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An exploration of inquiry based science education in Irish primary schools

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UNIVERSITY of LIMERICK

OLLSCOIL LUIMNIGH

**An Exploration of Inquiry Based Science
Education in Irish Primary Schools**

By

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Submitted for the degree of
Doctor of Philosophy

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Abstract

This thesis is concerned with exploring the state of primary science education in Ireland, with a particular focus on devising a developmental framework and a form of an intervention for supporting the promotion of the ideals of inquiry in science teaching and learning in primary schools. Current research shows that primary science education in Ireland and internationally is facing major issues relating to teacher confidence, teacher pedagogies and teacher content knowledge. In Ireland, this has resulted in a situation where primary school teachers appear to be avoiding science teaching. This investigation, therefore, explores the concept of Inquiry Based Science Education (IBSE) and its application to primary science education, with the aim of demonstrating the positive impact of IBSE on teaching. To achieve this, this research carried out a contextual analysis and an analysis of professional practice of Irish science education. These studies were then synthesised into the development of a form of teaching intervention which promoted the structures, processes and ideals of IBSE. These studies included a critical review and evaluation of current research on primary science education, teacher education and teacher resources, with a specific focus on the Irish system. Within this research, a number of observations of current teacher practices were carried out to discover whether IBSE is present in Irish primary schools. Synthesising these findings, a form of intervention was developed. This intervention consisted of an online learning environment designed to provide teachers with guidance and resources on how to plan and deliver IBSE lessons at primary education level. An evaluation of the impact of this intervention was carried out, with the help of a number of practising and pre-service primary science teachers, via feedback, observations and a Pedagogical Content Knowledge (PCK) analysis. The intervention was found to have a positive impact on the practice of teaching, held in high regard by the participant teachers and have a positive effect on the Pedagogical Content Knowledge of pre-service teachers.

Declaration

I hereby declare that all work detailed in this thesis is my own. All use of other research and material throughout this thesis has been clearly cited and referenced.

Signed _____

Jonathan Dunne, University of Limerick

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List of Abbreviations

CoRes	Content Representations
DES	Department of Education and Science (Ireland)
D.o.E	Department of Enterprise (Ireland)
IASSEE	Irish Association for Social, Scientific and Environmental Education
IBL	Inquiry Based Learning
IBSE	Inquiry Based Science Education
ICT	Information and Communication Technology
INTO	Irish National Teacher Organisation
NCCA	National Council for Curriculum and Assessment
PaP-ERs	Pedagogical and Practice Experience Repertoires
PCK	Pedagogical Content Knowledge
PD	Professional Development
SESE	Social, Environmental and Science Education

Chapter 1: Introduction

Science education enhances children's knowledge and understanding of themselves and the world in which they live

(Department of Education and Skills (DES.) 1999, P3)

This chapter provides an overview of the current situation and recent developments in primary level science education in Ireland. The chapter begins with a brief history of primary school curriculum development in Ireland. This sets the context of this research, whereby a detailed description of the project's aim, objectives and research questions is presented. The chapter concludes with an outline of the organisation of this thesis.

1.1: Curriculum Development in Ireland

Education in Ireland¹ is divided into three stages, Primary, Secondary and Tertiary or Higher education. Primary and Secondary education are mandatory in Ireland and consist of eight and six years respectively. Students are typically aged between five and twelve in Primary Education. Within second level there are two official department examinations, the Junior and Leaving Certificate, carried out in 3rd and 6th years respectively. Tertiary education is optional and follows secondary level education. Science education was formally introduced into the primary school curriculum in Ireland in 1999 (DES, 1999a). The subject of science was added as part of the redevelopment of the 1971 primary school curriculum and assigned a role within Social, Environmental and Science Education (SESE) (DES, 1999a). This new subject grouped Science, History and Geography under a single heading and aimed to highlight various crossover topics between the three subjects. Before the introduction of the new curriculum, science was not considered a subject under the national curriculum. Teachers generally taught nature studies with little or no emphasis on the

¹ The context of this research refers to the Republic of Ireland. Whenever referring to the Republic of Ireland the words "Irish" or "Ireland" are used. Whenever Northern Ireland is meant it will be explained in the text.

physical sciences (Walsh, 2004). The 1999 curriculum was created based on the belief that science and technology can play vital roles in the holistic development of the student by developing an understanding of the physical universe, developing scientific methods of investigation and developing positive attitudes towards science (DES, 1999, 1999a).

Only four primary school curricula have been developed and implemented in Ireland since 1900. These curricula were introduced in 1900, 1922, 1971 and 1999. The pre-1971 curricula concentrated on cultural reform and the students' needs, interests and abilities were given a low regard (Walsh, 2004). In 1971 a new curriculum was developed which would place more emphasis on an integrated curriculum and the needs of the student. This curriculum was designed to be centred around the student and

Was designed to facilitate the full and harmonious development of the child, with inherent flexibility to adapt to the needs and abilities of the individual child

(Walsh, 2004, p.7)

In the 1990s the curriculum was once again re-examined which resulted in the 1999 curriculum. This curriculum became mandatory for schools in 2003 (DES, 1999, 1999a). The curriculum is divided into four main strand units; Living Things, Energy and Forces, Properties and Characteristics of Materials and finally Environmental Awareness and Care (DES, 1999). The 1999 curriculum recognises how every student is an individual learner and how different students can learn in different ways by promoting varied teaching pedagogies (DES, 1999, 1999a). It allows the teacher to accommodate student interests and prior knowledge. It is designed to be cyclical in nature by allowing the teacher to revisit previously taught subjects in order to build upon prior learning, to address misunderstandings and to reinforce knowledge and understanding. The current curriculum acknowledges the importance of science and the impact it has on social and economic life, as well as the role it has in the daily lives of students (Varley et al., 2008a). Student's own experiences can be built on within the classroom and used to provide opportunities to investigate a subject with particular attention on student reflection and assessment. Encompassed within the curriculum is a particular emphasis on skills development. The skills that students

develop in their primary education are given as much importance as the content knowledge of the subject. The 1999 curriculum also promotes proper lesson planning in an effort to develop better lessons, which are tailor-made to the individual teacher's classroom context. It can be argued that the curriculum embraces the ideals of inquiry²; however the practical implementation and realisation of these ideals may not have been entirely successful (DES, 1999, 1999a, Varley et al., 2008a, 2013).

1.2: Research Context

The 1999 curriculum promotes Inquiry Based Learning (IBL) based on constructivist ideology which is in-line with international best practice in science education (DES, 1999, 1999a). IBL has become the focus in literature examining the reform of education (Abell 2008, Anderson, 2002, Darling-Hammond, 2008, Rocard et al., 2007). Darling-Hammond argues that IBL is based on the principles of teaching for effective learning, which encompass identifying prior knowledge, knowledge organisation and utilising students' understanding of their learning style (metacognition) (Darling-Hammond, 2008). Inquiry based methodologies have been shown to aid the development of cognitive skills and to aid student learning and understanding (Anderson, 2002, Bybee 2006, Rocard et al., 2007). In relation to this research, science has been identified as a subject that can lend itself easily to the practice of inquiry (Darling-Hammond, 2008, Rocard et al. 2007, Varley et al., 2008a, 2008b). A recent review of science education in Europe highlighted the need to implement more inquiry based learning, in order to endeavour to improve both the teaching and learning of the subject (Rocard et al., 2007).

European initiatives, such as those described in the Rocard et al. report, combined with the explicit inclusion of science in the Irish 1999 primary curriculum, actively seek to address falling retention rates in science in Secondary and Tertiary education (Department of Enterprise, 2006, Rocard et al. 2007). The Irish science curriculum

² It must be noted that the studies researched as part of this thesis may use the spelling "enquiry" instead of inquiry. For consistency this spelling will be changed if the enquiry described meets the description and description of inquiry as proposed by this research.

intends for students to experience science in a way that gives students a clear knowledge of genuine methods of scientific investigation employed by professional scientists, and thus promote the epistemology of science (Enfield, 2000, Roth 1995). The introduction of the new curriculum was accompanied by reform in teacher education colleges, as well as in-service education to practicing teachers, many of whom had never received any formal training in science education (Varley et al., 2008a, 2008b).

Coinciding with the development of the Irish curriculum, England and Wales both completed reforms of their science curricula, being published in 1999 and 2000, respectively (Varley et al., 2008a). In 2007, results from a survey carried out across the UK highlighted how half of the teachers surveyed did not feel they had the ability to teach primary school science. This was linked with a lack of teacher confidence in the subject (Murphy et al., 2007). The Rocard et al. report also expands the context of research into Europe and found that lessons were still being taught with traditional didactic methodologies as opposed to constructivist ones (Rocard et al., 2007). In order to assess the impact of the Irish curriculum, a longitudinal study was carried out on primary science education by the National Council for Curriculum Assessment (NCCA) between 2003 and 2008. This study consisted of a two-phase approach, with each published in separate reports (Varley et al., 2008a, 2008b). Phase 1 collected data from current primary education students regarding their experiences and perceptions of science. Phase 2 surveyed Secondary students, to assess their thoughts on the primary school science curriculum. The study highlighted several key findings both positive and negative, both of which will be discussed throughout this research. Utilising the same results of the NCCA report, expanding the subjects across SESE, the Irish Association for Social, Scientific and Environmental Education (IASSEE) published a report examining cross-border (Republic of Ireland and Northern Ireland) pre-service student teachers' perceptions and experiences of History, Geography and Science (Waldron et al., 2009).

The NCCA and IASSEE studies highlighted that, in general, primary school students enjoy and are enthusiastic about studying science (Varley et al., 2008a, 2008b, 2013, Waldron et al., 2009). Positive student experiences were particularly linked with the use of Information and Communications Technology (ICT) and the study of science

outside of the classroom (ibid). Students were also found to have positive attitudes towards the use of hands-on activities, such as experiments and investigations in the classroom. The primary concerns related to low teacher levels of science Pedagogical Content Knowledge (PCK), the employment of didactic teaching methodologies and low levels of teacher confidence and content knowledge in science (Waldron et al., 2009). Pedagogical Content Knowledge (PCK) is a specific knowledge an educator uses to provide teaching situations that help learners make sense of particular content and will be expanded in Chapter 2 (Loughran et al., 2000, 2001, Magnusson et al., 1999, Shulman 1986, 1987).

The NCCA study discovered that teachers tend to avoid teaching subject in the Energy and Forces, Characteristics of Materials and Environmental Awareness and Care curriculum strands (Varley et al., 2008). This is attributed to a lack of content knowledge or confidence in those subjects. This has resulted in teachers choosing to teach the subject they know most about, or are more confident teaching (Varley et al., 2008a, 2008b, 2013, Waldron et al., 2009,).

When describing pre-service primary science education in Ireland, a distinction must be made between pre- and post- introduction of the 1999 curriculum. Prior to the 1999 curriculum there was no formal science education curriculum in primary schools in Ireland. A study, published in 1987, identified that only 31% of the teachers surveyed carried out experiments with their students (Irish National Teachers Organisation, 1987 cited in Varley et al., 2008a). Pre-service education courses were also developed alongside the publication of the new curriculum. Pre-service teacher education in Ireland for primary school teachers is carried out in one of five institutions. These institutions are;

- The Church of Ireland College of Education, Dublin³
- Coláiste Mhuire, Marino Institute of Education, Dublin³
- Froebel College of Education, Dublin⁴
- Mary Immaculate College, Limerick
- St. Patricks College, Dublin

(DES, 2011)

³ Awarded by the University of Dublin, Trinity College

⁴ Awarded by the National University of Ireland, Maynooth

Teacher education in these colleges follows a three-year full time course, leading to a Bachelor of Education degree upon successful completion. The structure of the courses differs widely between the various colleges of education. These differences will be made explicit in Chapter 4.

With the introduction of the new science curriculum in 1999, practicing teachers were allocated three days in-service in science education. The content of in-service courses is not available to non-practicing teachers but two of the days were devoted to the subject of science and the third day was allocated to school planning (Varley et al., 2008a). There has been a total of 32 hours (4 days) science in-service provided by the DES since the introduction of the curriculum (ibid). Waldron et al. suggests that this in-service was insufficient for teachers, resulting in teachers with low confidence levels, low content knowledge and low pedagogical knowledge in science (Waldron et al., 2009). There are twenty-one education centres throughout Ireland who offer in-service courses for teachers (PPDS, 2009). The lack of accreditation for these courses, combined with the amount of different courses offered, highlights the lack of accountability regarding their usefulness in educating teachers to teach science. In brief, the current status of in-service science training can be described as uneven and therefore could contribute significantly to the low confidence levels of many teachers and the didactic methodologies employed in their classrooms (Varley et al., 2008a, 2013)

The Primary Professional Development Service was also created as a support service for primary school teachers (PPDS). This service supplies lesson plans, resources, information and advice for teachers across all of the subjects of the curriculum. Teachers can access any resources presented, print them and carry out the lesson as dictated by the cards if they wish. Other resources are disseminated by the private entity; Discovery Primary Science (DPS, 2012). As it is a private company the resources offered by it are generally aimed at promoting science rather than curriculum knowledge.

The use of textbooks in teaching also emerged as an issue from the NCCA study which described how 72% of responding teachers were still using textbooks in their

classrooms (NCCA, 2008a) even though the teacher guidelines state: “Science lessons should not be work card or textbook based” (DES, 1999a, p27, emphasis in original). The IASSEE report described how textbook based teaching was still dominant in SESE as a whole (Waldron et al. 2009). Textbooks in Ireland are not standardised and are based on the author’s interpretations of both the curriculum and teaching methodologies.

1.2.1: Research Context Conclusions

The introduction of the new curriculum in 1999 was designed to initiate a new era of science teaching in primary schools with more contemporary ideologies and methodologies being employed. However, a wide variance in pre-service education, a lack of in-service education and sparse support tools each with different approaches, aims and objectives, may have resulted in the issues that have been identified in the NCCA study (Varley et al., 2008a). The scenario is, therefore, that current primary school teachers in Ireland have experienced a different forms of education which has resulted in teachers lacking PCK in science, to the level where teachers have been found to be avoiding the teaching of science completely (ibid). The question that arises here is how to best address these issues and, hence, improve both the teaching and learning of science at primary education level in Ireland. According to the NCCA report, the main recommendation for challenging these issues revolves around teacher education (ibid). The report advocates professional development that should promote the use of inquiry based methodologies by teachers (Varley et al., 2008a). This is echoed in research on improving science education in Europe (Rocard et al., 2007). This research project therefore attempts to tackle the issues identified above by developing a teaching intervention that promotes and supports the use and application of inquiry in science teaching at primary level education in Ireland.

1.3: Research Aims and Objectives

The aim of this research is to characterise Inquiry Based Science Education and promote the use of IBSE through a form of intervention. This intervention will attempt to promote an inquiry-orientated approach to science teaching from the

practice of current teachers with a hope that it may be used to tackle the issues mentioned above.

To achieve this, a three-stage investigative approach has been developed. The first stage involves a literature review of science education and a contextual analysis of Irish science education. The second stage focuses on observing and identifying current practices and implementations of the new curriculum. The third stage involves synthesising what has been learned into a form of teaching intervention based on the findings of the first and second stages.

1.3.1: Stage 1: Contextual Analysis

Objective 1: Analyse the literature to determine best practice in epistemic approaches to primary science teaching, specifically concerning IBSE

Objective 1 is concerned with conducting a literature review on primary science education, both nationally and internationally, to identify current trends, issues and best practices. The literature review, presented in Chapter 2, will identify and describe why the methodology of IBSE was chosen as the best practice approach to science teaching.

Objective 2: Carry out a contextual exploration into current Irish primary school science

Objective 2 will be informed through four studies, the previously mentioned literature review, interviews with teacher educators, teacher education observations and a content analysis of textbooks.

1.3.2: Stage 2: Professional Practice

Objective 3: Identify elements of IBSE in Irish Primary Science Education through a 5E lens

This objective is concerned with identifying the implementation of the curriculum in Ireland. It will be informed through a series of observations aimed at discovering

IBSE in Irish classrooms. These observations will be guided by an analytical framework which has been developed to synthesise the literature on IBSE.

1.3.3: Stage 3: Synthesis

Objective 4: Devise a form of intervention to support and promote IBSE

Objective 4 is concerned with the design, development and evaluation of an intervention to support and promote IBSE. This intervention will be in the form of a learning environment and multimedia resources hosted on the internet. This intervention will be formed through a synthesis of all that has been learned from the previous objectives.

1.4: The Research Questions

The work presented in this thesis attempts to address three principal research questions in relation to the aims and objectives.

Question 1: Science Education

What is the nature of IBSE and how is primary science education practiced in Ireland?

This question will be answered through the literature review and observations of practice in Chapters 2 and 5 respectively. By reviewing literature, the nature of IBSE will be uncovered. This question includes an element of discovering the nature of the practice of science education Ireland. This practice will be determined through the observation of science lessons in the classroom and will determine whether teachers are carrying out IBSE and, if so, how they accomplish this.

Question 2: An Exploration into Irish Primary Science

What contextual factors play a role in Irish primary science which can affect the implementation of IBSE in the classroom?

The answer to this question will be developed through a contextual analysis of Irish primary science presented in Chapter 4. Different contextual factors will be used to develop ideas of IBSE use in pre-service education and the use of science textbooks.

Question 3: A synthesis of exploration

What kind of intervention can be synthesised to support and encourage the ideals of IBSE while accounting for the issues and factors in Irish primary science education?

Answering this question will focus on synthesising the previous research to develop an intervention, incorporating teaching guides and multimedia resources designed to support and promote IBSE and will be described in Chapter 6.

1.5: Thesis Outline

This thesis is divided into seven chapters. This chapter highlighted the background and context underpinning this research work, and provided details of the research questions to be addressed, and the aims and objectives that govern this research project. Chapter 2 will describe the literature review carried out, with particular focus on the subjects of educational change, PCK, constructivism and IBSE. Chapter 3 describes the research methodology employed in this project and references the exploratory nature of this work, as well as the case study approach that was taken. Chapter 4 details the contextual analysis of Irish primary science which consisted of a series of interviews with teacher-educators, observation of teacher education lectures and an analysis of current textbooks available to teachers. Chapter 5 describes the development and application of analytical framework of IBSE to a series of discovery observations of teachers practising science. Included in this chapter is a study which describes the PCK of the participant teachers in magnetism. Chapter 6 describes the development and impact of the intervention created as part of this research. Finally Chapter 7 provides a discussion and the conclusions that can be drawn from this

research. This chapter will conclude with a personal reflection of the research by the primary researcher.

