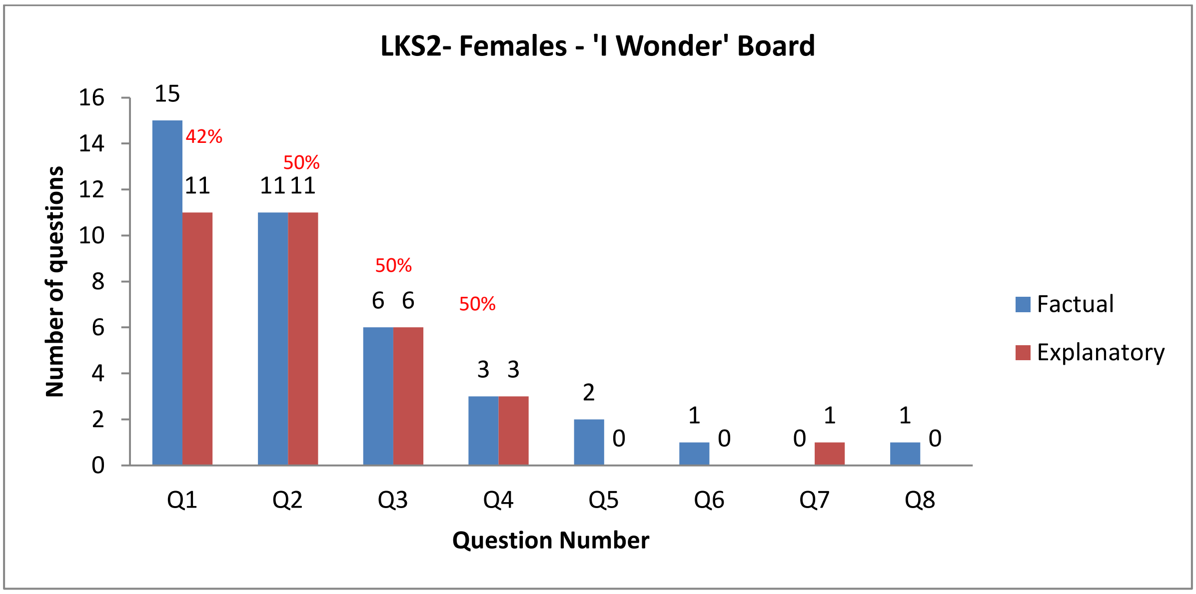

Figure 9.67 Lower KS2 Females: Number and Pattern of Factual and Explanatory Questions

(Percentages are calculated with respect to the number of explanatory questions to the total number of science questions (both factual and explanatory questions.)

Upper KS2: Number and Pattern of Factual and Explanatory Questions (Topic Earth & Space)

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	17	2	19
Q2	10	4	14
Q3	7	0	7
Q4	2	2	4
Q5	2	1	3
Q6	2	0	2
Q7	1	0	1
Q8	0	0	0
	41	9	50

Upper KS2: Number and Pattern of Factual and Explanatory Questions (Topic- Electricity)

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	13	4	17
Q2	10	4	14
Q3	3	1	4
Q4	0	0	0
Q5	0	0	0
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
	26	9	35

Lower KS2: Number and Pattern of Factual and Explanatory Questions (Topic Food Chain)

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	13	15	28
Q2	11	13	24
Q3	8	4	12
Q4	5	2	7
Q5	3	1	4
Q6	2	0	2
Q7	0	1	1
Q8	1	0	1
	43	36	79

Lower KS2: Number and Pattern of Factual and Explanatory Questions (Topic-Plants)

Questions	Factual Questions	Explanatory Questions	Science Questions
Q1	12	2	14
Q2	7	3	10
Q3	2	3	5
Q4	0	1	1
Q5	0	0	0
Q6	0	0	0
Q7	0	0	0
Q8	0	0	0
	21	9	30

Strategy 1: Question Starters on the Dice

RODIN analysis of questions under the whole KS2 based on the topic content

Whole KS2 Topics 'Eggs' and 'Bags': RODIN Analysis of Questions

Questions	R	O	D	I	N	Science Questions
Q1	66	0	0	32	1	99
Q2	71	0	0	44	0	115
Q3	53	8	0	58	2	121
Q4	30	4	0	90	5	129
Q5	39	2	0	75	0	116
Q6	33	2	0	32	0	67
Q7	1	0	0	6	0	7
Q8	1	0	0	2	0	3
Q9	1	0	0	0	0	1
Q10	0	0	0	0	0	0
	295	16	0	339	8	658

More Investigative and Research questions were generated from RODIN analysis of question starter strategy.