Chapter 2: Literature Review

How do teachers decide what to teach, how to represent it, how to question students about it and how to deal with the problems of misunderstanding?

(Shulman, 1986, p.8)

As stated in the previous chapter, the aim of this research is to characterise Inquiry Based Science Education and promote the use of IBSE through a form of intervention. This chapter presents a literature review that accompanies this aim. This chapter will describe Constructivism, which is the basis of Inquiry Based Science Education (IBSE). This will be followed by a literature review of IBSE itself. The chapter will continue by considering educational change, acknowledging that any developmental process must recognise the cultural factors within which it operates. The concept of Pedagogical Content Knowledge (PCK) will then be discussed as a factor in the development of teacher education and analysis. Finally two case studies have been included which have similar objectives to this research but were carried out in different research contexts.

2.1: Constructivism

Across the broad fields of educational theory and research, constructivism has become something akin to a secular religion

(Phillips, D. C., 1995, p.5)

This section will examine the educational philosophy of constructivism as the underlying theory behind Inquiry Based Science Education (Darling-Hammod et al., 2005, Driver et al., 1996). Constructivism has been developed from interpretations of work as far back as Socrates (Matthews, 2003) and has become a "religion" (Phillips, 1995) of sorts within educational research. The vast wealth of publications and research on constructivism has divided the research community into "sects" (ibid) who argue about the interpretations, complexity, components, advantages and disadvantages of constructivism. Therefore, in order to better understand constructivism, the history of constructivism will first be considered.

2.1.1 What is Constructivism?

The advent of constructivism can be traced back to the works of Socrates, but it is only in the latter half of the twentieth century that it has gained momentum in the philosophy of learning (Harris, 1994, Matthews, 2003, O'Loughlin, 1992, Osborne, 1996, Kanuka and Anderson, 1998). Socrates described teaching practice as revolving around the idea of reducing knowledge "to order", through the use of questioning (Fenshaw et. al., 1994). This reductionist approach involves a student creating their own meaning from the information supplied to them (ibid). Indeed the interpretist description by Kroll and LaBoskey is described as a reductionist approach accompanied with empirical data (Kroll and LaBoskey, 1996). In the 18th Century, Vico is also associated with a reductionist approach believing that humans could only believe knowledge that is made true (Von Glasersfeld, 1984). It is generally accepted that the authors above are the fundamental authors of the philosophy of constructivism (Boudourides, 1998, Von Glasersfeld, 1984, Kanuka and Anderson, 1998, Matthews, 2003). However, as it will be described in Section 2.1.2, constructivism has a large research base which has developed many different interpretations, descriptions and ideas as to what constructivism is (Phillips, 2005). More modern interpretations of the constructivism pedagogy have been developed through two interpretations of constructivism developed by Piaget and Vygotsky (Osborne, 1996, Piaget, 1951, Staver, 1997, Vygotsky 1978).

Generally, the various sects of constructivism can be divided into two primary headings radical and social constructivism. The radical constructivist approach is based upon the work of Piaget and the Social Constructivist approach is based on the works of Vygotsky (O'Loughlin, 1992, Osborne, 1996, Rodriguez, 1998, Staver, 1997). Piaget developed the reductionist approach further into the constructivist theory, that learning is a dynamic process within the construction of knowledge (Matthews, 2003, Osborne, 1996, Piaget, 1951, Staver, 1997). Radical constructivism concludes that knowledge can only be developed if: the knowledge about the world is true, the person believes the knowledge and there is reasonable belief that the knowledge is true (ibid). The issue with this approach in constructivism lies in the bivalence principle, whereby knowledge can only be true or false. If any of these criteria is not met then the knowledge is false and cannot be considered learned (ibid). Highlighting the difficulties with constructivism is Kroll and LaBoskey, whose

theoretical constructivism mirrors the ideas presented within radical constructivism (Kroll and LaBoskey, 1996). This is also applicable to Moshman's endogenous constructivism (Moshman, 1982 cited in Harris, 1994). It is this type of multi-classification of similar constructs which lead to Phillips describing researchers as being placed into "sects" depending on what research you are basing your studies on (Phillips, 1995). The alternative to Radical or Theoretical constructivism is described as Social Constructivism.

It is accepted that Piaget neglected to include a social aspect to his constructivist theory (Kanuka and Anderson, 1998, Kroll and LaBoskey, 1996, Matthews, 2003, O'Loughlin, 1992, Osborne, 1996, Rodriguez, 1998, Staver, 1997). Vygotsky, on the other hand, emphasised the idea of how the culture and social contexts in which we develop, influence our learning. Vygotsky argued that intellectual growth happens twice for a child, firstly on a social level and then on a personal level, describing how the social aspect of development is crucial (Matthews, 2003, Vygotsky, 1978). This Social constructivism, or a more socio-cultural interpretation of constructivism, described how knowledge can be developed through social interaction and discourse (Driver et al., 1994, Osborne, 1996). This concept is also analogous to Moshman's exogenous constructivism (Moshman, 1982 cited in Harris, 1994). This method allows the learner to learn from their tutors or peers, or what Osborne describes as enculturation, where the learner becomes part of the culture of a subject (Osborne, 1996). This idea marries the context of a subject to the learning of that subject (ibid). Social constructivist pedagogy has been linked to science education as it can for the epistemology of science as well as the science content (ibid).

Interestingly Bruner (1961) expands both of these theories by describing the role of the teacher within a constructivist lesson. Bruner hypothesized that including the student in the learning process with the teacher would allow students to recall material more readily (ibid). This however could cause an issue with teachers who are not confident or competent in the subject to which they are trying to teach. Indeed if a teacher is to carry out a social constructivist approach it could be argued that the teacher must understand the epistemology of science. Therefore it could be argued that a social constructivist approach should be taken in teacher education in order to develop teachers who can effectively teach through a social constructivist method.

Goodson and Hargreaves (1996) argue that this form of social development could create professional teachers in science through shared communities and a culture of collaboration.

As one of the most contextually relevant papers, the Rocard report describes a constructivist as centring on the idea of student directed learning and includes methodologies such as questioning, discussion and investigations (Rocard et al., 2007). This limited description could lead to the belief that a teacher is carrying out a constructivist lesson if they do one of these methodologies in their classroom. It also omits a description of the role of the teacher, a key factor in Bruner's (1961) research. Moving to the Irish context, a constructivist approach to teaching was exemplified in the implementation of the new Irish primary science curriculum (DES, 1999a). The report defined the ideologies behind science education as;

Science may be seen as the active process of the personal construction of meaning and understanding

(DES, 1999a, p.13)

This description reduces constructivism to "constructing meaning and understanding". This interpretation is very vague and omits any of the understanding of the history of constructivism. It has been described that constructivism is not only the construction of knowledge but that it involves the search for believable truth (radical constructivism) based on a social interaction and discourse (social constructivism) (Kanuka and Anderson, 1998, Kroll and LaBoskey, 1996, Matthews, 2003, Osborne, 1996, Piaget, 1951, Vygotsky, 1978). It also omits the role of the teacher, meaning the interactive nature of constructivism is not captured. The point must be raised that if both the contextually relevant Rocard report and the Primary Science Curriculum do not accurately describe constructivism, then confusion may develop about what constructivism is as well as the role of the teacher in the classroom (DES, 1999a, Rocard et al., 2007). Indeed this will be revisited in Section 2.3 when issues in practicing teacher education will be discussed.

2.1.2 Issues within Constructivism

There are several issues associated with Constructivism. Osborne argues;

The failure of constructivism to recognize its own limitations has led to it enjoying hegemony in the research community which is undeserved

(Osborne, 1996, p.53)

Von Glaserfeld (1989) coined the term trivial constructivism in order to describe when the term constructivism was used because it was "fashionable".

Ismat describes constructivism as:

[...] an epistemology, a learning or meaning-making theory, that offers an explanation of the nature of knowledge and how human beings learn.

(Ismat, 1998, p.1)

This definition by Ismat describes constructivism in such a broad vision that it could easily apply to any form of epistemology. Rodriguez (1998) warns how researchers should avoid the "epistemological trap" of referring to constructivism as a blanket term. This idea is also echoed by Golding (2011).

Ismat (1998) and Matthews (2003) describe how the various definitions and descriptions of constructivism can be interpreted in multiple ways leading to confusion as to what constructivism is and how it should be enacted. Mayer, in a literature review on constructivism, found that utilising a pure discovery method of constructivism can have a negative impact on learning (Mayer, 2004). Pure discovery is described as unguided learning by the learner, with no external influence. Mayer instead argues for the idea of guided discovery instead. Guided discovery relies on learning being constructed by the student but being guided by an educator (Mayer, 2004). This would also highlight the role of the teacher as being crucial to effective learning (Bruner, 1961). Mayer also describes the "constructivist teaching fallacy" in this paper. This, he believes, is the confusion of the term constructivism to mean 'active learning'. 'Active learning' refers to the idea of an active classroom. While the students are active, no thought is applied to the learning that is taking place, an issue which has been described in Section 2.1 (Appleton et al., 2002, Davis et al., 2008, Varley et al., 2008a, Zembal-Saul, 2009).

Other opponents of the constructivist methodology include Kirschner, Sweller and Clark (Kirschner et al., 2006). Kirschner et al. (2006) argue how there is little empirical evidence to support the constructivist argument of 'learning by doing'. While this may be the case, the definition that they apply to constructivism is isolated to the use of unguided discovery. This places a limit on constructivism and therefore their conclusions cannot be applied to general constructivism, as constructivism can be both guided and unguided (Anderson, 2002, Ford, 2008, Mayer, 2004, Rocard et al., 2007). Both of these issues relate to the idea of novice learners. Returning to the basis of constructivism above, as suggested by Vygotsky, the development of knowledge by a learner depends on where they are in their Zone of Proximal Development (ZPD) (Vygotsky, 1978). Here Vygotsky argues that the more knowledge a learner has about a subject, the less support they would require to pursue their learning further. This would infer that unguided discovery is only effective when the learner has a basis of knowledge to build upon. Therefore using Vygotskian theories as a basis for constructivism, ensures that discovery should be guided for a novice learner and as knowledge and understanding increase, unguided discovery can be carried out. The argument for this approach is supported in the paper by Kirschner et al, whereby it is stated that these learning techniques are not suitable for novice users (Kirschner et al., 2006). Another area of conflict within the Kirschner et al. paper revolves around the grouping of the various elements of constructivism (Kirschner et al., 2006). In their argument they group discovery learning, problem-based, experiential and Inquiry Based Learning under the heading of 'learning by doing' and consider them all as one element. This heading generalizes the various approaches to the different strands of constructivism and may not highlight any benefits of its individual elements within constructivism.

2.1.3 Constructivism Conclusion

As it can be seen constructivism is a very complex pedagogy in science education which lends itself to many interpretations (Ford, 2008, Ismat, 1998, Matthews, 2003, Osborne, 2006, Phillips, 1995, Staver, 1997). These interpretations cause difficulties in describing and enacting specific constructivist pedagogies.

The term constructivism, with its ideological overtones, suggests a single philosophy and a uniquely potent method—like one of those miracle knives advertised on late-night TV that will cut anything, even tin cans. But we could look at constructivism in another way, more like a Swiss army knife with various blades for various needs.

(Perkins, 1999, cited in Golding, 2011, p.467)

While constructivism does have its opponents it must be noted that the DES is actively promoting constructivism (DES, 1999a). This promotion is based upon the ideals of constructivism and how constructivism has been shown to have a positive impact on student learning and development as well as direct links to the epistemology of science (Abd-El-Khalick and Akerson, 2006, Ford, 2008, Osborne, 1996, Staver, 1997). While this is the case, the issues above create difficulties in applying a constructivist definition to teaching. The Rocard report divides constructivism into two sub headings, Problem Based Learning and Inquiry based Learning. While this is a very simplistic view of constructivism, it does describe how science education lends itself naturally to Inquiry Based Learning (IBL). The next section will discuss Inquiry Based Science Education (IBSE). IBSE is a subset of Inquiry Based Learning (IBL) which isolates elements of IBL into a science context. It is widely promoted as a social constructivist methodology which can aid in the teaching and learning of science (Anderson, 2002, DES, 1999a, Darling-Hammod et al., 2005, Driver et al., 1996, Minner et al., 2010, Rocard et al., 2007, Zion et al., 2007). IBSE was also chosen as it is actively promoted by the Rocard report and the DES (Rocard et. al., 2007, DES, 1999, 1999a). IBSE accounts for the issues identified by Kirschner et al. and Mayer, by being a structured process of learning rather than being "pure discovery" or limited to "active learning" (Kirschner et al., 2006, Mayer, 2004). Rocard et al. (2007) describe how IBSE has been found to increase students interest in science as well as teachers willingness to teach science, the latter of which has been shown to be an issue in Irish primary science, (see section 2.2). Attempts will also be made to define and describe IBSE in order to eliminate confusion as to what IBSE is and how it should be enacted, therefore addressing the issues brought forth by Ismat (1998) and Matthews (2003). For the purposes of this literature review IBL will be used to describe general theories under the heading of inquiry whereas IBSE will be used to denote where they actively relate to, or address, science education.

2.2: Inquiry Based Science Education

IBSE is a methodology for the teaching of science education that is being promoted throughout Ireland and worldwide (Anderson, 2002, DES, 1999, 1999a, NRC, 1996, Primary Connections, 2009, Rocard et al., 2007, Varley et al., 2008, 2013). The Department of Education and Science and the Rocard Report identify IBSE as a best practice methodology for science education which will improve falling retention rates and produce meaningful learning and understanding in science (ibid). IBSE has its roots embedded in constructivism and the specific methodology of Inquiry Based Learning (IBL) (ibid). IBSE isolates specific elements of IBL and builds them into the subject of science to promote the epistemology of science (Eshach et al., 2011, Rocard et al., 2007). IBSE has also been linked to the development of teacher's science PCK (Shulman, 1986, 1987). The nature of IBSE can be uncovered through a description of IBSE, its components and approaches and considerations of its advantages and disadvantages.

The findings of the Rocard et al. (2007) study identify IBSE as the most beneficial methodology to increase interest in science, to increase cooperation between practitioners and that projects utilising IBSE have already shown to have positive results in learning and development. IBSE is based around the epistemology of scientific research. This process means students study science as a scientist would investigate a new research topic (Enfield, 2000, Rocard et al., 2007, Roth 1995). In recent years there has been a push towards utilising IBSE in the classroom (Darling-Hammod et al., 2005, Driver et al., 1996). This push has included the adaptation of teacher education methods, professional development courses and curricula (Anderson, 2002, Minner et al., 2010, Zion et al., 2007). In America, organisations such as the National Science Foundation (NSF), the National Research Council (NRC) and the American Association for the Advancement of Science (AAAS) have developed new curricula and professional development courses to further the advancement of IBSE (Akerson et al., 2008, Anderson 2002, Marek et al, 2003, Minner et al., 2010). Primary Connections is a project being carried out in Australia with an aim of enhancing primary teacher's confidence and competence (Primary Connections, 2009). Several European projects have also been developed to try to promote IBSE in various countries. One of these projects is the Pollen Project (Pollen,

2009). Pollen provided resources and training in methodologies which were adapted to suit the local curriculum in “seed” cities throughout Europe. Both Primary connections and the Pollen project will be discussed through case studies in Section 2.5.

Blanchard et al., 2010 developed a level system for the practice of Inquiry. This level system is shown in Table 1. As it can be seen the various levels of inquiry assigned by Blanchard et al., depend on the person who is asking a question, collecting data and interpreting results (Blanchard et al., 2010). Truly open ended inquiry, according to Blanchard et al., is entirely left to the will of the student who asks the question, collects the data and interprets it. Guided inquiry, according to Blanchard et al., requires a teacher to present a question for the student to collect data on and interpret the data. Finally structured inquiry requires the teacher to pose a question and collect the data. Using this model as a comparison tool it can be seen that the majority of the inquiry viewed within the lesson observations would be considered guided, whereby the teacher began the lesson and the students carried out the data collection methods and interpretation.

Table 1: Levels of Inquiry

	Source of the Question	Data Collection Methods	Interpretation of results
Level 0: Verification	Given by Teacher	Given by Teacher	Given by Teacher
Level 1: Structured	Given by Teacher	Given by Teacher	Open to Student
Level 2: Guided	Given by Teacher	Open to Student	Open to Student
Level 3: Open	Open to Student	Open to Student	Open to Student

(Blanchard et al., 2010)

There are however several issues regarding IBSE that must be discussed. The first issue regarding IBSE is the lack of a conclusive definition. Like the foundations of constructivism, the various approaches and designs attributed to IBSE over the past half century have led to many varied definitions being developed (Anderson, 2002). Once the definition of IBSE has been described the next stages of research is to describe the approaches that are attributed to IBSE and its practice. Following this the

constituents of IBSE will be discussed. Combining these three elements will describe the nature of IBSE in order for it to be applied throughout this research.

2.2.2a A Definition of IBSE

The Primary Science Curriculum was firstly analysed for a definition or description of IBSE (DES, 1999). This curriculum, as stated above, was designed to be an experiential curriculum and therefore it should promote IBL. It was hoped that this document would supply the research with a working definition of IBL that could be utilised. An analysis of the curriculum and the teacher guidelines found that while inquiry was discussed, there was no specific definition supplied to teachers (DES, 1999a, DES, 1999b). This is important as teachers and teacher educators utilising the new curriculum are left to decide what an inquiry approach to teaching actually is, which can create diverse practices some of which may not be considered as inquiry.

The literature on the subject of IBL can also contribute to the confusion of practice in IBL. As Anderson states:

Inquiry Teaching is defined differently by different researchers or the researcher may choose to use a different term for an approach that others apparently would identify with the inquiry label.

(Anderson, 2002, p.3)

This comment arises from the large body of literature that is available on the topic of IBL and means that if there is no definition that both teachers and teacher educators can become confused as to what actually inquiry teaching consists of.

In an effort to clarify what IBL is, especially in the context of science education, the National Science Education Standards (NSES) attempts to define inquiry as consisting of three main areas: scientific inquiry, inquiry learning and inquiry teaching (NRC, 1996). In this division, scientific inquiry relates to the way in which a scientist works, or the epistemology of science (Abd-El-Khalick and Akerson, 2009, Lederman 1992). Inquiry learning refers to the active practice of learning through inquiry and inquiry teaching refers to the specific methodologies that are used by teachers. Both scientific

inquiry and inquiry learning are also heavily related to the Nature of Science (NoS) (Abd-El-Khalick and Akerson, 2009). By practicing science through inquiry a teacher is therefore actively using the NoS to teach the students. This definition does not aid in understanding the nature of IBSE as it separates IBSE for teachers, learners and science.

The documents described above were created in the period between 1999 and 2003. In the past few years research was carried out across Europe into the practice of science education. This research resulted in the publication of the Rocard et al. report in 2007 (Rocard et al., 2007). This report highlights the move from the term of IBL into IBSE. Building on the problem of a definition of inquiry the Rocard et al. report selected one of the definitions of inquiry from the literature. This definition states that inquiry is;

The intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments.

(Rocard et al., 2007, p.9)

This definition clearly describes what an inquiry approach to science education should consist of; however it is not specifically a definition of IBSE. The Rocard et al. report states that IBSE is a problem based approach to teaching with the importance given to the experimental approach. A problem based approach is described by a student being supplied with a problem which they must develop a solution to. This description therefore can be equated to Rocard et al. describing IBSE through students being provided with a problem and having to develop and experimental solution. Indeed this concept is captured through the quote above but the quote above proceeds beyond this limited idea to include methodologies of research, model construction, debate and argument construction. This is another clear example, within the one document, of the lack of clarity about the concept of IBSE. It is for this reason that the above quote alone was selected as the primary description or definition to be used within this literature. The definition is clear and concise with exact examples of the components of IBSE which can be easily referred through in research.

The difficulty in identifying a specific definition of IBSE is a major challenge across science education internationally. Indeed, it is hoped, that the selection of this particular definition will guide this research to ensure its validity. It could be argued however, that another definition may also be valid. Researchers, teachers and policy makers must however identify a relevant definition to guide their work, to focus it and to ensure that the research can be completed. The next section will therefore attempt to clarify IBSE further through literature review of the components of IBSE.

2.2.2b Components of IBSE

While there is ambiguity over the definition of IBL there is consistency in the description of the components of IBL in the literature (Rocard et al., 2007, Varley et al., 2008a, Varley et al., 2008b, Walker, 2007, Zion et al., 2007). According to Zion et al, both students and teachers play a role in inquiry education, where teachers should not expect the students to do inquiry on their own (Kirschner et al., 2006, Mayer, 2004, Zion et al., 2007). This recalls the previous descriptions of guided and unguided discovery by Mayer (Mayer, 2004). Zion et al. state that the teacher's role encompasses facilitating, focussing, challenging and encouraging students in inquiry (Zion et al., 2007). This means that while it would be up to the student to carry out the components of IBSE, it is still up to the teacher to facilitate these to ensure that the students do not develop misunderstandings. This is particularly important in the context of this research where, early primary school students would not have the basic knowledge of inquiry or science needed to carry out an investigation alone. It could be argued however, that scaffolding the IBSE process across school years would allow older primary school students to carry out investigations with only facilitation by the teacher. The scaffolding process will be described further below (Hmelo-Silver et al., 2007). The concept also relates heavily to the idea of the teacher's schema which must be sufficiently developed in order to have the ability to facilitate science rather than deductively teach it (Korthagen, 2010).

The concept of scaffolding learning is a primary component of inquiry (Hmelo-Silver et al., 2007, Walker, 2007, Zembal-Saul, 2009). Scaffolding is the development of knowledge and understanding from building on prior knowledge and understanding (ibid). With relation to this research, the importance of scaffolding and guided

development does not only apply to student's knowledge and learning but can also be applied to the knowledge and development of inquiry skills for the teacher. The 5E model, which will be discussed in the next Section, could be considered as a scaffold for the pedagogy of inquiry (Bybee et al, 1996). Returning to the concept of teacher education, inquiry through the lens of the 5Es may also be argued as developing a teacher's schema in inquiry.

In order to identify the components of inquiry both the curriculum and the teacher guidelines in Ireland were consulted. The Irish curriculum lists the components of inquiry as; observing, hypothesising, predicting, experimenting, planning fair tests and analysing results (DES, 1999a, DES, 1999b). These components are in line with the description of the NoS above and may be presented as a reason to why science should be carried out through inquiry. The National Research Council of America has, as its components of inquiry; questioning, develop and evaluate explanations, format explanations, evaluate student experiences and communicate and justify student explanations (NRC, 2000). It is obvious from the definition that the Rocard et al. report expands on these elements of inquiry and individual methodologies such as "diagnosing, critiquing, planning investigations, researching, debating and arguing" (Rocard et al., 2007). These individual methodologies support the elements of IBSE as put forward from the NCCA. This provides further evidence that the selection of the Rocard et al. definition of inquiry should be the one taken for this research.

As it can be seen from above the literature highlights the uses of both questioning and explanations in an inquiry lesson. One of the principle constituents of inquiry teaching and learning is the idea of questioning (Anderson, 2002, Davis and Smithey, 2008, DES, 1999a, Van Zee and Roberts, 2006, Kahn and O'Rourke, 2004, Zion et al., 2007). In using questioning as a methodology the teacher can either begin an inquiry lesson by asking a question or let the student ask their own questions to begin studying a new topic. Interestingly, the Irish primary school curriculum does not specifically state questioning as a component of inquiry. It does however list questioning as one of the key skills of SESE (DES, 1999). The key skills are listed as; observe, question, investigate, understand and think logically. Most of these components are present in the use of investigations which form one of the key methodologies of IBSE. Investigations are seen as ways of including several

constructivist and inquiry based methodologies such as planning, designing, researching, exploring and questioning (DES, 1999, 1999a).

Another key constituent of inquiry is the idea of constructing explanations from inquiry. Here the teacher uses an inquiry lesson to elicit students' explanations of phenomena from their previous knowledge and experiences. Explanation construction is important to an inquiry lesson as it forms a way for the teacher to identify misunderstandings in the classroom (Allen, 1997, Zembal-Saul, 2009). While these are the components of IBSE it must be pointed out that the Rocard et al. report stated that a teacher may include deductive teaching methods as well as inductive teaching in order to suit the different learning styles of students (Rocard et al., 2007). It is for this reason that more traditional methodologies such as experiment demonstrations can still be included in resources supporting the practice of inquiry, once they are properly structured and placed within a student centred environment. As stated previously, the NCCA report discovered that teachers were still using textbooks as primary resources in their teaching in Ireland (Varley et al., 2008a, 2013). A study was carried out as part of this research into textbooks, and whether they could be used to support inquiry in the classroom. This study will be described further in Chapter 4.

Now that the components of inquiry have been described, the question arises as to how to utilise these components in the classroom. A teacher may use any of these components individually and believe that they have carried out an inquiry lesson. The next section will take these components and show how, in order to carry out an inquiry lesson, a teacher must use them in a process rather than individually.

2.2.2c Approaches and models of IBSE

Approaches to IBSE highlight how IBSE is a process and not constricted to an individual methodology. The idea of inquiry as a process was described by Anderson and Hapgood (Anderson 2002, Hapgood et al., 2004). Describing inquiry as a process allows a teacher to combine all of the constituents of inquiry into a clear structure for learning. This also reduces the need for a specific definition of inquiry to be developed. If a teacher can take a series of methodologies and build them into a student centred process of learning then it may be considered as the practice of

inquiry. Hapgood follows a process of preparing, investigation, data collection and analysis, preparing report and finally reporting and discussing. Other models that can be attributed to IBSE include the 5Es model and the Predict Observe Explain (POE) model (PrimaryConnections, 2009, White and Gunstone, 1992, Bybee, 2006).

Table 2: The 5E model of teaching

Engagement	Strategies or activities designed to elicit thoughts or actions by the student that relate directly to the lesson's objective
Exploration	Experiences where students' current understandings are challenged by activities, discussions and currently held concepts to explain experiences
Explanation	Presentations of scientific concepts that change students' explanations to align with scientific explanations
Elaboration	Activities that require the applications and use of scientific concepts and vocabulary in new situations
Evaluation	Culminating activity that provides the student and teachers with an opportunity to assess scientific understanding and intellectual abilities

(Bybee, 2006, P.15)

The 5Es are known as: Engagement, Exploration, Explanation, Elaboration and Evaluation (Bybee 1997, 2006, NCCA, 2004, PrimaryConnections, 2009). This process carries through a lesson and contains many elements of IBSE that are described above. Table 2 describes the phases of the 5Es (Bybee, 2006, p15). In the Engagement phase, students are engaged with the subject and their prior knowledge is identified. The Exploration phase relates to the exploration of a subject by students developing their own knowledge and understanding. The Explanation phase relates to information that may not have been gained during the explore phase and may have to be supplied to the student. The Elaboration phase involves the application of the knowledge and understanding students have gained into contexts outside the classroom. The Evaluation phase reviews the knowledge and understanding which have been gained through study (Bybee, 1997, Primary Connections, 2009). It was for

the reasons of structure and easy application of the 5E model that it was chosen as the primary model that would be utilized in this research. It can be seen that Walker's lesson design, which will be described below, follows a similar line of thinking to the 5Es model, however the 5Es model is more suited for the primary science curriculum as it involves the teacher-led facilitation of knowledge development through scaffolding (Hmelo-Silver et al., 2007, Walker, 2007, Zembal-Saul, 2009).

POE model was developed by White and Gunstone (1992) and it involves the student firstly predicting the outcome of an event (White and Gunstone, 1992). This prediction must be justified in order to eliminate guessing. This clarification is directly related to the findings of the NCCA studies which observed students randomly guessing answers rather than justifying predictions (Varley et al., 2008a). By getting the students to justify their prediction a teacher can become aware of the previous knowledge the student has utilised to come up with the prediction. The observation phase involves the students describing what has happened. Finally the student must explain what they saw and describe how the observation may be different to their prediction and explain why this is the case. This particular approach to inquiry is suited to IBSE as it can be directly adopted for an experiment or an investigation in the classroom. In this approach both questioning and explanation construction are key components of IBSE (Allen, 1997, Davis and Smithey, 2008, DES, 1999a).

While these approaches to inquiry have been described as individual entities a teacher is not constrained to using them. They can take the components of inquiry and create their own process as shown by Hapgood and Walker (Hapgood et al., 2004, Walker, 2007). Walker divides the lesson into several stages: Introduction, generating questions, planning an experiment, conducting the experiment and formulating conclusions (Walker, 2007). This approach contains all the components of Inquiry as listed by the NRC and the idea of using questions to guide inquiry after the particular topic has been set up (NRC, 1996).

As it can be seen there are many and models within the methodology of IBSE. All of these models contain their own approaches to IBSE. As it has been previously stated the 5Es model was chosen to be the primary model by this research. This decision was

made due to the popularity of the 5Es model in projects such as Primary Connections, as well as its rigorous structure which could be easily applied to different contexts.

2.2.2d Advantages and Disadvantages of IBSE

It becomes apparent, in the literature, that while advantages to IBL methodologies are discussed, there is little concrete evidence to conclude whether IBL is a viable methodology or not (Anderson, 2002, Cuevas, 2005, Kahn and O'Rourke, 2004, Kirschner et al., 2006, Walker, 2007). Anderson (2002) lists several sources of positive results in classroom based IBL studies. According to Shymansky, Kyle and Alport (1983), IBL produced positive results in the areas of cognitive skills, attitudes of the students to science and the students processing skills (Shymansky et al., 1983). This research has however been questioned by Anderson as IBL cannot be distinguished as the defining factor in creating these achievements (Anderson 2002). Anderson then raises a very important point in relation to this: "One must be specific about what the criterion measures are and what the basis is for judging success" (ibid). This statement highlights the need for the selection of a specific definition and set of factors that are deemed as inquiry.

According to Kahn and O'Rourke, in their handbook on inquiry-based learning, there are several advantages to IBL (Kahn and O'Rourke, 2004). These advantages are not only limited to the creation of knowledge but expand to encompass interpersonal skills development such as team-working, presentations, literary developments, problem solving, creativity and project management (ibid). If a teacher understands the various learning styles or intelligences in their classroom then, according to Kahn and O'Rourke, they may cater for many of these by using inquiry. While these advantages are described in this handbook there is no source of reference listed, which may mean that this description arises from anecdotal evidence. Positive experiences relating to the practice of open ended investigations was recorded by Roberts et al. (2010). This study found that using open ended investigations (Blanchard et al., 2010) in an undergraduate course has a positive impact on understanding of data and the application what had been learned. This study was carried out with undergraduate students however, who would have had previous science instruction. Primary school students would not have this prior knowledge and Kirschner et al., (2006) argue that IBSE provides negative results when using open ended inquiry with novice students.

The conclusion of this point must be stated that if IBSE is to be used as a methodology, its key components must be identified in the context of this research and then isolated as the determining factors in any effects on student learning, attitudes or teachers' PCK.

Kirschner et al, 2006, state that unguided instruction is normally less effective and that there is evidence that it may have negative results when students acquire misunderstandings or incomplete knowledge. However the concept of unguided instruction is not a key component of IBL. In fact, while looking at the definition of inquiry used within this research, there is no specific unguided methodology involved. A teacher may employ any of the methodologies listed and still have input into the students work. In the context of this research it is important to remember that scaffolding or guided learning, as described above, is an important element of IBSE. The argument for using scaffolding as part of IBL was given in a response to the paper by Kirschner et al, Hmelo-Silver et al (Hmelo-Silver et al., 2007). This paper highlights that definition of IBL used by Kirschner et al is incomplete by not including scaffolding as a technique in IBL. They highlight several studies (Hickey et al., 2000, Geier, 2007, Lynch et al., 2005 cited in Hmelo-Silver et al., 2007) which contained positive results when using Inquiry based methodologies.

2.2.3: Constructivism and IBSE Conclusion

As it can be seen from the above review, IBSE is very suited to the needs and aims of this research. By using IBSE it is hoped not only to contribute to the support of IBSE by the NCCA and the DES, but that both teaching and learning in science can be improved through its use (DES, 1999a, DES, 1999b, Kahn and O'Rourke, 2004, Varley et al., 2008a, 2008b, 2013). Even with the issues that have been described IBSE can be utilised for teachers in order to improve their practice and develop their schema (Korthagen, 2010).

It has been shown that issues relating to the definition of IBL and therefore IBSE can cause confusion to teachers willing to implement it (Anderson, 2002, Rocard et al., 2007). The Rocard et al. was chosen as the primary definition of IBSE by this

research as it contains many of the elements which are found to be throughout the literature on IBL or IBSE and is the closest contextual definition that can be found.

One final point to be raised in a review of the literature on IBSE is the link between IBSE and primary or elementary schools. As it has been described in Chapter 1, the DES designed the primary school curriculum to be an experiential curriculum. This means that the students carry out science lessons as a scientist would, thus emphasising the NoS to the students (Abd-El-Khalick and Akerson, 2009, Lederman 1992). While it has been argued that inquiry may have both positive and negative results in the classroom, it is still the primary focus of this research. This is substantiated by the amount of literature that proposes inquiry for elementary education (Appleton et al., 2002, Bitan-Friedlander et al., 2004, Gomez-Zwiep, 2008, Howes et al., 2008, Newman et al., 2004, Cuevas, 2005, Zembal-Saul et al., 2001). This large amount of literature shows that young students are capable of carrying out inquiry, even if it requires the use of scaffolding as mentioned above (Hmelo-Silver et al., 2007). It also means that by implementing inquiry early into a student's science career they will be more capable of carrying out inquiry when it comes to Secondary and Tertiary education.

2.3: Educational Change

To accomplish any reform of teaching practice, the concept of educational change must be considered (Fullan, 2007, Metz, 2009). While Metz uses the term analytical change rather than educational change, the two terms are comparable as the process of analytical change is accompanied with curriculum reform (Metz, 2009). Fullan describes how educational change is crucial to ensure changes in the educational system, including policy, reform and practices can be successfully implemented (Fullan, 2007). Fullan argues that, in order to successfully initiate educational change, the reform must address the needs of all the stakeholders of the body to which the reform is being applied (ibid).

Large-scale reform failed [...] because it focussed primarily on the development of innovations and paid scant attention to the culture of schools and districts in which innovations would reside

(Fullan, 2007, p.9)

These “stakeholders” include the teachers, students, the school administration, board of managers and student’s parents (ibid). This, he argues, will ensure that any measure of educational change will succeed as it take into account the needs and wants of each of these stakeholders to ensure that each party knows and understands the reform that is occurring (ibid).

Fullan also describes the importance of naturalistic generalisations (ibid). Naturalistic generalisation is a process of developing insight into practice by identifying with other cases (Melrose, 2009). In the case of education research, Fullan describes this process as teachers being mainly convinced of reform by the practice of other teachers (Fullan, 2007). Therefore, the implementation of any new curriculum should be accompanied with the professional development of practising teachers. Cohen and Ball argue how curriculum reform will be less successful if the teachers are not involved with analytical change (Cohen and Ball, 1990). It could be argued that the curriculum implementation in Ireland did not take into account the stakeholders. This is made apparent by the lack of in-service training afforded to practicing teachers, for both content and pedagogical development, and the lack of additional time allotted for the introduction of a new subject (DES.1999, 1999a, Harlen, 1995, Varley et al., 2008a, 2008b).

Educational change therefore highlights two primary concerns for the progression of any research into implementing reform of practice. Firstly, in order to implement any form of change into the system of education, all of the stakeholders involved must be aware and willing to promote the efforts. This will substantially reduce the reluctance to the change. Secondly, if the professional development of teachers is to be considered, the most efficient method would be to utilise the experiences of practicing teachers to convince others to change their practices.

2.3.1: Driving Forces of Change in Science Education

Before the concept of educational change is applied to Irish primary science education the question as to why changes are needed in science education must be asked. The introduction of the new primary science curriculum in Ireland was designed to provide students with an opportunity to engage with science at a younger age (DES, 1999). It is a general view that studying science at a young age affords students a chance to develop their curiosities and interest in the world (Eshach et al., 2011, Murphy et al. 2012). Eshach et al. argues for the introduction of science at pre-school levels and that, through their observations, students at that age are capable of understanding concepts and developing inquiry based skills.