Whole KS2 Topic 'Eggs' RODIN Analysis of Questions

Questions	R	O	D	I	N	Science Questions
Q1	54	0	0	17	1	72
Q2	47	0	0	16	0	63
Q3	41	8	0	27	1	77
Q4	26	4	0	30	4	64
Q5	33	2	0	28	0	63
Q6	28	1	0	13	0	42
Q7	1	0	0	4	0	5
Q8	1	0	0	2	0	3
Q9	0	0	0	0	0	0
Q10	0	0	0	0	0	0
	231	15	0	137	6	389

More Investigative and Research questions were generated.

Whole KS2 'Bags': RODIN Analysis of Questions

Questions	R	O	D	I	N	Science Questions
Q1	12	0	0	15	0	27
Q2	24	0	0	28	0	52
Q3	13	0	0	32	1	46
Q4	4	0	0	60	1	65
Q5	6	0	0	47	0	53
Q6	5	1	0	19	0	25
Q7	0	0	0	2	0	2
Q8	0	0	0	0	0	0
Q9	1	0	0	0	0	1
Q10	0	0	0	0	0	0
	65	1	0	203	2	271

More Investigative and Research questions were generated in all the above RODIN tables. Both the Eggs and Bags topics produced more Research questions as well as Investigative questions. Providing question starters can generate different types of questions.

Strategy 2 Elephant Strategy: RODIN Analysis

Whole KS2:.RODIN Analysis of the Questions (Elephant in the Wild, Captivity, and Embryo combined)

Topics	R	O	D	I	N	Science Questions
Q1	109	0	0	0	3	112
Q2	109	0	0	0	3	112
Q3	100	0	0	0	3	103
Q4	86	0	0	0	2	88
Q5	57	0	0	0	1	58
Q6	25	0	0	0	2	27
Q7	14	0	0	0	2	16
Q8	8	0	0	0	0	8
Q9	5	0	0	0	1	6
Q10	2	0	0	0	0	2
Q11	1	0	0	0	0	1
	516	0	0	0	17	533

(Research, Observation, Demonstration, Investigation and None of these)

Whole KS2: RODIN Analysis of the Questions ('Elephant in Captivity')

Topics	R	O	D	I	N	Science Questions
Q1	38	0	0	0	0	38
Q2	39	0	0	0	0	39
Q3	35	0	0	0	0	35
Q4	28	0	0	0	0	28
Q5	20	0	0	0	0	20
Q6	12	0	0	0	0	12
Q7	10	0	0	0	0	10
Q8	5	0	0	0	0	5
Q9	4	0	0	0	0	4
Q10	2	0	0	0	0	2
Q11	1	0	0	0	0	1
	194	0	0	0	0	194

(Research, Observation, Demonstration, Investigation and None of these)

Whole KS2: RODIN Analysis of the Questions ('Elephant in the Wild')

Topics	**R**	**O**	**D**	**I**	**N**	**Science Questions**
Q1	37	0	0	0	0	37
Q2	37	0	0	0	0	37
Q3	36	0	0	0	0	36
Q4	31	0	0	0	1	32
Q5	22	0	0	0	0	22
Q6	6	0	0	0	0	6
Q7	3	0	0	0	0	3
Q8	1	0	0	0	0	1
Q9	0	0	0	0	1	1
Q10	0	0	0	0	0	0
Q11	0	0	0	0	0	0
	173	0	0	0	2	175

(Research, Observation, Demonstration, Investigation and None of these)

Whole KS2: RODIN Analysis of the Questions ('Elephant Embryo in the Womb')

Topics	**R**	**O**	**D**	**I**	**N**	**Science Questions**
Q1	34	0	0	0	3	37
Q2	33	0	0	0	3	36
Q3	29	0	0	0	3	32
Q4	27	0	0	0	1	28
Q5	15	0	0	0	1	16
Q6	7	0	0	0	2	9
Q7	1	0	0	0	2	3
Q8	2	0	0	0	0	2
Q9	1	0	0	0	0	1
Q10	0	0	0	0	0	0
Q11	0	0	0	0	0	0
	149	0	0	0	15	164

(Research, Observation, Demonstration, Investigation and None of these)

Most of the questions generated were Research questions which could be answered through more reading and research.

Strategy3: Question Generation Workshop Using Real Eggs & Bags: RODIN Analysis

RODIN Analysis of the Questions in the Whole KS2 (Eggs and Bags combined)

Questions	R	O	D	I	N	Science Questions
Q1	144	2	0	11	2	159
Q2	147	0	2	8	0	157
Q3	134	2	0	16	0	152
Q4	121	0	1	20	0	142
Q5	96	0	0	28	2	126
Q6	72	2	0	17	2	93
Q7	55	0	0	14	0	69
Q8	33	0	0	6	0	39
Q9	8	1	0	2	0	11
Q10	5	0	0	2	0	7
Q11	2	0	0	0	0	2
Q12	1	0	0	0	0	1
	818	7	3	124	6	958

(RODIN: Research, Observation, Demonstration, Investigation and None of these)

From RODIN analysis it was observed that majority (85%) of the science questions generated were research questions (researching books, news papers and other online resources, videos etc). Some (13%) of the questions were investigative questions that could be answered through classroom investigations. A few questions that could lend to observations and classroom demonstrations were there.