It has also been discussed previously, that science education is currently facing a number of issues and challenges with respect to curriculum implementation, teaching methods and falling retention rates of science in second and third level education (Appleton and Kindt, 2002, D.o.E., 2006, Harlen et al. 1995, Rocard et al., 2007, Varley et al., 2008a, 2008b, 2013, Waldron et al. 2009). The primary source of information relating to Irish primary science education is the National Council for Curriculum and Assessment (NCCA) Phase 1 and 2 reports by Varley et al. (2008a, 2008b). The NCCA report, and a publication by the Irish Association for Social, Environmental and Scientific Education (IASSEE), describes findings of teachers demonstrating rather than exploring science with their students, explaining concepts rather than investigating them, carrying out activities without meaningful learning goals and teachers who have low confidence levels (Varley et al., 2008a, Waldron et al., 2009). Indeed, throughout the literature, there are several challenges and issues in primary education which are common worldwide. These issues include the amount of subjects that a primary school teacher has to teach, teacher confidence levels and issues with teacher education (Appleton and Kindt, 2002, Harlen et al., 1995, Murphy et al., 2007, Varley et al., 2008a, 2013, Victor and Kellugh, 1997).

It becomes evident when analysing the literature on the subject of primary science education that many of the issues are intertwined and cannot be thought of as singular entities. Figure 1 describes some of these issues as well as their links and factors divided under four headings; teacher content knowledge, teacher pedagogical

knowledge, teacher education and teacher confidence (Appleton and Kindt, 2002, D.o.E., 2006, Harlen et al. 1995, Murphy et al., 2007, Rocard et al., 2007, Varley et al., 2008a, 2008b, 2013, Waldron et al. 2009). It became clear that a regulating factor needed to be identified which can easily categorise each of these issues for clarity and comprehension.

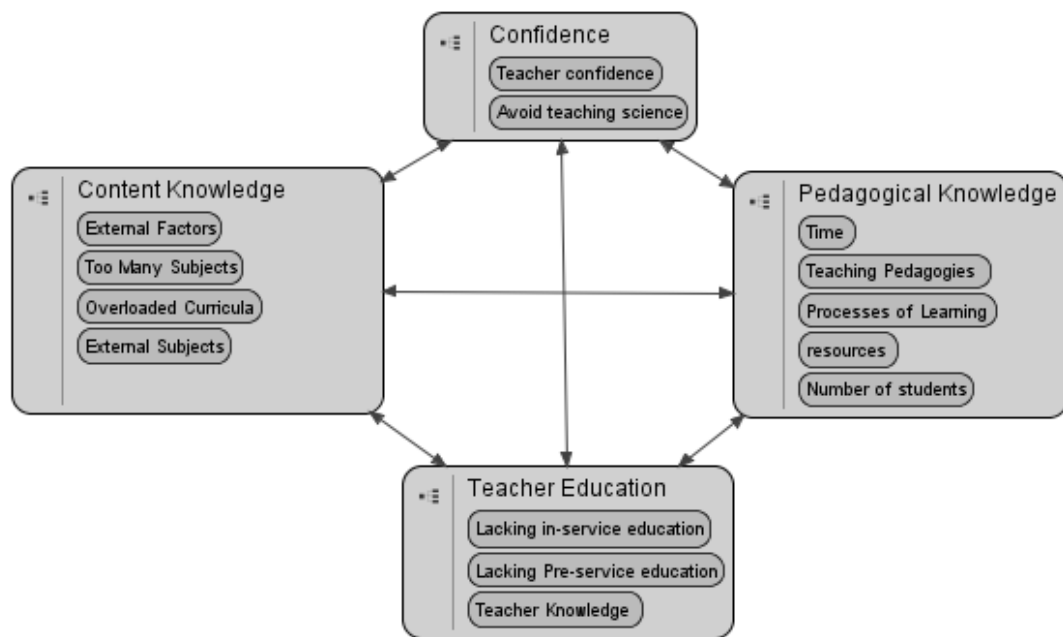


Figure 1: Categorised Science Education issues

2.3.1a Content Knowledge

With regard to teacher content knowledge, the issues that are identified within the literature include teachers being overloaded with too many subjects and the knowledge that teachers have about the individual subjects themselves (Varley et al., 2008, 2013, NCCA, 2010). Within Irish primary science in particular concerns have also been raised about the addition of extra-curricular subjects (ibid). These include the Seven Sacraments of the Catholic Faith and the Safe Cross Code, amongst others. The latter issues will be discussed further in Chapter 4 in a follow up study on teacher educators' views on science education and inquiry.

In 2010 the NCCA in Ireland published the report on Curriculum Overload in Primary Schools (NCCA, 2010). This document highlighted how it is the current view of teachers that there is insufficient time to address all of the objectives in all subjects and acknowledged that for an Irish primary school teacher the entire curriculum

comprises of 23 books, not including teacher guidelines (ibid). The issue of an overloaded curricula is not isolated to Ireland however as the NCCA document quotes the Cambridge Primary review which found its curriculum to be “overloaded and unmanageable” (Cambridge Primary Review, 2009 quoted in NCCA, 2010). Curriculum reform is provided as reasoning behind the development of overloaded curricula (ibid). The 2010 NCCA report also quoted teachers who stated that “It can be difficult to plan for so much in so short a time scale” (NCCA, 2005 quoted in NCCA 2010).

In Chapter 1, it was discussed how of the three days in-service awarded to Irish science teachers in science, one day was devoted to planning. Indeed, the Teacher Guidelines also emphasise the importance of lesson planning (DES. 1999a, Varley et al., 2008a). A lack of proper planning has shown to result in teachers relying heavily on didactic methodologies (Harlen, 1995, Rocard et al., 2007, Murphy et al., 2007, Varley et al., 2008a). Didactic methodologies are described as the presentation of information to students and was described in Section 2.1. A lack of planning and the large amount of subjects can make it difficult for a teacher to concentrate on teaching science for skills development and understanding (Appleton and Kindt, 2002, Beyer and Davis, 2009). While Planning is important, Appleton and Kindt discovered that it may be difficult for teachers, especially Newly Qualified Teachers (NQT), to develop a balance in their teaching (Appleton and Kindt, 2002). Here they describe how a NQT may be too busy planning a lesson to cope with the demands of practice. An overloaded curricula and lack of time for planning lessons may result in teachers relying on curriculum support materials to carry out their lessons (Varley et al., 2008a).

Beyer and Davis carried out a critique of the use of lesson support materials in the practice of pre-service teachers. This research discovered that if the support material was provided without training and coaching, teachers can revert to using these materials as primary tools in their practice without consideration of learning objectives (Beyer and Davis, 2009). A heavy use of science support curriculum materials was directly observed in many of the lessons within the NCCA Phase 1 report (Varley et al., 2008a, 2013). This report found that many of the teachers in Ireland who are using curriculum support materials are using them to dictate a lesson

rather than emphasising their use as a tool to support further learning (ibid). Harlen provides reasoning behind this issue by stating that teachers who lack the necessary knowledge and understanding in a subject could lead to them relying heavily on pre-scripted methodologies (Harlen et al., 1995).

Another major issue in science education is the idea that teachers are emphasising the activity of learning over developing understanding (Appleton, 2005, Davis et al., 2008, Zembal-Saul, 2009). Davis explains how this idea is mainly prevalent with beginning science teachers who may lack content knowledge and understandings of the Nature of Science (NoS) and therefore seek to engage their students with the subject rather than explore it in detail (Davis et al., 2008). The NoS is described as “The epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge” (Abd-El-Khalick and Akerson, 2009). The NCCA study found that a significant amount of Irish teachers emphasised an activity without meaningful learning goals (Varley et al., 2008a). Murphy et al. describe how science can be used to foster questions, hypothesise, predict and examine (Murphy et al., 2012). The description of engaging with students would therefore not afford students the opportunity to carry out any of these activities. In fact, if the definition of Engagement is taken from the 5Es construct, which is described in Section 2.2, then these teachers are mainly carrying out short activities that promote curiosity and elicit prior knowledge (Bybee, 1997, 2006, 2006a). This means that students, who according to Eshach et al. are able to carry out deep thinking activities, are not being afforded lessons which can develop these skills due to their teacher’s lack of pedagogical or content knowledge (Eshach et al., 2011, Davis et al., 2008).

2.3.1b Pedagogical Knowledge issues

The pedagogical issues identified within the literature relate to the use of teaching pedagogies and the process of learning in science education. The literature on the subject of teaching pedagogies in science divides these pedagogies into two ideas, didactic (or deductive) pedagogies and constructivist (or inductive) pedagogies (Rocard et al., 2007). Didactic pedagogies are described as the presentation of data, ideas or concepts for memorization by students. Constructivist pedagogies relate to the development or construction of data, ideas or concepts through the study of a

subject (*ibid*). The issue relating to teaching pedagogies describes how, while efforts to promote constructivist pedagogies are being employed and shown to have positive results, that there is still a large cohort of teacher's mainly employing didactic pedagogies (Harlen et al., 1995, Hmelo-Silver et al., 2007, Murphy et al., 2007, Rocard et al., 2007).

The Rocard et al. (2007) report described how the quality of primary science teaching and learning could be improved by a move to constructivist teaching pedagogies. Constructivism was detailed in Section 2.1. The Irish primary science curriculum, and the accompanying teacher guidelines, also promotes these teaching practices (DES 1999a, NCCA, 2008a). There is much literature on the positive impact of constructivist teaching methodologies (Rocard et al., 2007, Hmelo-Silver et al., 2007, Minner et al. 2010). The combination of these positives and the approach utilised by the curriculum isolated constructivist pedagogies as a primary focus of this research.

The Rocard et al. report also describes how didactic and constructivist teaching pedagogies are not mutually exclusive. In its description of constructivist teaching practices it states that there is a place for didactic practices (Rocard et al., 2007). This point therefore means that utilizing constructivist teaching practices does not mean abandoning didactic methodologies. If teachers are being evaluated and shown to still be mainly employing didactic teaching, the question must be asked as to how their teaching can be redeveloped to create the habits of mind that include constructivist pedagogies.

A teachers' pedagogical knowledge is also informed by their views on the Nature of Science (NoS) (Abd-El-Khalick et al., 1998, Davis et al., 2008, Murphy et al., 2011). With the description of NoS above, it can be therefore extrapolated that the teacher's beliefs about difficulties in science and the pedagogies that accompany it may affect the way that they teach it. Murphy et al. argue that NoS should be actively studied in science as their results suggest students who study NoS develop a view of science that makes more sense to them than excluding it (Murphy et al. 2010).

2.3.1c Pre-Service Teacher Education

The issue of teacher relates to the amount and frequency of in-service and the setup of pre-service education. Palmer (2007) describes how primary teacher education students are a particularly notable group that propose to have low self-efficacy and confidence levels. Teacher confidence levels will be described further below.

Research has shown how teacher education has been proven to be ineffective if the education is not carefully structured between the processes of learning, the pedagogies of teaching and the investment of teacher educators (Korthagen, 2010, Labaree, 1992, Lanier and Little, 1986). The investment of teacher educators is described as the effort they place into their teaching and the concentration on the promotion of science content and pedagogical knowledge. Palmer would argue however that these two concepts are not necessarily isolated (Palmer, 2007). Recommendations in this paper describe how teacher educators should carry out activities that promote both content and pedagogy simultaneously. Positive impacts were recorded by students attending environmental tours or viewing science in popular movies. This provided students with methods to present science in interesting and innovative ways while still expanding their content knowledge on the subject (ibid). Throughout the five teacher training colleges in Ireland, pre-service teachers are receiving between twelve and forty-four total hours of education in science in their undergraduate studies (Varley et al., 2008a). The wide variance in hours alone shows how universities in Ireland do not provide equal levels of education in science. Education must therefore be supported by the inclusion of structured and maintained in-service studies for teachers as well as Continuous Professional Development (CPD).

CPD has also been found to have positive effects on teacher confidence levels (Harlen et al., 1995, Murphy et al. 2007) and the teachers' views on the NoS (Akerson et al., 2008). The NCCA study within Ireland also recommended the use of further in-service initiatives, as well as an improvement to pre-service education (Varley et al., 2008a, 2013). Harlen argues that teachers should have a minimum of 80 hours of training for the introduction of a new subject into the curriculum (Harlen, 2004). From the in-service that was awarded to Irish school teachers only sixteen hours of the training was mandatory with the final eight hours being optional (Varley et al., 2008a). These figures are well below the time as described by Harlen, and could be attributed to Irish teachers currently having difficulties (ibid).

The idea that teacher education is a continuous process, throughout the career of the teacher is argued by Feiman-Nemser (Feiman-Nemser, 2001). This is supported by the Korthagen model which concludes that a teacher's Gestalt, see Figure 2, is continuously developing throughout their lives (Korthagen, 2010).

How do teachers decide what to teach, how to represent it, how to question students about it and how to deal with the problems of misunderstanding?

(Shulman, 1986, p.8)

The idea of questioning how a teacher decides what and how to teach is mainly informed through teacher education and professional development. One method to challenge issues in teacher education is to give consideration to a theory of how teachers learn. Korthagen and Lagerwerf devised a three level model in order to analyse a theory on teacher learning (Korthagen and Lagerwerf, 1996). This structure is comprised of the Gestalt level, the Schema level and the Theory level.

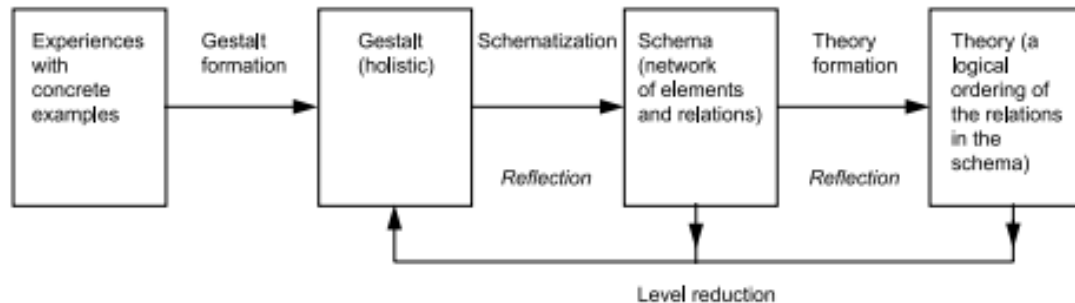


Figure 2: The Korthagen three level model (Korthagen, 2010, p.410)

As it can be seen the Gestalt is a holistic idea, which is formed through the experience of teachers, who can recall a how they responded to previous circumstances and develop an appropriate response to new situations. The development of a teacher's Gestalt is based on the practical experiences of a teacher and may lead to implicit actions and pedagogies being carried out by the teacher (ibid). The idea behind the development of the gestalt is the development of a logical theory of teacher learning, through experience, making implicit actions explicit (Korthagen and Lagerwerf, 1996, Korthagen, 2010). Documenting a change in Gestalt may be a difficult process, however, due to the Gestalt being a holistic idea. Education Change however, is based

on a reform of practice (Fullan, 2007). Therefore Educational Change can only be documented through a change in a teacher's Schema, through the analysis of a network of elements and relations. This network of elements and relations will be returned to in the discussion of IBSE practices, but it becomes evident that the impact of educational reform through teacher education can be gauged through a documented change in a teacher's Schema.

2.3.1d Teacher Confidence

Finally an area that accompanies many of these previous issues is the issue of teacher confidence. The confidence levels of teachers can affect many elements of their practices. The issue of teacher confidence in science has been linked to a lack of understanding of ideas in science, pedagogical practices in science and content knowledge (Harlen et al., 1995, Holroyd and Harlen, 1996, Victor and Kellugh, 1997, Yates and Goodrum, 1990). In Ireland, a lack of confidence in teaching was identified amongst teachers who chose to study science in particular in 1990 (NCCA, 1990 cited in NCCA, 2008a). A cross-UK study carried out by Murphy in 2007 found that, while teacher confidence had increased over the previous ten years through the use of teacher initiatives, there was still approximately half of the survey population that confessed to low levels of confidence in their science teaching (Murphy et al., 2007). As described previously CPD was shown to have a large effect on the confidence levels of teachers.

Appleton and Kindt describe how teachers with low confidence levels relied on mainly didactic teaching methodologies in their classrooms (Appleton and Kindt, 1999). Harlen's study of Scottish primary teachers highlighted the fact that teachers who lack confidence in teaching science often rely on approaches to science which emphasise content knowledge over understanding such as using step-by-step lessons (Harlen et al., 1995). The NCCA discovered that many activities that were observed in Irish classrooms mirrored the lesson support tools offered by the Primary Professional Development Service (PPDS) and Discover Primary Science (DPS) (Varley et al., 2008a). This was linked to a lack of confidence levels in lesson planning for science whereby a teacher, rather than accessing the support tool and modifying it to be suitable for their lessons, was carrying out every detail of the support tool as it was provided to them. While this was the case, no strict conclusion

was made on whether teachers were not able to develop their own lessons which could explain why they were relying on the support lessons. Teacher confidence levels can therefore be linked heavily with the pedagogical issues that were described previously.

The issue of teacher confidence in science has been linked to a lack of understanding of ideas in science, pedagogical practices in science and content knowledge. Confidence levels are also found to vary within the topics of science. Research has shown how science teachers were less confident at teaching the physical sciences than the biological sciences (Harlen et al., 1995). While this may be due to several reasons, it is important to note the NCCA study found

Children's experiences of science within the strand units of forces, and properties and characteristics of materials, appear to be rather limited.

(Varley et al., 2008, p.8)

These strand units relate to the physical science elements of the curriculum. This means that the implementation of the Irish science curriculum has not been able to address one of the key issues in science education raised by Harlen in 1995 (Harlen et al., 1995). This idea will be revisited in Chapter 4 where teacher educators discuss how the recent intakes of pre-service teachers have generally only studied Biology to Leaving Certificate level. This could account for the lack of teaching of the physical sciences as these teachers may be more confident teaching living things based on their own education.