RODIN Analysis of the Questions in the Whole KS2 (Eggs)

Questions	R	O	D	I	N	Science Questions
Q1	144	2	0	11	2	159
Q2	145	0	2	7	0	154
Q3	116	2	0	12	0	130
Q4	69	0	1	7	0	77
Q5	14	0	0	3	0	17
Q6	2	0	0	0	0	2
Q7	1	0	0	0	0	1
Q8	0	0	0	0	0	0
Q9	0	0	0	0	0	0
Q10	0	0	0	0	0	0
Q11	0	0	0	0	0	0
Q12	0	0	0	0	0	0
	491	4	3	40	2	540

(RODIN: Research, Observation, Demonstration, Investigation and None of these)

RODIN Analysis of the Questions in the Whole KS2 (Bags)

Questions	R	O	D	I	N	Science Questions
Q1	118	0	0	33	2	153
Q2	98	2	0	28	1	129
Q3	68	0	0	16	1	85
Q4	36	1	0	5	0	42
Q5	5	0	0	2	0	7
Q6	2	0	0	0	0	2
Q7	0	0	0	0	0	0
Q8	0	0	0	0	0	0
Q9	0	0	0	0	0	0
Q10	0	0	0	0	0	0
Q11	0	0	0	0	0	0
Q12	0	0	0	0	0	0
	327	3	0	84	4	418

(RODIN: Research, Observation, Demonstration, Investigation and None of these)

From separate RODIN analysis of Eggs and Bags data, it was observed that majority of the science questions generated were research questions and some investigative questions were there.

Strategy 4: Science Stories RODIN Analysis

RODIN Analysis of the Questions in the Whole KS2 (Double Yolk Story & Foraging Cow Story)

Questions	R	O	D	I	N	Science Questions
Q1	159	0	0	0	2	161
Q2	140	0	0	0	6	146
Q3	121	0	0	0	0	121
Q4	92	0	0	0	2	94
Q5	60	0	0	0	0	60
Q6	33	0	0	0	2	35
Q7	4	0	0	0	1	5
Q8	3	0	0	0	0	3
Q9	0	0	0	0	0	0
Q10	0	0	0	0	0	0
	612	0	0	0	13	625

(RODIN: Research, Observation, Demonstration, Investigation and None of these)

RODIN Analysis of the Questions Whole KS2- Double Yolk Story

Questions	R	O	D	I	N	Science Questions
Q1	6	0	0	0	0	6
Q2	39	0	0	0	0	39
Q3	72	0	0	0	0	72
Q4	88	0	0	0	2	90
Q5	59	0	0	0	0	59
Q6	32	0	0	0	2	34
Q7	4	0	0	0	1	5
Q8	3	0	0	0	0	3
Q9	0	0	0	0	0	0
Q10	0	0	0	0	0	0
Q11	0	0	0	0	0	0
Q12	0	0	0	0	0	0
	303	0	0	0	5	308

(Percentages are calculated with respect to the number of questions in each category to the total number of science questions (both factual and explanatory questions).

RODIN Analysis of the Questions Whole KS2-Foraging Cow Story

Questions	R	O	D	I	N (SQ)	Total Science Questions
Q1	153	0	0	0	2	155
Q2	101	0	0	0	6	107
Q3	49	0	0	0	0	49
Q4	4	0	0	0	0	4
Q5	1	0	0	0	0	1
Q6	1	0	0	0	0	1
Q7	0	0	0	0	0	0
Q8	0	0	0	0	0	0
Q9	0	0	0	0	0	0
Q10	0	0	0	0	0	0
Q11	0	0	0	0	0	0
Q12	0	0	0	0	0	0
	309	0	0	0	8	317

(Percentages are calculated with respect to the number of questions in each category to the total number of science questions (both factual and explanatory questions.)

Majority of the questions generated by the 'Foraging Cow' topic were research questions that could be answered through researching by reading books, online resources etc. When separate RODIN analysis was conducted for 'Double Yolk' and 'Foraging Cow' topics, it was seen that the 'Double Yolk' topic generated around fifty percent (50%) of the science questions while the rest (50%) were generated by the 'Foraging Cow' topic. Majority of the questions generated by the 'Double Yolk' scenario were Research questions that could be answered by research.