2.3.1e Driving Forces of Change Conclusion

It becomes clear when analysing the literature on primary science education that there are many issues that exist throughout the subject. It is mutually agreed that beginning primary school teachers face more of these issues than teachers who have been practicing for many years (Appleton and Kindt, 2002, Davis et al., 2008). This view is also supported through the discussion on a Schema whereby practicing teachers have had the opportunity to develop their ways of knowing how to teach through experience (Korthagen, 2010). It is however possible to say that the majority of these issues traverse all levels of teaching. Efforts must therefore be made to challenge

these issues and develop effective primary school teachers who are confident, competent professionals, who can develop meaningful knowledge and an understanding of science. This research will attempt to address these issues through the development of an intervention which will use teacher experiences to support other teachers in their teaching of science.

2.3.2: Supported Educational Change

The conclusion of several of the reports described above recommend the Professional Development (PD) of teachers to promote inquiry and science education (Murphy, 2012, Rocard et al., 2007, Varley et al., 2008a, 2013). It was therefore determined that an analysis of the literature regarding professional development in science education would be required. Indeed several organisations such as the National Science Foundation (NSF), the National Research Council (NRC) and the American Association for the Advancement of Science (AAAS) have developed new curricula and professional development courses to further the advancement of IBSE (Akerson et al., 2008, Anderson 2002, Marek et al, 2003, Minner et al., 2010).

2.3.2a Methods of Professional Development

When analysing the literature on PD in science education the previous issues relating to science education begin to reappear (Beamer et al., 2008, Duran et al., 2009, Khourey-Bowers and Simonis, 2004, Seraphin et al., 2012, Wee et al., 2007). Several PD programs have reported positive results with regard to teacher confidence, teacher knowledge, teacher pedagogy and inquiry practice (Beamer et al., 2008, Duran et al., 2009 and Seraphin et al., 2012). Some of the primary topics that emerge through an analysis of the literature on PD are; the amount of time the PD course consists of, the promotion of pedagogy and content, the use of experience, the use of tools and the use of technology.

It has been previously stated how Harlen argues for 80 hours instruction for the introduction of a new topic into a curriculum (Harlen, 1995). Duran et al., Beamer et al., and Seraphin et al., all discovered positive outcomes for their PD courses which all ranged at approximately 30 hours (Beamer et al., 2008, Duran et al., 2009 and

Seraphin et al., 2012). All three of these studies described how the teachers' attitudes towards inquiry had been positively affected in this period and the latter two describe how the teachers' confidence levels in teaching inquiry had been increased. Beamer et al. however discovered that their participants had developed an in-depth knowledge of inquiry through their PD course but failed, two years later, to be implementing the practice in the classroom (Beamer et al., 2008). This PD course was described as 250 hours total. Comparing this with the 24 hours PD provided to Irish teachers on the introduction of a science into the topic it becomes clear how much instruction was involved in the study by Beamer et al. While this is the case the study does show that with PD teachers can modify their teaching practice to be more constructivist in nature. Duran et al. may suggest a reason for why the extended period of time proved to be less effective than the shorter courses. They recommend that PD needs to be provided on a continuous basis for teachers, a sentiment echoed in the recommendations of the NCCA report (Duran et al., 2009, Varley et al., 2008a, 2013). By instilling the PD aims on teachers on a continuous basis the PD can ensure that the teachers are continuously implementing the ideas presented. Seraphin et al. argues that this PD may be in the form of an instructor led PD session supported through online supplemental sessions (Seraphin et al., 2012).

The next idea that emerges from the literature is the use of curriculum support tools in the classroom. The study by Duran et al. described how the use of pre-prepared materials aided the teachers in the practice of inquiry in their classrooms (Duran et al., 2009). These materials had been provided to the participant teachers during the PD. The teachers were then allowed to develop their own knowledge on how to apply the materials in the classroom. Beyer and Davis' study discovered that when support materials were removed, teachers reverted to teaching without regarding the principles they had been trying to maintain using the curriculum support materials (Beyer and Davis, 2009). While this may be an issue with PD courses, the context of the NCCA results must also be described. The NCCA study however highlighted an issue with pre-prepared materials whereby the teachers were only using them for their lessons and not developing the practices that they were attempting to convey (Varley et al., 2008a).

The issue of context also arises in the literature on PD. Guskey argued how the lack of contextual factors in PD can result in courses which do not meet their outcomes (Guskey, 1986). This may be particularly prevalent in PD courses which are carried out externally to the classroom (Duran et al., 2009, Seraphin et al., 2012). Duran et al. (2009) found that the use of the 5E model resulted in significant changes in teacher's beliefs about inquiry and that teachers believed that inquiry enabled students to explore more topics in depth than previously. The 5E model was discussed in Section 2.2.

Wee et al. determined that the professional development enhanced a teacher's ability to develop inquiry based lessons but that there was little or no change in the teacher's knowledge or implementation of inquiry (Wee et al., 2007). This could be due to the PD program being separate from the context of the classroom. There were however some positive outcomes from this study which determined that teachers could produce more inquiry based lesson plans, but their implementation of those plans did not meet their criteria for inquiry. This could be described as the teachers having knowledge of inquiry but, as a result of their PD program not being carried out parallel to their teaching, the effect on the classroom was limited.

Another element that emerges from the literature is the importance of teachers experience on their PD (Khourey-Bowers and Simonis, 2004, Seraphin et al., 2012). Shulman, Fullan and Loughran have all described the importance of a teachers experience on development of their teaching (Fullan, 2007, Loughran et al., 2000, 2001, Shulman, 1986, 1987). Seraphin et al. implemented a process of PD by including the experiences of other teachers (Seraphin et al., 2012). The use of technology was particularly prevalent in this PD which used a Learning Management System to allow teachers to meet online, video and text chat and share their experiences of the PD program. This system was generally seen to be a positive element by the participants who found that they could develop their knowledge further through the sharing of experiences.

As it can be seen, the idea of PD becomes quite complicated in education with many studies providing conflicting results with similar approaches and ideas. Through describing the methods and results of the studies above several conclusions can be

drawn. The first conclusion is that, generally, results of studies would indicate that PD should be a continuous process rather than a single entity afforded to teachers (Duran et al., 2009, Seraphin et al., 2012). This allows teachers to maintain and strengthen confidence levels and views they may develop through the course. The next conclusion is that curriculum development tools can provide worthwhile learning opportunities for teachers, but must be developed in such a way that the teacher does not rely on them in the classroom as a primary resource in their teaching (Beyer and Davis, 2009, Duran et al., 2009). Combining PD with the context of teaching seems to provide more positive results than separating the two (Guskey, 1986, Seraphin et al., 2012). This point follows from the ideas of a continuous PD course which aids teachers in remembering practices and maintaining confidence levels. Finally the importance of teachers experience can be seen to be a primary element of PD. By enabling peer learning and development teachers can develop their practice based on the experience of others and ensure that they are adequately prepared for their lessons (Harlen, 1995, Loughran et al. 2000, 2001, Shulman, 1986, 1987, Seraphin et al., 2012).

2.4: Pedagogical Content Knowledge

In 1995 Reynolds argued that newly qualified primary teachers have limited content-specific pedagogic practices in science (Reynolds, 1995). Shulman, 1987, described how experienced teachers had a special amalgam of pedagogy and content knowledge (Shulman, 1987). This concept, known as Pedagogical Content Knowledge, was designed in order to create a link between a teacher's knowledge of their subject and their pedagogical practices (Shulman, 1986). The result, PCK, is the knowledge that a teacher uses to provide teaching situations that help learners make sense of particular content. (Abell, 2008, Berry et al., 2008, Loughran et al., 2000, 2001, Shulman, 1987). Shulman explained PCK as the "ways of representing and formulating the subject that make it comprehensible to others" (Shulman 1986). PCK is described as being specific to an individual teacher and being in a constant state of development. While this concept is defined, the analyticalization of PCK has been interpreted differently throughout the literature (Lee and Luft 2008).

The first description of PCK as described by Shulman included seven categories. These categories were:

- Content Knowledge
- General Pedagogical Knowledge
- Curriculum knowledge
- Pedagogical content knowledge
- Knowledge of learners and their characteristics
- Knowledge of educational contexts
- Knowledge of educational needs

(Shulman 1987, p.8)

It can be seen that these seven categories cover many of the attributes of teaching and learning. Magnusson et al. (1999) interpreted PCK in a much broader sense than the categories as presented by Shulman. These categories described PCK as being composed of three main areas, a teacher's pedagogical knowledge, subject matter or content knowledge and contextual knowledge. Here the teacher's pedagogical knowledge is their knowledge of the methods of how to teach a particular subject to their classroom (ibid). The subject matter knowledge was composed of their knowledge about the subject they were teaching and their contextual knowledge consisted of their knowledge of the class group and environment (ibid). This comprehensive model has been chosen as the primary model of PCK by this research as it combines all of the elements of PCK and can be easily referred to in an analysis of a teacher PCK. Veal and MaKinster expanded the categories of PCK into specific elements of PCK for the aid of future studies into the subject (Veal and MaKinster, 1999). These elements of PCK divided pedagogy into general PCK, relating to overarching teaching of all subject, domain specific PCK, relating to a specific subject being taught and topic specific PCK, relating to the individual topics within the subjects. This then divided PCK between the various elements that wished to be taught. The links between PCK and IBSE was described in Section 2.2 which will describe the specific operation of PCK with relation to science education.

A key point raised from the literature on the PCK is the links that have developed between inquiry and PCK. One of the characteristics of PCK is that it is constantly changing for a teacher as they progress throughout their career (Abell, 2008,

Loughran, 2000). This development process may be fuelled by the use of IBSE where a teacher's knowledge of a topic may be expanded by using questions to investigate an area or topic the teacher has not explored before (Bybee, 2006, Rocard et al., 2007). If a student asks a particular question regarding new science content for the teacher, the resulting research or investigation may be described as the development of specific areas of a teacher's PCK.

The Content Representations (CoRes) tool was developed in 2000 as a tool to quantify a teacher's PCK (Loughran et al, 2000). This tool was later expanded to include the Pedagogical and Professional Experiences Repertoire (PaP-ERs) tool (Loughran et. al, 2001). The tool has emerged as the primary method for describing a teacher's PCK. Due to the ever changing nature of a teacher's PCK the tool can only capture snapshots of a teacher's PCK at any time (Loughran, 2000). The CoRes and PaP-ERs tool will be utilised in this research as a method to evaluate the effect of any resources developed on the PCK of teachers within the project. Both of these tools will be described further in Chapter 3.

2.5: Case Studies on Promoting Inquiry in Primary Science

In this section, two case studies of projects promoting inquiry in primary science will be examined. These case studies are presented as part of the literature review as they serve to inform the research about the methods and practices of similar projects. The two case studies that have been chosen are the Pollen Project (Pollen, 2009) and Primary Connections (Primary Connections, 2009). Within both of these projects elements will be shown where comparisons can be drawn with this research. As both projects attempt to promote inquiry, the method and data collected will also be discussed. This information forms a specific element of the concatenation process, see Chapter 3, for exploration into Inquiry Based Science and therefore should be included in any literature review. Elements and recommendations from these projects will also be used by this research as a frame of reference for the development of the intervention.

2.5.1: The Pollen Project

Years Active: 2006 – 2009

Region: Europe

Source of Information: Main project website: <http://www.pollen-europa.net/> (Pollen, 2009)

The Pollen project was launched in Germany with 12 cities taking part across Europe. Pollen provided resources and training in methodologies which were adapted to suit the local curriculum in that city. According to pollen:

The major goal of pollen was to provide an empirical illustration of how science teaching can be reformed on a local level whilst involving the whole community

(Pollen, 2009)

The pollen project utilised many approaches in order to achieve this aim. In-service courses, lesson tools and resources were all used to develop the teacher's knowledge of IBSE and aid in its practice in the schools. The pollen project evaluated teacher attitudes and confidence in science teaching. It discovered, upon completion of the project, that while the attitude towards science education remained consistent that teacher confidence levels had improved significantly (Pollen, 2009a).

The methods used by Pollen have proven to raise primary teachers' interest, self-confidence and skills in science teaching and therefore the quality and quantity of science teaching sessions

(Rocard et al., 2007)

While this goal is in line with the recommendations within the Rocard et al. report (Rocard et al., 2007), the project is not without its shortcomings. The project isolated each city locally to investigate a different issue. For example Leicester (UK) was assigned "Science as a cross-disciplinary approach", whereas Brussels (Belgium) was assigned "Science and low-income areas". This means that while these issues were being addressed, they were being addressed in a single seed city context. The results of these issues were then applied to the development of the project as a whole. This means that an assumption was made that if an issue is addressed in a particular context this method can be applied across all contexts within Europe. Pollen did however accurately describe the concept of context within each city. A seed city was described as

An educative territory that supports primary science education through the commitment of the whole community (families, the science community and the scientific schools and research centres, local/regional authorities, local/regional representatives of the central ministries etc.)

(Pollen, 2009)

This quote shows how Pollen attempted to reform science education through a form of educational change (Fullan, 2007). Pollen produced three primary reports on its results.

Report 1 was titled: “Changes in pupils attitudes towards science”. This report evaluated students attitudes towards science in Germany, France, Hungary, Portugal, Slovenia, Sweden and the UK. This report asked students to rate, using Likert scales, the answer to approximately thirty-five questions. These questions were presented under the headings of: What do you think of being at school? What do you think of science at school? What about you and science? and What do you think of science in society? Report 2, titled “Teachers changing practice” analysed teachers’ confidence and attitudes across ten of the seed cities. Report 3: “Community Participation” reported on school and community collaboration during the project.

Interestingly, Pollen describes the outcomes of these reports as showing that the Pollen objectives have been positively achieved. It is unclear from these reports what that statement means without specific context. Report 1 displays the data that was collected from the Likert scales for each of the cities described. And while this data is provided, connecting the objectives to positive increases in the students’ attitudes is quite difficult. The highlighted data in the report does not display clearly that there is a significant increase in attitude for students between the two questionnaire attempts in the majority of cities. This therefore may indicate that only minor improvements in students’ attitudes towards science were gained through participation in the project. Report 2 however provides greater detail into the outcomes of the project. The report does show that the methods used in the project garnered significant improvement in teacher confidence levels in France with improvement in Germany, Slovenia and the United Kingdom. Supporting the statements made above, the Pollen project determined that teachers’ confidence levels can be increased in science with high

quality, long term, in-service. This report goes into further detail describing how novice teachers should concentrate on the development in science knowledge and IBSE skills. Once these have been developed a more experienced teacher may move into further development of IBSE strategies such as using the environment to improve their teaching. The final report on community collaboration resulted in a high collaboration across all countries with educational authorities, local authorities, the scientific community and parents. Cultural institutions, Non-Government associations and the private sector emerged as co-operating the least with the project.

The overall outcome of the Pollen project therefore can be described as a mixed result. While positive results were obtained in all three of the deciding reports the gains do not emerge as being significant. Several conclusions can be determined from this project. Firstly student's attitudes can be affected by the change in methodology implemented by the teacher, and that this can be positively influenced by IBSE methodologies. Secondly the conclusions about teacher confidence highlight the need for further in-service and professional development initiatives and thirdly, generally, across Europe support for community based science education lessons can be found for teachers, even with non-school related bodies.

2.5.2: Primary Connections

Years active: 2003 – 2011

Region: Australia

Source of information: Main project website:

<http://science.org.au/primaryconnections/> (Primary Connections, 2009)

Primary Connections is a project launched in Australia with an aim to enhance primary teachers' confidence and competence (Primary Connections, 2009). This project follows along similar lines to Pollen and this research by providing resources and training in teaching science through IBSE (ibid). Primary Connections adopts the 5Es teaching model in order to promote IBSE (Bybee 1997, 2006, NCCA, 2004, PrimaryConnections, 2009). Primary Connections uses facilitators across jurisdictions in Australia. These facilitators deliver workshops for the project. By using facilitators in their model, Primary Connections has reduced the need of individual teachers

travelling to them for the training. This is important when it comes to a model of PD. The teachers can contact the facilitators who can then train large groups of teachers in their jurisdiction. It is also important to note that several teachers from the one school should be involved in the Primary Connections training. The reason for this was to ensure that there are easily contactable and local support mechanisms in place for teachers using Primary Connections. The Primary Connections project not only promoted science education and IBSE but also provided a mechanism for the continuous PD of teachers through online resources and guides (Primary Connections, 2009).

As this project was developed and carried out in Australia, similarities may be drawn from the approaches of the project rather than the context. Data on the Primary Connections project was collected through teacher responses to specific questions. The answers provided by teachers were analysed using both deductive and inductive process. The deductive process included comparing a teacher's answers to three checklists; the purposes of each phase as described by Primary Connections, The 5E components and the descriptors of teacher and student roles. The inductive coding was also applied where a teacher's answer did not directly relate to the specific codes in the deductive checklists.

Due to the longitudinal term of the Primary Connections project it has developed several research outcomes and publications. As such only certain publications will be discussed as part of this case study. The described reports include: Report 1: Implementation of the 5E model; teacher feedback, Report 2: Implementation of the 5E phases; teacher feedback, Report 3: A constructivism lens on Primary Connections and Report 4: The inquiry focus in Primary Connections. The results of Report 1 provide insights into the implementation of the 5E model as a whole. The significant outcome of this report found that few teachers found any weaknesses with using the 5E model in their teaching. Any limitations described specified that there were issues with the content of the units that had been developed rather than the 5E method. Teachers generally recorded positive impacts with students learning and student's attitudes toward science. This report did highlight that some of the issues that can be associated with the implementation of the 5Es into teaching are teachers eliminating one or more of the phases, teachers inappropriately implementing a phase and the

time allotted for science education. When looking at Report 2 the primary findings indicated that each of the 5E phases were appropriately implemented with teachers being adequately prepared and knowledgeable about the outcomes of each phase. One interesting outcome arose with relation to the Evaluation phase. This result found that, in several instances, teachers did not complete the evaluate phase as part of a lesson, a finding which was not found with the other phases. Teachers were however found to carry out their own evaluations of the students learning, outside of the prescribed methods. This could highlight that teachers were not comfortable or confident at implementing evaluation activities but this is not addressed in the publication. Report 3 and Report 4 had similar findings due to their connected nature. The outcomes of these studies found positive student responses to the application of both constructivist and specifically inquiry methodologies. These responses relate both to the application of the constructivist lesson and the students attitude upon the conclusion of the lesson. Interestingly, the concentration of the constructivist ideals is placed on the central idea of evidence in teaching in the Primary Connections report. This idea ensured that students were working with evidence at all times in their learning to enable specific and clear learning to occur.