Strategy 6:'I Wonder' Board/ Folder: RODIN Analysis

Whole KS2:RODIN Analysis of Science Questions (Food Chain, Plants, Earth and Space, Electricity combined)

Questions	R	O	D	I	N	Science Questions
Q1	73	3	0	0	2	78
Q2	57	2	0	3	0	62
Q3	28	0	0	0	0	28
Q4	12	0	0	0	0	12
Q5	7	0	0	0	0	7
Q6	3	1	0	0	0	4
Q7	2	0	0	0	0	2
Q8	1	0	0	0	0	1
Q9	0	0	0	0	0	0
	183	6	0	3	2	194

(RODIN Research, Observation, Demonstration, Investigations and None)

It was found that majority of the science questions generated by students were research questions.

Lower KS2:RODIN Analysis of Science Questions (Topic Food Chain)

Questions	R	O	D	I	N	Science Questions
Q1	26	1	0	0	1	28
Q2	24	0	0	0	0	24
Q3	12	0	0	0	0	12
Q4	7	0	0	0	0	7
Q5	4	0	0	0	0	4
Q6	1	1	0	0	0	2
Q7	1	0	0	0	0	1
Q8	1	0	0	0	0	1
Q9	0	0	0	0	0	0
	76	2	0	0	1	79

(RODIN Research, Observation, Demonstration, Investigations and None)

Lower KS2:RODIN Analysis of Science questions (Topic Plants)

Questions	**R**	**O**	**D**	**I**	**N**	**Science Questions**
Q1	11	2		0	1	14
Q2	7	2	0	1	0	10
Q3	5	0	0	0	0	5
Q4	1	0	0	0	0	1
Q5	0	0	0	0	0	0
Q6	0	0	0	0	0	0
Q7	0	0	0	0	0	0
Q8	0	0	0	0	0	0
Q9	0	0	0	0	0	0
	24	4	0	1	1	30

(RODIN Research, Observation, Demonstration, Investigations and None)

Upper KS2:RODIN Analysis of of Science questions (Topic Earth and Space)

Questions	R	O	D	I	N	Science Questions
Q1	19	0	0	0	0	19
Q2	14	0	0	0	0	14
Q3	7	0	0	0	0	7
Q4	4	0	0	0	0	4
Q5	3	0	0	0	0	3
Q6	2	0	0	0	0	2
Q7	1	0	0	0	0	1
Q8	0	0	0	0	0	0
Q9	0	0	0	0	0	0
	50	0	0	0	0	50

(RODIN Research, Observation, Demonstration, Investigations and None)

Upper KS2:RODIN Analysis of Science Questions (Topic-Electricity)

Questions	R	O	D	I	N	Science Questions
Q1	17	0	0	0	0	17
Q2	12	0	0	2	0	14
Q3	4	0	0	0	0	4
Q4	0	0	0	0	0	0
Q5	0	0	0	0	0	0
Q6	0	0	0	0	0	0
Q7	0	0	0	0	0	0
Q8	0	0	0	0	0	0
Q9	0	0	0	0	0	0
	33	0	0	2	0	35

(RODIN Research, Observation, Demonstration, Investigations and None)

From the RODIN analysis it was observed that majority (93%) of the science questions generated were research (R) questions that could be answered through research.

12.16 APPENDIX 7a CPD with Comments from Teachers

CPD Package

Can we Generate a CPD Package for Teachers to Engage Children in Question Asking for Problem Finding in Science?

Introduction

This chapter discusses the findings from the research questions of this study leading to the development of a CPD package (strategies)for engaging children in question asking for finding problems in science to solve. It presents some of findings obtained from the student teachers' and teachers' questionnaire survey, classroom observations and content analysis of text materials' conducted as part of this study, as they show evidence that there is a lack of clear understanding of what constitutes creative thinking in science and different ways to encourage it. Some of the relevant comments made by the student teachers and teachers have been copied under each section. This is also supported by relevant literature which includes some recent literature showing the need for a CPD. A short section on the main purpose of the present study and the main findings from the strategy trials with children constitutes the main content of the CPD. A description on the CPD workshops conducted with student teachers and teachers and their feedback on the CPD leading to its refinement forms the rest of the chapter with a summary at the end.

Why there is a need for a CPD to encourage children's question asking for problem finding and creative thinking in science?

- **Findings from the Student Teachers' Questionnaire Survey**

A questionnaire survey was conducted at the start of this study to understand primary teachers, both student and in-service teachers' of notions of creative thinking in science. Insights from the student teachers' survey show that they perceive practical fact-finding problem solving tasks, conducting experiments or tests to confirm children's ideas about the world and the application of scientific knowledge in real life as examples of scientific creative thinking. A study by Newton & Newton (2009) found similar narrow conceptions of scientific creativity among student teachers, focussing on fact finding practical investigations and application of scientific knowledge to solve practical problems. They also cautioned that student teachers may leave out important opportunities for encouraging creative thinking through the generation of explanations, an important aspect to consider when planning training programs for student teachers (Newton & Newton, 2009). Similar findings were reported by a recent study by Alsahou (Alsahou, 2015).

Student teachers' comments from the survey:

'Insulation, Children design jackets to keep a frozen water bottle warm. See which materials best insulate it.'

'Investigating a range of materials to identify which ones float.'

'Flowers (parts, seeds, pollination, germination etc)- It helps students to have a beautiful garden in their home.'

Some student teachers viewed lessons involving hands-on reproductive tasks like model making and non-scientific creative activities like teaching using a story or a poem as encouraging scientific creativity, confirming findings of Newton & Newton, (Newton & Newton, 2009b).They suggested these activities were more to do with creative teaching (teacher's creativity, not learner's) than teaching for creativity in science(Newton & Newton, 2009b). This shows some student teachers hold misconceptions about creativity in science.

Student teachers' comments:

'Digestion in Human beings-Creative part: Preparation of model of digestive system, innovative chart on the topic,'

'Using a story book such as hungry caterpillar to introduce life cycles'

Most of the student teachers reported that they don't encourage problem finding but they will try, in future. Majority of the participants saw problem finding as related to creative thinking because one should think creatively to discover problem situations. Some commented that

problem finding encourages deep learning, seek new information and applies it to investigate and solve problems and promotes critical thinking and student engagement.
Student teachers' comments:
'Again thinking flexibly- creatively will help discover situations.'
'Because creative thinking helps to identify problems'
'Problem finding will help the students to think creatively and critically. It help them to develop a scientific attitude.'
'Pupils try to collect new information and apply that.'
Majority of the student teachers suggested problem finding is hard because:

- it depends on child factors like ability to think independently, prior knowledge and understanding, individual differences and interest,
- subject knowledge and resourcefulness of the teacher,
- factual nature of science
- misconceptions, and
- the pressure to meet curriculum targets.

Student teachers' comments:
'Requires a deeper level of thinking'
'It takes lot of time for students to understand certain topics in depth. Problem finding starts only when they try to find answers for questions, why, how etc.'
'Every individual may not be interested.'
'Both finding out the problem and finding out the solution to the problem are difficult tasks for a teacher. A teacher should posses good sub knowledge.'
'There are often misconceptions in science.'
'It can appear daunting but does make science real.'

- **Findings from Teachers' Questionnaire Survey and Classroom Observations**

Findings from primary teachers' survey also show teachers tendency to associate practical problem solving involving designing and carrying out a test to get information and application of scientific ideas to construct a working model or solve a problem as incidents of creative thinking. They do not seem to identify generation of explanations as encouraging scientific creative thought. This may be due to their narrow conceptions of creative thought in science. Newton and Newton also confirmed teachers' tendency to favour fact-seeking practical work and the application of facts to solve practical problems as opportunities for scientific creativity neglecting opportunities to be creative in the hypothesis space (Newton & Newton, 2010b). Similar findings were noticed during the classroom observations of teachers' teaching science. Though teachers asked 'why?' or 'what if?' questions which prompt children's generation of tentative explanations, there were not many. This may not be the case with experienced, passionate science teachers with science specialisation. These findings may not be generalised due to the small sample size.
Teachers' comments:
'*Waterproof materials - Which material would be best to make a boat that would get the gingerbread man to the other side of the river safely?'*
'Children were using various types of exercise to measure their pulse rates. They were able to identify that exercise increased pulse rates which was beneficial to the body.'
'Using electric circuits to create a board game.'
'During a topic on the Water Cycle children had a range of activities to work through.'
Some teachers tend to possess a narrow artistic view of creativity and saw reproductive making activities (making models using junk) and non-scientific creative teaching of the science concepts using drama or role play, reciting, writing etc as incidents of scientific creativity. This supports the findings of Newton & Newton (2010b). Similar art-based view among teachers was reported by other studies especially in the West (Cachia & Ferrari, 2010; Bereczki & Karpati, 2018).
Teachers' comments:

'Human digestion- children made a junk model of the human body, involving all major organs involved in digestion.'
'Topic: Sound, We learnt actions to understand the process of hearing sound. We recited these as a whole class. Then, we extended pupils' learning by listening to different well known songs and writing what the song was called. Pupils had to describe the sound and explain how they could hear it.'
'Cities in the country.' (Writing about an imaginative city- creative writing)
Most participant teachers saw problem finding as related to creative thinking because children have to think creatively to find problems, children are active, engaged and interested when thinking about problems, posing problems, exploring and finding answers to them makes learning active and child led.
Teachers' comments:
'One needs to think out of the box to go beyond what already exits. Therefore finding a problem with existent information requires creativity.'
'Thinking creatively around an idea should raise questions and therefore how to answer the questions.'
'I feel it is. they topics can then be child initiated and led.'
'It involves an active learning process and enables pupils to explore and find an answer to problems posed.'
Majority of the teachers in the survey reported problem finding was hard because:

- it is harder to set the stage to find questions,
- time and topic constraints,
- pressure on teachers,
- difficulty to access resource and funding,
- large class size with no support,
- need for teacher prompts or scaffolds,
- lack of assessment on areas like creative thinking and problem finding,
- it depends on child factors like ability to think independently, prior knowledge, observation skill, perseverance etc,
- difficulty to access equipments and facilities for encouraging problem finding.

Teachers' comments:
'As I teach the curriculum, it can be more about teaching each topic, than spending time looking at different areas that aren't assessed.'
'It's harder to set the stage for them to find it for themselves.'
'Having the resources and space can make it difficult.'
'It requires the children to be independent learners and to think for themselves. This is a skill some children have and others do not.'
'Some children find it difficult to grasp- don't have the knowledge and understanding.'
'With a large class and often no support, it is hard to give time and space to creative thinking with such a pressured and full curriculum.'
'Contextual. Time is a problem. Not tried it. Some of them would be able to do it. May need guidance & help from the teacher.'
From the survey, it is clear that, most pre-service and in-service teachers favour fact-seeking practical work and the application of facts to solve practical problems as opportunities for scientific creativity ignoring opportunities to be creative through the generation of explanations (Newton & Newton, 2009;Newton & Newton, 2010b). Though teachers gave opportunity to generate explanations by asking 'Why?' questions, there were not many. They mostly associated creativity with investigative and problem solving tasks. Some student teachers and teachers tend to hold narrow artistic view of creativity in science (Newton & Newton, 2009b; 2010b, Cachia & Ferrari, 2010; Bereczki & Karpati, 2018). Policy expectations (Craft et al., 2015), lack of time (Craft, et al., 2015; Sternberg, 2015; Alsahou, 2015; Alsahou, H.J. & Alsammari, A.S., 2019; Bereczki, E. O. & Karpati, A., 2018), lack of training and adequate resources, overloaded curriculum, standardised tests and problems with assessing creativity seemed to be the main

barriers in promoting creativity in education (Sternberg, 2015 in Bereczki, E. O. & Karpati, A., 2018; Bereczki, E. O. & Karpati, A., 2018).Pre-service teachers also viewed lack of time and efforts as the most common barriers towards encouraging creativity (Alsahou, 2015, Alsahou, H.J. & Alsammari, A.S., 2019). Bereczki & Karpati (2018) reviewed several studies on teachers' conceptions of creativity stated that, though many teachers believe that they are capable of encouraging creativity and perceive themselves as doing it, the data from several studies show an incongruence between teachers' beliefs and their classroom practices, suggesting, the fostering of creativity in the classroom is questionable. Teachers' misconceptions about creativity and in-sufficient knowledge on ways of fostering creativity in the classroom, manifested in their teaching practices make the implementation of creativity, highly unlikely (Bereczki & Karpati, 2018). In the present study, though most student teachers and teachers saw problem finding as related to creativity, they think encouraging problem find is hard. Though, teachers sometimes allow children to ask questions, they limit questioning opportunities to a small number of children and they don't follow up those questions or use them as starters for further investigations or research.

- **Findings from the Content Analysis of Text Materials (Text Books, Schemes of Work, Online Text Materials)**

Creative thinking opportunities identified in texts were mostly those asking children to plan and carry out a practical investigation to find reliable factual information promoting creativity in the experiment space. Opportunities for creative thinking through the generation of tentative explanations (within the hypothesis space)and the testing of a tentative explanations (within the experimental space) were rare (Newton & Newton, 2010b). Some questions like 'In what way do you think walking on the Moon would be different from walking on the Earth?' prompt children to use scientific information to imagine situations. They could act as good starting points for further creative thinking through teachers' wise use of questions, especially higher-order 'Why..?' and 'What happens if...?'questions. This depends on how teachers use these questions to scaffold children's thinking which may also stem from their notions of scientific creative thinking. A recent study by Biggers (2018) points to the teacher-directed nature of the investigation questions in the existing science curriculum materials and the need for training teachers on strategies for adapting the teacher-directed questions in a way to allow students more opportunities to raise questions (Biggers, 2018).With limited opportunities for creative thought in the text materials and lack of direction for teachers for promoting it, there is an urgent need for a CPD to support teachers. Above all, text materials didn't seem to provide children opportunities for generating their own questions or problems in science.