As stated previously, the large nature of the Primary connections project has allowed data to be collected on many varied topics including the reports described above as well as several others. The four reports selected above were chosen due to the relative comparisons of the nature of their subject to this research. Overall the Primary Connections project has shown how the implementation of a Professional Development course using the 5E framework in Inquiry based lessons can have a positive influence on teaching and learning in science.

2.5.3: Overall Case Study Results

As it can be seen both the Pollen project and Primary connections present valuable information when it comes to research into the field on IBSE. By understanding the approaches, methodologies and recommendations that have been developed from these large projects, research can be developed into the subject that accounts for many

of the issues viewed in these projects. Also attempts can be made to draw comparisons and contrasts on the results of research to these projects.

2.6: Chapter Summary

This chapter has analysed the literature relating to several different areas which relate to the promotion of IBSE in Irish primary science. The chapter began by describing the history and philosophy of constructivism. Constructivism was described to be very difficult to describe and categorize. While this is the case it is actively being promoted by the DES in the Irish primary science curriculum (D.E.S., 1999). This was then built into the development of IBSE from its constructivist roots and IBL basis. As recent research has been promoting the use of constructivist, and more specifically inquiry based, methodologies a description of each of these methodologies was provided (Fenshaw et al., 1994, Rocard et al., 2007). The identification of inquiry as the primary focus of this research raised several questions, such as what is the nature of IBSE, which was describe through its definition, approaches, components , advantages and disadvantages. IBSE was shown to have no strict definition that can be applied to all research (Anderson, 2002). The description of inquiry by the Rocard et al. report was identified to be the most appropriate definition that could be applied to this research due to its publication in such an important document promoting IBSE (Rocard et al., 2007). This also allowed for several of the components of IBSE to be identified and described by this research. The 5E method of teaching was identified to be the best fit approach to IBSE for the purposes of this research (Bybee, 1997a, 2006, BSCS, 2006, Primary Connections, 2009). Finally, while IBSE was shown to have advantages and disadvantages, the promotion of IBSE by the NCCA and the Rocard et al. report ensured that IBSE was selected as the methodology most suited to aiding in the practice of science education in Ireland (Rocard et al., 2007, Varley et al. 2008a, 2013).

From here the concept of Educational Change was described a concept which must be considered when any type of educational intervention is being considered (Fullan, 2007, Metz, 2009). The concept of educational change attempts to ensure that any reform of practice can succeed because it will consider the needs of the stakeholders

in the educational process. In this section the driving forces behind the need for educational change in science education was discussed as well as methods of supporting educational change. The methods of supporting education change included a discussion on Professional Development as part of this research (Beamer et al., 2008, Duran et al., 2009, Seraphin et al., 2012, Wee et al., 2007). The concept of Professional Development was mentioned in the recommendations of several recent important studies such as the NCCA report and the Rocard et al. report as a method to support educational change (Rocard et al., 2007, Varley et al. 2008a).

Building on this idea, the concept of Pedagogical Content knowledge was introduced. This concept was introduced early in the chapter as it forms a basic construct in this research. PCK is described as the ever changing knowledge that a teacher has about their field (Abell, 2008, Berry et al., 2008, Loughran, 2000, 2001, Shulman, 1987). This includes knowledge of pedagogical practices, science content knowledge and knowledge of the context in which they teach. The concept, like educational change had to be considered early in this research as it would ensure that the appropriate considerations were being made in the research methodology.

Included within this chapter were two case studies which were described of studies that aimed to implement an inquiry based approach to teaching in Europe and Australia (Pollen, 2009, Primary Connections, 2009). The outcomes of these case studies showed positive effects in several areas of promoting IBSE and these will be considered in the approach dictated by this research.

As it can be seen there are many facets relating to an exploration of Irish primary science which show that, while science education faces many issues and challenges, by encouraging current, relevant pedagogies such as inquiry many of these issues can be addressed and the teaching and learning of science can be improved.

Chapter 3: Research Methodology

Researchers explore when they have little or no scientific knowledge about the group, process, activity they want to examine but nevertheless believe it has elements worth discovering

(Stebbins, 2001, p.6)

This chapter describes the research methodology that was followed in this work. The chapter will begin by reviewing the research questions detailed in Chapter 1. This investigation is primarily qualitative in nature and Section 3.2 will detail this approach. Section 3.3 will describe the case study approach that was used. Moving from the theory to the practice, the research methodologies employed will then be described in reference to the chapters in this thesis where they were applied. These methodologies will be divided amongst the three key stages of the investigation: the contextual analysis, the professional practice and the synthesis stage.

3.1: Review of the Research Questions

Question 1: What is the nature of IBSE and how is primary science education practiced in Ireland?

This research reviewed many literature sources in the field of primary and elementary science education. As it has been shown in Chapter 2, IBSE emerges from the literature as a promising methodology when attempting to improve knowledge and understanding in science education. By comparing the practice of science education in Ireland with the practice of IBSE, conclusions can be drawn as to whether Irish primary science teachers naturally utilise IBSE, whether their practice is mainly didactic in nature or whether there is a mix of the two. The comparison of results will then lead to a thick description (Holloway, 1997) of the practice of science teaching in Irish primary science education.

Question 2: What contextual factors play a role in Irish primary science which can affect the implementation of IBSE in the classroom?

The second question delves deeper into the nature of Irish primary science education by identifying the key factors and issues that affect its practice and development. Here the target

of this research moves beyond the literature and practice of science education into elements of teacher education. By answering this question, knowledge of what factors affect the implementation of IBSE in the classroom will be developed. Using this knowledge, a professional development tool can be developed which attempts to account for as many of these factors as possible. The methodologies which were employed to answer the second question include semi-structured interviews, observations of practice and content analysis.

Question 3: What kind of intervention can be synthesised to support and encourage the ideals of IBSE while accounting for the issues and factors in Irish primary science education?

Answering this question involves utilising the results and findings of the first two stages of this exploration to develop a form of lesson intervention that emphasises the nature of IBSE and, at the same time, accounts for the specific issues and factors related to introducing IBSE into the Irish primary science.

The above research questions highlight the predominantly exploratory nature of this research project. In order to inform the exploration, a case studies approach combined within the three stages of the research allows this research to be used as a template for the future promotion of IBSE in primary science.

3.2: Qualitative Research

Dillon and Wals describe how a researcher must consider the ramifications of the research strategy that they choose (Dillon and Wals, 2006). They classify three strategies for research; the use of quantitative, qualitative or a mixed method of research (ibid). Qualitative research is concerned with understanding “individuals’ perceptions of the world” (Bell, 1993, P6), i.e. seeking insight instead of statistical analysis. Quantitative data is data which can be ordered in terms of magnitude and is typically empirical in nature (Schutt, 2006). Schutt (2006) highlights the distinction between qualitative and quantitative i.e. the data collected in qualitative research is typically text rather than numbers. It must be noted that many researchers qualify that quantitative and qualitative data collection can be carried out in unison and that they are not mutually exclusive (Bentley et al., 2011, Bryman, 2008, Flick, 2002, Schutt, 2006, Silverman, 2006)

Lincon (2010) describes how the emergence of Qualitative research occurred in the 1970's as a combination of new paradigms, postmodernism, feminist theories, ethnic theories with action and participatory research which have led to

- Deep studies of teaching, learning, and teacher practices
- Deep and publicly accessible studies of hidden and oppressive infrastructures in our public schools
- Thoughtful, trenchant, meticulously documented and damning studies of the effects of racism, gender discrimination, and classism—in society, in the public schools, in higher education

(Lincoln, 2010, p.4)

Snape and Spencer (2003) describe this emergence in the 1970's as being due to debate on the legitimacy of social research based on 'scientific method'. Here they state how social research cannot account for control variables due to the nature of the research being carried out. They also argue that the scientific method eliminates contextual variables, the idea of purpose, the application of world theories all which have an effect on the social research that is being carried out (ibid).

There is a general consensus on the features of qualitative research. Flick (2006) describes, appropriate methods, participant perspective and diversity, reflexivity of the researcher and a variety of approaches as being the key features. Snape and Spencer (2003) also describe the idea of taking the participants perspective, a flexible strategy and mixed methods of data collection as key features. Schutt (2002) presents ideas of inductive reasoning, an orientation to the social context, a focus on human subjectivity and the use of idiographic causal relations. These features, when combined, ensure that any qualitative research will be able to determine the relationships and patterns that are present in the social construct that is being analysed.

The concept of phenomenology, or the development of a shared meaning, is observed to be a key feature throughout the literature on qualitative research (Flick, 2006, McCaslin and Scott, 2003, Schutt, 2002, Snape and Spencer, 2003). Relating to the features listed above, phenomenology can be described as a consideration of the perspective of the participant (ibid). Participant perspective involves accounting for the contextual factors, or the participants' "life experiences", that influence the participant in order to understand the

reasoning behind the actions or ideas they present in the data (Flick, 2006, Schutt, 2002). Understanding these contextual factors will lead to the development of a "shared meaning" of the research participants. Within the context of this research, developing this shared meaning should involve any stakeholders in the educational process (Fullan, 2006). These stakeholders are people and groups which have an influence on the participant and can affect how the participant acts (ibid). The concept of "life experiences" in education is also identified by the description of the Gestalt (Korthagen, 2010). The Gestalt is a holistic idea of formation of responses based on experience and cannot be described through empirical methods (ibid). Therefore the use of qualitative methods can lead to the development of causal relations from a shared meaning which can describe how participants respond to situations.

Another feature of qualitative research is a flexibility to reflect on the data collected and to adapt process or methods to refine studies further (Flick, 2006, Schutt, 2002, Seale, 2002, Snape and Spencer, 2003). By remaining flexible this research will attempt to ensure that all considerations in the observations, such as context, content and actions are represented fairly in the data analysis. While this is the case, there are concerns about the validity of qualitative data collected in research, as much of the data is subjected to the researcher's interpretation of events (Bryman, 2008, Schutt, 2006). While developing shared meanings, the research participant can arguably create more contextually aware data however, these meanings are based on the researchers interpretation of that data collected. This is also the case where any causal relations described in the research may also be subjective. Indeed, the role of the researcher may lead to value laden judgements being applied throughout qualitative research (Bryman, 2008, Flick, 2006, Schutt, 2002, Seale, 2002). When considering research, a researcher must account for the ethical considerations within the research. Christians (2005) describes four features that must govern research for it to be deemed ethical. Within these features is accurately representing the data that has been collected (ibid). The use of value-laden judgements could therefore compromise the ethics and the validity of the research. Indeed through the thorough consideration of the validity of the research the use of value laden judgements, and therefore the perspective of the researcher, should be eliminated from any qualitative research. The validity of this research will be described in section 3.2.1.

Schutt describes a grounded theory as the aspiration of much of qualitative research (Schutt, 2006). A grounded theory is "to build up, inductively, a systematic theory that is "grounded" in, or based on, the observations" (Schutt, 2006.p. 348). This means that a theory of practice

can be developed through observation which understands the nature of the subject. The development of a grounded theory is a continuous process with constant refinement of the data that is being analysed (Flick, 2002, Schutt, 2006). Both Flick (2002) and Schutt's (2006) descriptions of a grounded theory are based on the idea of observation. In the development of a grounded theory, data should be analysed for its relevance to the research topic rather than the "representativeness" to a theory (Flick, 2006). As such, the development of a grounded theory therefore attempts to include as much relevant data as possible, including contextual information and methods (ibid). Urquhart et al., (2009) describe how a grounded theory approach has proven useful in the development of context-based, process-orientated systems. This is of particular relevance to this research where IBSE, and its parent constructivism, were also shown to be context dependant and process-orientated in Chapter 2. Therefore the aim of developing a grounded theory aligns with the methods and ideas presented in this research.

This research will serve to inform the development of a grounded theory but will not specify the theory that has been developed. This is due to the level of theory that can be developed from the research. A grounded theory is a substantive collection of data from the research subject which has been verified throughout the research data collection (Strauss and Corbin, 1994). The theories that are developed as part of this research will not be verified throughout but instead presented at the conclusion of the research. Therefore, while this research shares similarities with a grounded theory approach it cannot be considered one (ibid). Instead, the primary approach of the research is described as an exploratory case study, which will be described in Section 3.3.

Figure 3 describes the considerations that have taken place in this research. Specifically the figure highlights how IBSE in Irish primary science will be described through a consideration of current research, contextual factors and current practices. The consideration of current research has taken place through the literature review. The contextual factors are informed through studies of teacher educators, teacher education and a study carried out on textbooks. Current practice is also considered through observations of practice and an analysis of teachers PCK. This approach adds to the credibility of this research as it considers many of the stakeholders that have an impact on primary science education. All of these headings combine to inform the data and create an idea of the grounded theory of science education in Ireland which will be used to develop the intervention. It must be noted that this research

does not specifically aim to describe a grounded theory but will instead use its construct as a guiding principle in the data collection.

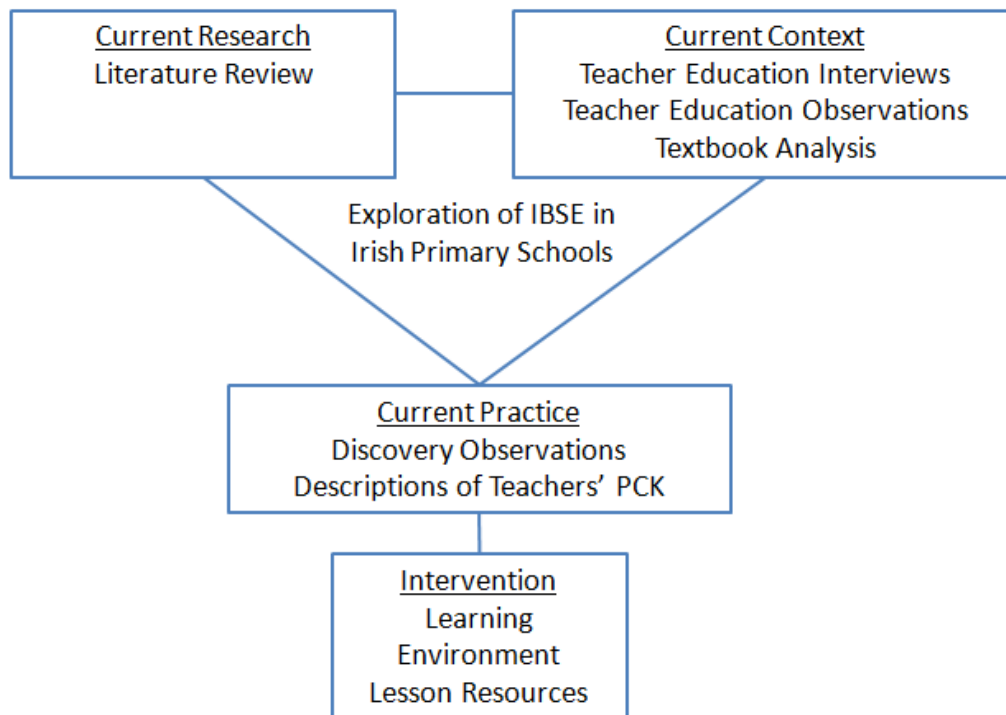


Figure 3: The approach of this research

Diamond et al. (1997) describe how taking the perspective of the research participants is "crucial to qualitative inquiry". This relates to the way the researchers view the data collection. If the researcher does not understand the context of which they are observing then they cannot extrapolate elements of contextual data from the observations. Chapter 2 detailed the pedagogy of constructivism which underpins this entire research. Within this section, it was described that constructivism can take many forms but that a social constructivist approach would be the primary focus of this research (O'Loughlin, 1992, Osborne, 1996, Rodriguez, 1998, Staver, 1997). This approach, however, does not lend itself to the collection of data which can be ordered in terms of magnitude. Instead a qualitative approach must be used to gather and analyse data for patterns to understand the practice of science teaching in Irish primary schools. It must be noted that quantitative research is also relevant to the study of constructivism. However quantitative data can neglect the context and interpretation of the observations collected. Bentley et al. (2011) describes how when research is analysing a change in behaviour, with the aim of developing a form of intervention, then the research requires an underlining theory or framework. It has been discussed previously that the 5Es

model of inquiry has been chosen as a framework within this research (Bybee, 2006a). It will be shown in the data analysis that the descriptions present in Table 2 were not specific enough to be applied with this research. Flick (2006) describes how flexibility is one of the key features of qualitative research. The 5E model was therefore developed into an analytical framework, described in Section 5.2, which was specifically defined for the data analysis as part of this research.

Bentley et al (2011) also describe how, independent of the research that is taking place, any qualitative research should have a "systematic approach and a defensible research design". She categorises three primary considerations to a systematic approach to data collection; the setting, the source and the sample. The setting relates to the context of the research (ibid). As shown, the considerations in developing a grounded theory ensure that the context of the research subject is properly accounted for. While Bentley et al. (2011) describe the source of the data coming from a multitude of media, such as text, audio and video, Flick (2006) argues that secondary data sources can lead to presumptions in the data analysis. Again this is accounted for in this research where the researcher will be present during the data collection as well as the data analysis. Bentley et al, (2011) described how qualitative research often has difficulties selecting sample sizes. Stebbins (2001, p.27) proposes that approximately thirty cases are required to allow for the inductive approach of exploratory research to move from tentative hypothesis to theory with confirmatory power. This is rarely undertaken in research in the social sciences/humanities and Stebbins (ibid.) argues that this significantly undermines the knowledge claims of these domains. The methodology of this research then begins the process of concatenation in developing a tentative hypothesis regarding the nature of IBSE in Irish primary schools and in so doing invites other researchers to add cases employing the same methodology towards theoretical saturation. Stake (1995) argues that a limited number of case studies may produce "petite generalizations" but also that even a single case can allow those working in the field of study to learn much. This can also allow for "naturalistic generalizations" which are "conclusions arrived at through personal engagement in life's affairs or by vicarious experience so well constructed that the person feels as if it happened to themselves" (ibid, p.85). This argument means that a small sample size can still be used within qualitative data analysis to develop generalizations but only if the samples are analysed thoroughly.

3.2.1 Research Validity

As with any research into education the issue of research validity must be discussed. Schutt (2006) states "We have reached the goal of validity when our statements or conclusions about this [...] reality are correct" (Schutt, 2006, p.19). Therefore research can be considered valid when the statements made about a research subject are determined as correct. This however, raises an issue with social science research whereby data can be interpreted differently by different researchers. Arguing for the credibility for this research methodology, Bryman (2008) describes research as being valid through repetition. If the data is analysed by the same method, then the results should be repeated (ibid). While this could be easily proven with quantitative data, the concept can still relate to qualitative data. If this research is to be determined as valid then the interpretations of the qualitative data must be determined to be empirically correct and this can be done by achieving the same results if studied using the same tool. In order to identify whether research is valid or not, Schutt (2006) and Bryman (2008) provide four characteristics of research validity: Measurement Validity, Generalizability (external Validity), Causal Validity (Internal Validity) and Authenticity (Ecological validity). Measurement validity is concerned with the idea that the measurement tool measures what it has been designed to measure. Generalizability relates to the extent a sample can be determined to be representative of the general population group. Causal validity refers to the truthfulness of statements and authenticity relates to statements being representative of the data collected. Silverman (2006) relates "Credibility" to the validity of research and the reliability of the data collected.

It has previously been argued that science education is currently facing difficulties (Appleton and Kindt, 2002, D.o.E., 2006, Harlen et al. 1995, Murphy et al., 2007, Rocard et al., 2007, Varley et al., 2008a, 2008b, 2013, Waldron et al. 2009). While the requirement for reform needs to be addressed the relevant educational change factors must be considered for any reform to be successful. Relating to this research, the validity emerges from the analysis of the major factors influencing educational reform. This analysis is developed through the extensive contextual study which partners literature analysis, observations of practice, observations of initial teacher education and the analysis of teaching resources to develop an in-depth and current view of science education in Ireland. Ensuring the reliability of this research is the systematic research methods that are described throughout this thesis. The methodological considerations for each of the methods will be described from Section 3.4 onwards. As the research is developed through so many individual methods, it was important

that each study was developed with its own considerations. This would ensure that any data collected could be developed further combining it in the concatenation process. This therefore verifies the credibility of the research as throughout the research methodology the ideas of validity and reliability are considered.

The development of a Grounded Theory may create issues when considering the validity of the research, as the categorizations that are developed must be scrutinized to ensure that they are appropriate for the research. This is of particular concern to this research whereby the primary data collection is developed through observations. Flick (2002) highlights how grounded theory gives preference to the data collected over the theoretical assumptions in the research. Flick quantifies this statement by highlighting that if a researcher abandons the theoretical assumptions then the research may reduce its relevance in that field (ibid). If research concentrates on the data alone, it also lends itself to criticisms over the data analysis method. Flick (2002) highlights the following issue with relation to data collection:

Decisions on data to be integrated and methods to be used for this are based on the state of the developing theory after analysing the data already at hand at that moment.

(Flick, 2002, p.42)

This means that data analysis methods can only be scrutinised for validity after the data has been collected, an issue which cannot be overcome. Therefore it is up to the researcher to ensure that the analysis method is continually examined for validity rather than the data collection method. Stake (2006) also argues that a ground theory can only be developed through a cyclical analysis of the categorizations that are being considered in the research. By continually analysing the categorizations the research can ensure that the research is applicable to the field and that it maintains its validity. Returning to the approach carried out in this research, it becomes apparent that the research method must consider theories and hypotheses of inquiry in primary science education, do not allow these hypotheses and theories to influence data collection and finally to continually re-examine the categorizations of data collection to maintain their relevance and validity to the field.

As it will be shown in the methodology presented, the primary tool used for the categorization of this research is the 5Es analytical framework which will be discussed in Chapter 5. This framework was developed from the 5Es model, a model which is consistent

with the structure and process of Inquiry in education, as shown in Section 2.2. While it has been shown that the 5E model is an accepted model for the development of inquiry lessons, it was not assumed to be valid for the purposes of this research. In order to ensure its validity, this model was analysed with relation to the needs and processes involved in this research. Indeed, it will be described in the textbook analysis, Section 4.3, that the analytical framework was developed using the 5Es model concurrently to the textbook analysis. It became evident when analysing the textbooks that the definitions used in the 5E model, see Table 2, may lead to ambiguous definitions of the purpose of each activity in textbooks. Therefore the 5E model was re-examined to define its purpose and structure in the form of an analytical framework. This framework was then used to categorize a coding structure that was used to analyse the textbooks. Again it was found that there were ambiguities in the structure and the analytical framework was redefined. This method of cyclically applying the framework and coding to the textbooks refined the framework into a set of specifically determined codes that could then be applied throughout this research. It must be noted that while the coding structure was applicable to the textbooks, it was again re-examined with the analysis of the observations. This led to the framework and coding structures being further refined, ensuring that they remained valid to the data collection in this research.

When carrying out research quantitative data can reduce many of the issues of research validity. For example causal relations are easier to depict with quantitative data than the interpretation of a researcher's qualitative data. Cohen et al. (2000) argue that a mixed method approach is more suited to studies of human behaviour. Indeed if mixed methods are utilised in research and they identify similar results then the validity of the findings can be confirmed (Silverman, 2006). Therefore this research comprised a mix of qualitative and quantitative methods. Using multiple methods to carry out research is known as triangulation (Schutt, 2006).

3.2.2 Research triangulation

Research triangulation is the convergence of truth from data (Adami and Kiger, 2005). Denzin and Lincoln state that triangulation "reflects an attempt to secure an in-depth understanding of the phenomena in question" (Denzin and Lincoln, 1994, cited in Adami and Kiger, 2005). Many researchers would argue that this in-depth understanding is best identified through the use of a mixed method of data analysis (Bentley et al., 2011, Flick, 2002, Schutt, 2006, Taylor and Wallace, 2007). As described previously, qualitative research

can lend itself to queries into research validity (Bentley et al., 2011, Bryman, 2008, Flick, 2002, Schutt, 2006, Silverman, 2006, Taylor and Wallace, 2007). The use of empirical data in qualitative research eliminates many of the validity issues such as interpretation (Bentley et al., 2011, Flick, 2002, Schutt, 2006). In order to address the issues with validity this research used a triangulation approach. The mixed methods that were employed in this research are described from Section 3.5 onwards. These methods are divided amongst the three primary stages of this research, the contextual analysis, the analysis of professional practice and the development of the intervention. Each of these sections will now be described with relation to the triangulation approach that was employed as well as reference to the validity of this approach.

For the contextual analysis, described in Section 3.5, both qualitative and quantitative elements were used to improve validity. Concerning the teacher educator interviews, the validity of these interviews was improved by capturing opinions of a relative large sample set of teacher educators, ensuring the results could be generalized. Accuracy is also ensured as the interviews were representative of the teacher educators, who would have had no reason to be untruthful. There may have been issues with measurement and bias in the interviews. In order to reduce the issue with measurement the interviews were designed to be semi-structured, allowing for the researcher to rephrase a question if it was misinterpreted. Also, while there is an issue with bias in one of the questions, it is actively acknowledged within the research, and there are no impacts to the data because of this bias. The observations of pre-service education were based on the interpretations of observations of the primary researcher. In order to ensure validity these observations were assessed by the lecturer to ensure that no area was misinterpreted. The lecturer agreed with each point that will be described. Finally the textbook analysis used qualitative data and a blind coding method to ensure validity. The blind coding method ensured that the results were repeated before the measurement tool was applied throughout the study.

The sections relating to professional practice, Section 3.5, and the intervention, Section 3.6, employed similar methods. These included qualitative observations combined with quantitative coding. The discovery and intervention observations were observed and interpreted by the primary researcher. In order to remove any bias or personal interpretations the analytical framework was then used to code the observations. This ensured that when a statement was made by the researcher it was verified by the data collected. So, for example, if

the researcher stated that the lesson comprised a majority of Engagement activities, this could be verified by the coding applied. Blind coding was also employed to ensure that the measurement tool was accurate before the data analysis began. The PCK studies also included a triangulation of qualitative and quantitative methods. The CoRes tool has been verified through many research projects as a tool to capture snapshots of PCK (Berry et. al. 2008). The interpretations of the CoRes were also verified by the teachers who were asked to identify if an error in interpretation had occurred. The credibility of the data collected was ensured through the methods that were employed. By video recording observations, the data collected could be continually assessed and referred for different elements. This reduced the issue of the researcher omitting element of the lesson due to time passing or misinterpreting the data during the observations.

As it can be seen this research attempted to account for many issues in validity in social science research. The triangulation approach including qualitative and quantitative data allowed for qualified statements to be made on the various observations that form the majority of the data collection. The tools employed were also verified by blind-coding methods where possible. The area of concern in relation to this research applied to generalizability. Generalizations cannot be made about the entire teaching community based on the observations of these four teachers, however, as described previously, Stake (1995) describes "petite generalizations" which are generalizations that can be made on a small number of case studies which capture a large quantity of data. This case study approach will be discussed in Section 3.3.

3.2.3: Exploratory Research

Snape and Spencer (2003) describe how there is no simple, accepted way of doing qualitative research. McCaslin and Scott (2003) propose a five question method to decide whether a researcher should carry out a Biography, Phenomenology, Ethnography, Case Study or Grounded Theory. Demetriou (2009, p.203) highlights the value of the case study design, which is generally qualitative in nature, in that it is "versatile" and it facilitates understanding of "a complex issue or object and brings with it a familiarity to the case that no other research approach is able to do". This research seeks to develop a "thick" (Holloway, 1997) description of the nature of IBSE in Irish primary schools in order to inform future efforts for teacher professional development in primary science. The guiding philosophy and methodology of this work, therefore, is Exploration which Stebbins defines as:

Social science exploration is a broad-ranging, purposive, systematic, prearranged undertaking designed to maximise the discovery of generalizations leading to and understanding an area of social or psychological life. Such exploration is, depending on the standpoint taken, a distinctive way of conducting science – a scientific process – a special methodological approach (as contrasted with confirmation), and a pervasive personal orientation of the explorer. The emergent generalizations are many and varied; they include the descriptive facts, folk concepts, cultural artefacts, structural arrangement, social processes, and beliefs and belief systems normally found there.

(Stebbins, 2001, p.3)

As it can be seen from the quote at the beginning of this chapter, exploratory research is suited to studies where there is only a small body of knowledge available on the subject. Investigations of Irish primary science are confined to one primary source, which is the NCCA study introduced in Chapter 1 which is predominantly quantitative in nature.

The quote also states that exploratory researchers believe there is something worth discovering. This work aims to discover and analyse evidence of IBSE in Irish primary schools and as such represents what Stebbins (*ibid*) describes as a form of “limited” exploration where there is a specific focus in the exploration. Exploratory research, being strongly linked to Grounded Theory (Glaser and Strauss, 1967) is primarily inductive in nature where observations lead to identification of patterns of categories and which in turn generate tentative hypotheses. If research design allows for the significant accumulation of data this may in time lead to theory development which has confirmatory power. Stebbins (*ibid*, p.5) refers to this as the process of “Concatenation” and argues that “early weaknesses in sampling, validity, and generalizability tend to get corrected over the course of several exploratory studies”.

Stebbins (2001) argues that the most significant form of exploration occurs at the beginning of the longitudinal concatenation process where categories and patterns are identified that are further refined and grounded in subsequent cases. This implies a role for the researcher as “Interpreter” (Stake, 1995, p.97) who seeks to make these patterns comprehensible to others. While this is the case it is critical that the researcher needs to “...liberate the reader from simplistic views and illusion. The researcher is the agent of new interpretation, new knowledge, but also new illusion.” (Stake, 1995, p.99). Stake continues to argue that this recognises the essential nature of human knowledge as constructed rather than discovered.

The researcher then is cognisant of the fact that he is not engaging in a simple process of exploration but rather that the patterns and categories that emerge from data interpretation are a function of his lived experience. Conscious of this every attempt has been made to enhance the credibility of findings, as described below.

This work seeks to begin this process of the exploration of Irish primary school IBSE through a series of case studies of Irish primary school teachers. According to Stake (1995, p.3) this represents a form of “instrumental” case study where particular cases may illuminate a “puzzlement, a need for general understanding”. It is hoped that the findings presented here will help to reduce anecdotalism about the practice of IBSE in Irish primary schools through deepening an understanding of same. In recognising the potential power of naturalistic generalisations for professional practitioners and cognisant of Fullan’s warnings that educational change depends on “what teachers do and think – it’s as simple and as complex as that” (Fullan, 2007, p.129) and that teachers are most convinced by the practices of other teachers (ibid., p.133), much of the findings of this work have been synthesised in the intervention. The researcher would like to note the potential for this intervention to scaffold and support the concatenation process towards developing a Grounded Theory of primary school IBSE in Ireland which is reflective of the contested nature of IBSE (see Section 2.3) and its cultural representation in Ireland.

3.3: The Case Study Approach

3.3.1: The Case Study

In order to identify the key factors and science education practices in Ireland it was decided that a case study approach must be utilised. The case study would form a descriptive report of the practice of the participant teachers in order to identify natural elements of their practice which align to the methodology of IBSE. Abercrombie et al. define the case study as

The detailed examination of a single example of a class of phenomena, a case study [...] may be useful in the preliminary stages of an investigation as it provides hypotheses, which may be tested systematically with a larger number of cases.

(Abercrombie, Hill and Turner, 1984 cited in Flyvbjerg, 2006 p.220)

This methodology therefore suits the development of this research as it aims to provide the basis of the exploratory research methodology and form basic stages in the concatenation process.

Flyvbjerg describes how there are five common misunderstandings about the methodology of a case study (Flyvbjerg, 2006). These five misunderstandings are listed as

“Theoretical knowledge is more valuable than practical knowledge
One cannot generalize from a single case
Case studies are the most useful for generating hypotheses
The case study contains bias towards verification
It is often difficult to summarize specific case studies”

(Flyvbjerg, 2006, p.219)

The exploratory nature of this research eliminates the need to expand upon the third, fourth and fifth misunderstandings. In this research case studies are not being argued as the most useful methodology, the data analysis also attempted to eliminate any bias towards verification and any difficulties in summarizing the results. Flyvbjerg argues that case studies can form a valid practical knowledge of a subject rather than only developing a theoretical knowledge (ibid). This is particularly relevant to this research where the case study both informs and is developed from a practical knowledge. While this research has multiple case studies of teachers it could be theorized that a sample set of four participants is not large enough to develop generalizations about a subject, as argued by Stebbins (Stebbins, 2001). Flyvbjerg again challenges this misunderstanding, stating that generalizations can be developed on a subject using just one case study from a carefully selected participant (ibid). As it will be Section 3.2 the research participants for this research are all practicing teachers of science; have an interest in the promotion of science and have been teaching for many years, their experience therefore validates their use as case study participants.

It was decided that observations of practice would form the basis of these case studies (Stebbins, 2001). Friedrichs (1973) classifies observational procedures under five categories:

Covert versus overt observation
Non-participant versus participant observation
Systematic versus non-systemic observation
Natural versus artificial situations
Self observation versus observation of others

(Friedrichs, 1973, cited in Flick 2002)

The case study approach that was chosen for this project would consist of an overt, non-participant, systematic, natural observation of others (ibis). Schutt describes several ideas that must be accounted for in the practice of qualitative case studies (Schutt, 2006). As these case studies aimed to capture the natural method of practicing science teaching each of these ideas had to be addressed. These ideas consist of the role of the observer, entering the field, developing relationships, sampling and the recording of data.

The role of the observer for the purposes of this research was chosen to be an overt observer. An overt observation is carried out when the researcher announces their roles as a research observer to the participant (ibid). One of the issues with overt observations is the idea of reactive effects. Reactive effects consist of a change in the manner or practice of the participant caused by the presence of the observer. Selecting an alternative methodology of case study was not applicable to this research however. Covert observation is the observation of a participant without their knowledge. It benefits the case study approach as it means that the participant responds naturally in their field. The idea of covert observation would have created both ethical and logistic issues of recording teachers in their classrooms without their knowledge. Therefore overt observation was the only ethical observation method for this research. Efforts were made however, to convey that the teachers should act as naturally as possible around any observer or equipment in the classroom. It could also be theorized that if the participant teachers did not teach naturally in their observations, that this could signify how they believe science education should be practiced. This again reduced concerns in the validity of the observation approach used.

The next issue involved with a case study, according to Schutt, is the idea of entering the field (Schutt, 2006). This was another area of concern for the data collection in this research. Firstly in order to adequately account for the contextual factors facing teachers it was decided that all observations, within this research, would have to be carried out in the natural environment of the participant. This involved carrying out all observations in the school of the participant. This created further logistic issues as it would mean being present for the lessons with students present. These students would be aware of the presence of the observer in the classroom and then, possibly not react normally to the teaching situations. Schutt describes a method to reduce this impact by allowing the participant to introduce the observer to the environment. This method was used and reduced the impact of the students having a

“stranger” observe them in the classroom. The natural reactions of the students were not a primary component of this research which aimed to analyse the lesson as a whole for elements of IBSE.

The relationship with the participants was another consideration for the case study approach. It was important that the participants in this case study would feel comfortable carrying out natural teaching practices in front of the observer. As described by Flick, the role of the observer in the field can be classified under four headings; Stranger, Visitor, Initiate and Insider (Flick, 2003). The goal of the case study observations was to maintain a visitor presence in the classroom. This would reduce impact to the natural teaching as it would maintain an observational role rather than a participant role to the observer. Schutt also describes how every action the researcher takes can develop or undermine the relationship between participant and observer (Schutt, 2006). It therefore became a policy that the relationship between the observer and the participants would be developed outside of the observations so that the observations would remain as naturalistic as possible.

The final issue to any case study approach is the sampling and recording of data. This issue has elements of the previous issues intertwined with it in terms of naturalistic observation of practices. Efforts were made to ensure that the recording of data created as little impact on the classroom environment as possible. The research participants were also reassured that the data collection was not grading their performance but would be used to recall the lessons for data analysis. This would also account for teachers redeveloping their practice for the observations as there would be no benefit awarded to the teacher. As it can be seen many efforts and considerations were placed into the case study methodology to ensure that they were as close to an overt, non-participant, systematic, natural observation of others as possible.

3.2.2: Case Study Participants

Of the four participant teachers that volunteered for this research three teachers were based in Limerick and one was based in Dublin. The teachers selected each taught science to different class levels and were from different schools. All of the teachers are current practicing teachers with various levels of experience and education in science. While the research was

originally designed for more than four participant teachers, it has been previously argued that case studies with one participant could develop petite generalizations (Stake, 1995). The research was therefore redeveloped to ensure that the maximum amount of data could be identified from fewer, in-depth, cases rather than a broad overview from many cases. In order to maintain anonymity the research participants will be labelled Teacher A, B, C and D.