Strategies to Engage Primary School Children in Question Asking for Problem Finding to Encourage Creative Thinking in Science

Encouraging creative thinking is considered as the general function of education (NACCE, 1999) and one of the aims under the national curriculum of England (1999). Creative thinking is more likely to be seen as problem solving in science, mathematics and technology (Newton, 2010). A scientific problem takes shape as a puzzling event or observation that requires an explanation. In science, creative thinking is encouraged in the hypothesis space, when a child constructs plausible explanations. When a child, with teacher's support designs a method or a practical way to test these potential explanations, it promotes creative thinking in the experimental space (Newton, 2010; Newton, 2012a).

Generally, teachers and text materials provide questions or problems for children to solve. Alternatively, if children can notice or find a scientific problem to solve themselves in the classroom, there is opportunity for a fuller experience of the scientific creative process, and the potential for stimulating interest, motivation and engagement in satisfying the child's curiosity (Jarman, 1991; Ryan & Deci, 2002; LaBanca, 2012). Therefore, the study explored various ways of stimulating primary school children to ask questions in science. The strategies trialled show that children can ask science questions but questioning which reflects interest and curiosity was found to be complex, involving construction and articulation of descriptive and causal mental models of situations. When teaching something new, the children need to construct a descriptive mental model, and their questions reflect this constructive process and lead questioning. Such questions provide a basis for children to engage in research. To develop a causal mental model, questions must lead to explanations. Such questions may have the potential to support hypothesis construction and testing in the classroom encouraging creative thinking in the hypothesis space. Several factors especially the situation or the stimulus, the teaching and learning environment, and the attributes of the child influence and order the process. It requires time to generate questions that could lead to scientific enquiry and it needs teaching skill to provide effective opportunities for children to raise questions and help them frame them into a suitable form to make them more suitable for further research and investigation. This also highlights the need to ensure that the teachers, both student teachers as well as those in service are equipped with these skills. Teachers may also need to be aware of various strategies for stimulating question asking, their strengths and weaknesses. Therefore, CPD opportunities for teachers, both in-service and student teachers should be offered.

CPD Package for Teachers to Engage Primary School Children in Question Asking for Problem Finding in Science

Several studies acknowledge the need to provide training for primary teachers on encouraging questioning (Woodward, 1992; Cochran & Reinsvold, 2011; Biggers, 2018, Bereczki & Karpati, 2018). Teachers expressed that they had not thought clearly about opportunities for creative thinking in science (Craft, et al., 2015).Bereczki & Karpati, (2018) argued that if teachers have access to courses on creativity and ways of nurturing it, they will develop improved notions leading to more creativity-fostering practices in schools. Understanding subject-specific conceptions of creativity and generating more awareness on pedagogical practices promoting creativity across different subjects in the curriculum and at different education levels are some of the important areas where teachers need more support (Bereczki, E. O. & Karpati, A., 2018). This could be attained by allowing access to initial and in-service teacher training programs on encouraging creativity and development of resources and materials for teachers to promote creativity, specifically strategies, activities, materials and examples of promoting creativity informed by field research and providing access to them (Bereczki, E. O. & Karpati, A., 2018).

With the aim of developing a training program (CPD) for primary teachers and student teachers to engage children in question asking for problem finding in science, the researcher designed an interactive workshop. The researcher then worked with the student teachers to explore what they think about and how they would respond to the CPD. The researcher was also supported by the lecturer in charge who gave valuable suggestions for making the CPD more hands-on and engaging for student teachers. The researcher initially introduced the strategies and the theory behind the making and trialling of them. Due to time limit student teachers were divided into five groups and each group tried 5 different strategies arranged on their tables. This was followed by a question asking and discussion activity where one student from each group shared their experience of the particular strategy he/ she did and students from the other groups asked questions and clarified their doubts. The researcher also shared how the children responded to each strategy and the challenges faced during the trials. Student teachers responded positively and some expressed their difficulty to think and generate questions. As student teachers were put in the same position as children, I feel, they could better relate to how a child would feel when asked to generate questions in science. An outline of the CPD session and the feedback received from the student teachers are copied below.

10.5 Outline of the CPD Session

Talk, Argumentation and Question Asking in Primary School Science (Workshop for Student Teachers (PGCE) at Durham university - Session Plan)
Topic: **Engaging Children in Question Asking for Creative Thinking in Science (Strategies)**

- 10:00 -10:20 Introduction, Presentation (Power Point Slides) (15 min)
- 10:20 - 10:40 -Activity Strategies for Problem Finding (15 min (question generation activity, group discussion)5 different activities on 5 tables (5 -7 minutes) -Different on each table. Asked to observe, read and write some science questions on those topics. Worksheets were provided. Place the worksheets in the clear folder on each table after writing. Tables: (1X6 students) (5 strategies on 5 tables/ batch)(1. Eggs (1folder with worksheets) 2. Bags, 3. Question Dice with Question Starters 4. Science scenarios/ Science Stories, 5. Elephant strategy)
- 10:40-10:50 (Questions & Discussion)(10 min)
- 10:50-11:00: Evaluation Form filling (Also, students can have a look around to see all the 5 artefacts/ strategies used and disperse-10 min) (30 forms/ batch) (Last 5 minutes-Time to arrange tables and worksheets for the next session)

Feedback from student teachers on the CPD Workshop
1. Which part (s) did you enjoy most?
'Having real objects'
'Stimulating activities to inspire questions from kids'
'diff ways of presenting issues to pupils'
2. Which part did you learn most from?
'scenarios and science stories from real life'
'photos to generate questions'
'review of 5 activities'
'q starters - dice'
'idea of asking kids to make own questions'
3. What did you find most difficult or challenging?
'Thinking of questions like a child'
'thinking of what children would want to know'
'thinking of questions without prompts'
4. If I was to do this again, what should I add/remove/change?
'how to adapt this for ks1'
'explore all strategies -chance to try all
'more ethics based questions'
'how to link this to diff science topics?'
5. What did you learn?
'using real objects effective'
'How range of strategies opens up world of questions'
'adult questions are not very different from childrens''
'questions, real objects and photos are better'

Slight modifications were made in the CPD based on the feedback obtained from the student teachers. The researcher then worked with teachers in a primary school (that participated in the study) to explore their views and responses to the CPD package. Due the time constraint the researcher gave a power point presentation and a question answer and discussion session afterwards. Since most of the strategies were trialled in the school, most of the teachers who attended the session especially those in key stage 2, had viewed them. Some of the comments from the teachers and the head teacher are copied below.

Feedback from the teachers on the CPD Workshop
1. Which part (s) did you enjoy most?
'Various strategies for developing questions'
'Hearing the work after what had gone at school'
'Egg & Bag ideas'
2. Which part did you learn most from?
'stories/ dice'
'Practical ways to encourage questioning'
3. What did you find most difficult or challenging?
'Separating theories'
'Need to consider allowing time for questioning'
4. If I was to do this again, what should I add/remove/change?
'Too many graphs'
'Perhaps summarise findings to make implications for teachers clearer'
5. What did you learn?
'Great strategies for encouraging good questions'
'Importance of real life objects'
'About how to facilitate question asking in school'

The CPD was refined considering the feedback obtained from the teachers. A summary slide was added with main implications for teachers at the end. Teachers were more interested in hearing about the practical implications in the classroom. They expressed that it helped them to think about what they are doing in the classroom and why finding time for encouraging children's question asking is essential. Cochran & Reinsvold reported that teachers are asking for information on types of open-ended questions and specific contexts where these questions can be asked but it is not being supplied (Cochran & Reinsvold, 2011). Biggers (2018) argues there more research should be carried out on the development of curriculum materials and in-service training sessions to help teachers to gradually move across the continuum of teacher-directed to student-directed investigation questions in science. Teachers should be equipped with skills to support children to find problems and solve those (Biggers, 2018). Another recent study argues that teachers need support to align student questioning to curricular goals (Stokhof et al., 2017). There is a lot to be done to stimulate children to think and generate their own questions and teachers have to develop skills to support children. In the present scenario, a CPD for pre-service and in-service teachers on encouraging question asking would be timely. The CPD generated as an outcome of this study provides a mental model which explains the process of questioning, factors influencing questioning- especially the situation or stimulus, the teaching learning environment, and the child factors and strategies to encourage children's question asking. Due to the self-funded nature of the study, time limit, difficulty in accessing schools and teachers due to their workload and commitments, the CPD was trialled only in one primary school.

Conclusion

This chapter discusses the answer to the last research question of this study, ' Can we develop a CPD package for teachers to engage primary school children in question asking for problem finding in science?' The chapter presents some of findings from the student teachers' and teachers' survey, classroom observations and textual analysis that led to the development and trialling of strategies to encourage children's question asking for problem finding. Also includes the insights obtained from the strategy trials with children in the form of a CPD workshop supported by relevant literature. The outline of the CPD workshop presented to student teachers and in-service teachers, their feedback leading to the refinement of the CPD forms the main content of the chapter.

12.17 APPENDIX 8a: A copy of the published journal article generated from the study

Appendix8ajournalarticle2018.pdf

13 Bibliography and References

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