3.2.2a Teacher A:

Teacher A was a primary school principal in a rural school in Limerick County. This school combines several class groups in one room and the teacher taught a combination of fourth, fifth and sixth class students. This presented a challenge for this teacher to ensure that the lessons could cover all three years and that lessons weren't repeated for the older years. This also allowed the teacher to ensure groups consisted of students from the different years to encourage peer learning, an idea that will be revisited throughout this research. The class consisted of approximately twenty students. The teacher had a keen interest in teaching and learning and also an interest in science as a subject. She was a practicing teacher at the implementation of the new curriculum and had carried out the allocated science in-service. She stated that, in 2009, she had no memory of what was taught at the in-service. This teacher however, frequented non-department in-service in the Limerick Educational centre. The teacher regularly discussed what courses she was completing and expressed interest in the project as a way of improving her teaching in science as well as a sounding board for discussing her own further education.

Through the course of the research she also began a taught Doctorate of Education. This was being completed in St. Patricks College, Dublin. The teacher however, admitted that she had never encountered the idea of inquiry based teaching, but that her teaching closely matched the ideas promoted by it. Being a principal also meant that her classrooms were frequently disrupted by phone calls, teachers and other students. The teacher however, ensured that her class were aware of her dual role and that the disruption to any lessons was limited by ensuring the students had an activity to complete.

The classroom where the lessons took place was a standard classroom with a sink area for cleaning up and a teacher computer. The teacher displayed several educational posters on the walls for the students to see. Attached to the classroom was an area for extra equipment, which included general science equipment.

3.2.2b Teacher B:

This teacher taught first class students in a large primary school in a suburb of Dublin city. The school is segregated into a separate girls and boys school, and the teacher taught in the girls section. Teacher B was close to retiring age and also admitted to the researchers that, while she would love to do a proper course in science, she did not feel that she had it “in her” to do it. This teacher stated that she had a keen interest in science and improving her science teaching. She initially stated that she does not feel confident teaching science to her students. Her interest in this project was promoted by one of her students who was particularly interested in studying science and was continually discussing new scientific knowledge she was gaining outside of the classroom. The teacher was a practicing teacher upon the implementation of the new curriculum. This meant, as discussed previously, she only had the in-service education in science allocated to her for the teaching of the subject. The teacher also admitted that she had no prior knowledge of inquiry based methodologies before the start of this project but that she attempted to include as many “hands-on” and engaging activities in the classroom as possible in her observations.

The teacher taught in a standard classroom, located on the first floor of the school, with one computer for the students and the teacher. Being a standard classroom the teacher was required to reorganise the room for her science lessons. There were several continuous projects displayed throughout the classroom such as students’ plants and posters of their work, including work from subjects other than science. The class group that she taught was comprised of approximately twenty girls and the teacher believed they were enthusiastic about science. Extra time was also awarded before the lessons for students to discuss and explain any interesting science concepts or ideas that they had encountered in their daily lives. Throughout the course of the research the classroom had been outfitted with an interactive whiteboard, however use of this was reduced to the role of a whiteboard as the teacher admitted that she did not know how to use it.

3.2.2c Teacher C:

Teacher C taught fifth class students in an inner-city school in Limerick. The class group was mixed with approximately twenty-five students in the class. This teacher was a young male who had a keen interest in science, which was promoted by his brother who was a scientist. This enabled him to take areas of his brothers’ studies and develop interesting science lessons

that were beyond the curriculum for the students. The teacher also had attempted to promote science within his classroom through the attendance of educational lectures and demonstrations with his students. This teacher was not teaching upon the implementation of the new curriculum and therefore had completed science element as part of his pre-service education. He often expressed that the school was actively trying its best to promote science wherever possible and were therefore welcoming to projects such as this one. The principal of the school recommended Teacher C as one of the most active and motivated science teachers in the school.

The teacher carried out his lessons in both a classroom and the school laboratory. Typical lessons involve a pre-investigation discussion in the classroom and afterwards the class moved to the laboratory to carry out the investigations. The classroom contained areas to display the students work as well as educational posters. If the laboratory is not available due to timetabling issues investigations were also carried out in the classroom. The laboratory was equipped for all of the needs of the investigations and provided cookers, sinks as well as typical science apparatus. Students were required to wear lab coats whenever in the laboratory. The lessons that were observed and conducted by this teacher for the purposes of this research were all carried out in the laboratory.

3.2.2d Teacher D:

Teacher D also taught fifth class in an inner-city school in Limerick. The school was a special needs school and many of the students in this class had mild learning disabilities. As such, the teacher had a mixed group of nine students all with varying degrees of special needs. The teacher had the challenge of maintaining order and interest of the students within his lessons. This teacher was also a young male who had completed a science element of his pre-service education. The teachers' interest in the project stemmed from experiencing more active and meaningful learning based teaching. This, he felt, would appeal to his class. The teacher admitted that he was not confident at teaching science and therefore aimed to improve his teaching through the course of the project.

The classroom was outfitted with three student computers, a sink and an area to carry out experiments and demonstrations. The classroom displayed various elements of the students' studies on the walls in the form of posters and reports. As the students had special needs this added a different element to the lessons that were carried out by this teacher. The lessons

emphasised visual and interactive elements over content, however the lessons still included elements to encourage student thinking and learning.

As it can be seen the teachers selected from the project came from a wide variety of contexts and classes. Three of the teachers taught in classrooms and one in the school laboratory. This meant that if teachers using the developed learning environment, detailed in Chapter 6, had access to a school laboratory they would also have lessons that would be suitable to carry out. The various levels of IT and equipment also highlight to different teachers how science lessons can still be carried out even with few resources at hand.

3.4: Methodologies Associated with the Contextual Analysis

As the research is comprised of several studies the individual methods that were followed for each study will be described in the applicable Sections. While there may be some element of the process included, the sections are mainly to describe the philosophical basis for the methods followed.

There were three primary methodologies employed to develop the contextual analysis of Irish primary science education. These methodologies included semi-structured interviews, observations of practice and a content analysis. Each of these methodologies will now be discussed.

3.4.1: Semi-Structured Interviews

In order to fully understand the context of primary school science education it was decided that a set of interviews would be carried out with teacher educators from the various colleges of education in Ireland. The interview structure that was taken as part of this analysis was a semi-structured interview (Flick, 2002, Silverman, 2006). Semi-structured interviews allow the researchers to probe beyond the structure of the interview in order to develop a deeper understanding of the context of what the interviewee is discussing or can enable a researcher to gather extra data to qualify statements made (ibid). This technique also allowed the researcher to be ‘flexible, objective, empathic, persuasive [and] a good listener’ (Fontanna and Frey, 2000, p. 652 cited in Flick, 2002). Other interview techniques were determined not

to be suitable for the collection of this data. These methods included structured/ focussed interviews, open-ended interviews, group discussions, joint narratives and focus groups (Flick, 2002, Silverman, 2006). A structured/focussed interview is quantitative in nature requires the interviewer to ask each question as it is planned (Flick, 2002, Silverman, 2006). This limits the responses that can be provided by the interviewee. An open-ended interview allows a researcher to develop expansive knowledge about the subject matter to which is being discussed (Silverman, 2006) and is traditionally used to develop the researcher's knowledge from a subject matter expert. An open-ended interview does not suit the needs of a researcher who has an in-depth knowledge of the field but is identifying personal opinions and issues (ibid). Finally a focus group is an interview technique used to create a 'quasi-naturalistic method' for the generation of discussion (Flick, 2002). As it can be seen the semi-structured interview aimed to capture the required qualitative responses of the interviewees while still allowing for a discussion of topics that may have emerged in the interview.

3.4.2: Observations of Teacher Education

Insights into the practice of primary science teacher education were gained through observations of teacher education lectures. Due to time constraints and issues with access only one of the institutions described in Section 1.1 were observed.

[Observational] approaches stress that practices are only accessible through observation and that interviews and narratives merely make the accounts of practices accessible instead of the practices themselves.

(Flick, 2002, p. 134)

Here Flick is describing the limitations of a discussion of practice versus the observation of practice, maintaining that the observation of practice allows a researcher to identify more subtle elements of the practice than a discussion would allow. This also describes the motivation behind the observation of practical teacher education lectures, which would aid the development of the contextual factors of the research. The observations were overt, non-participant observations for all of the lectures (Friedrichs, 1973 Cited in Flick, 2002). This meant that the participants that were observed were briefed about the observation and that the researcher played no part in the progression of the lecture. Non-participant observation was

chosen to allow the researcher to observe the students carrying out the activities and the environment rather than concentrating on the activity itself. The observation was also carried out in a natural situation (ibid), meaning that no detail such as the classroom or the content of the lecture was changed to accommodate the lecture.

3.4.3: Contextual Analysis

The final element of the contextual analysis involved a content analysis of current primary school science textbooks to identify their ability to encourage IBSE in the classroom. This study emerged from the Waldron's publication which found that Irish primary school teachers were still relying heavily on the use of textbooks in their teaching of science (Waldron et al. 2009).

A 'structuring content analysis' was chosen as it identifies the structures present in texts and can identify patterns (Flick, 2002). It also allows for the quantity of data to be condensed so that features can be described easier (Mayring, 1983, cited in Flick, 2002). According to Mayring (ibid) the stages of a content analysis are: Defining the material, analyse the situation, characterize the material and define the direction for the analysis (Mayring, 1983, cited in Flick, 2002). Selecting this method the first stage was to define the material that was to be analysed. In order to carry out this study a selection of primary school textbooks were obtained. The textbooks were from three series which covered science across all of the eight years of primary school. Analysing the situation describes the current state of the primary school texts and their aims and objectives. For the purposes of this research the situation for the texts chosen is consistent across the textbooks. This is also true for the characterisation of the textbooks which are all created to meet the goals of the Irish primary school science curriculum. The direction of analysis was defined as the content analysis of textbooks to assess their suitability in supporting IBSE. This method was chosen in order to assign meaning to the various methods employed in textbooks and to make inference about this meaning (Krippendorff, 2004). As teachers are using textbooks as primary resources in their teaching, the activities presented in the textbooks are crucial to understanding how teachers are currently teaching science. In order to analyse the textbooks use within an inquiry context an analytical framework had to be created and applied to the textbooks (Wang, 1998, Wilkinson, 1999). For the purposes of this work a framework was developed based on the 5E

model of inquiry. The development of the framework is described in Section 5.1 which occurred alongside the textbook analysis in Section 4.3.

3.5: Methodologies associated with Professional Practice

3.5.1: Discovery Observations

Upon sourcing the participant teachers, the next stage of the project was to develop a protocol that would be used to identify areas of IBSE in the practice of the teachers. It was decided that the best way to analyse the teaching was to carry out observations of the practice of science education (Flick, 2002). Included in this was the idea that all observations would be recorded both visually and orally. This would aid in the data analysis. As such, each participant was asked to carry out two recorded observation lessons. These lessons would be created and taught by the teacher with no influence from the researchers. The lesson observations were planned to be non-participant, overt and in a natural situation as described above (Flick, 2002). The non-participant element would ensure that the researcher would have as little impact on the teaching of the lesson as possible. The observation was also overt, whereby the teachers and the students were aware they were being recorded. Finally the natural situation ensured that the teachers would only have their typical resources and classrooms available to them for the observations so as to make the observations as natural as possible. This natural situation also applied to the subject that the teacher was asked to teach. By giving the teacher the freedom to teach what they wished would be to reduce the disruption of cameras being placed in their classroom. This also added a second element of analysis which aimed to identify what content the teachers would choose to teach to identify what areas of the curriculum they felt more comfortable teaching. To add to the analysis of the videos a set of observation tools were designed to accompany the lesson observations and to ensure that all areas of the lesson could be analysed for elements of IBSE thoroughly.

There were two types of observation collected as part of this research. The discovery observations were composed of the first two recordings carried out by the four teachers. These observations aimed to discover the nature of teaching in Ireland. The Intervention observations were the third and fourth observations carried out with the same teachers. These observations followed the same principles of non-participant, overt observations with the

difference being the teacher were utilising the intervention, described in Chapter 6 of this research. The intervention observations aimed to assess the impact on the teaching and to draw conclusions about the change in the teachers' schema when they have developed their lessons using the intervention. The discovery observations will be described in Chapter 5: Professional Practice and the intervention observations will be described in Chapter 6: Intervention.

3.5.2: An analysis of Pedagogical Content Knowledge

It was decided that the Pedagogical Content Knowledge (PCK) of any participating teachers in this project must be evaluated in order to understand their thoughts and ideas about teaching science as well as to understand the context of their teaching. This would aim to accompany the case study data that was being collected. This process entailed an informal group session where two of the participating teachers completed Content Representations (CoRes) (Loughran et al. 2001). These snapshots would be developed through a focus group methodology. Here a selection of teachers would be asked the questions on the CoRes and, through discussion, develop answers. The analysis of the CoRes would then provide insights into the knowledge and practice of the participants.

Table 3: Content Representations

	Big Idea 1
1. What do you intend students to learn about this idea	
2. Why is it important for students to know this	
3. What else do you know about this idea (that you do not intend students to know yet)	
4. Difficulties/ Limitations connected with teaching this idea	
5. Knowledge about students' thinking which influences your teaching of this idea	
6. Other factors that influence your teaching of this idea	
7. Teaching procedures (and particular reasons for using these to engage with this idea)	
8. Specific ways of ascertaining students' understanding or confusion around this idea (including likely range of responses)	

The CoRes tool, which can be viewed in Table 3, was developed by Loughran et al. (2004). It is comprised of two primary components. The first row consists of elements called Big Ideas. Big Ideas are considered the primary subject matter that teachers wish to cover (ibid). Once the teachers have developed Big Ideas on a subject they begin the process of answering the eight questions in the first column on each Big Idea. These questions are designed to identify elements of a teacher's PCK through analysis of the answers.

3.6: Methodologies Associated with the Synthesis

The synthesis of this research was the design, development and implementation of a form of intervention which would host information and guides and resources for primary school teachers. The methodology for the synthesis of this research followed an ADDIE approach. The Analysis, Design, Development, Implementation and Evaluation (ADDIE) model is an umbrella term used in instruction design for the development process of multimedia products (Molenda, 2003). In the ADDIE model the analyse stage identifies the context of the product to be developed (Strickland, 2006) and was determined through the research described in above. The Design stage creates a method for the project to be carried out (ibid). The Develop stage creates the product that has been designed (ibid). The implement stage placed the product into the environment which it was developed for (ibid). Finally the Evaluate stage collects appropriate data about the implementation to assess whether changes are necessary (ibid). The ADDIE is a cyclical model meaning that the evaluate phase does not stop the production of the process but informs the future redevelopment of the project (Molenda, 2003, Strickland, 2006). This is appropriate to this research as the concatenation process will allow further refinement of the intervention developed.

3.7: The Software Analysis

In order to ensure that any data collected could be analysed appropriately the software package Nvivo was chosen as the data analysis software. Nvivo is software developed by QSR international which can accept both qualitative and quantitative data sets. Nvivo 8 was originally used but was upgraded to Nvivo 9 through the course of the research. The software allows the user to place all collected data into it including audio interviews, video lessons as well as lesson evaluations. Any audio tracks of videos can be transcribed in the software with the text matching the timestamp of the video. This allows the user to analyse the transcript as

well as the video file for different elements. Nvivo was chosen for its ease of use at coding each of the datasets collected. Nvivo allows the user to develop a set of tree nodes to which various elements of the collected data can be interpreted. Accompanying these tree nodes the software allows the user to attach memos to any existing data as a method to maintain thought structures and research developments. The coding structure that was applied to all of the data will be described in Chapter 5.

3.8: Ethical Considerations

As with any research the ethical implications of the research methodology had to be considered. This section will describe the ethical considerations that had to be taken upon carrying out this research. The ethical considerations can be divided into two groups firstly the ethics of research and secondly the ethics of the methodology described.

3.8.1: Ethics of Research

The ethics of this research revolve around the ethical implications of educational research. These ethics can be described as a set of fundamental principles which must be adhered to in order to ensure that the research is trustful, viable, replicable and will create no harm to any of the research participants. While educational ethics is not clearly defined in research it is governed by the principles of research ethics. The dictionary of sociology defines research ethics as:

The application of moral rules and professional codes of conduct to the collection, analysis, reporting, and publication of information about research subjects, in particular active acceptance of subjects' right to privacy, confidentiality and informed consent.

(Marshall, 1998)

This definition broadly covers all facets of research from the methodology, treatment of participants, to the publication and dissemination of material. Comparing the described methodology of this research to the definition it can be seen that the treatment of all data collected and disseminated as part of the intervention are causes of ethical concern. Section 3.8.2 will describe how methods were employed that would address these ethical concerns.

Schutt (2006) describes the "Belmont Report" as one of the earliest forms of ethical principles. These principles included; respect for persons, beneficence (minimizing risk) and justice (distributing benefits). Christians (2005) describes how, by the 1980s, many scholarly bodies had developed their own codes of ethics. An analysis of these codes identified four overlapping guidelines for ethical research (Christians, 2005). These guidelines are: informed consent, deception, privacy and confidentiality and accuracy. These guidelines are similar to those presented by American Sociological Association (ASA) who suggests, Research should cause no harm to subjects, subjects must give consent to participate in the research, researchers should fully disclose their identity, anonymity or confidentiality should be maintained for participants and the benefits of the research should outweigh the risks (Schutt, 2006).

Christians (2005) describes how social science codes of ethics uniformly oppose deception. Interestingly, Christian's description specifically mentions the paternalistic arguments for possible deception of children in elementary schools. This may hint that, prior to the implementation of codes of ethics, elementary school children were a vulnerable group to what could be considered unethical research. Privacy and confidentiality relate to the exposure of research participants against "unwanted exposure" (ibid).

These ethical principles are of particular relevance to this research which, aims to study human interactions, but also share videos and images of primary school students on the internet. Adhering to the principles described above, consent forms were signed by all teachers, principals and the guardians of the students. Using the above descriptions, the research participants should always be informed of observations that are taking place. This, as Flick (2003) argues, may lead to a difficulty in observations as the nature of some observations may inherently change the practice that is being observed. The act of having both the observer and a video camera in the classroom could have affected both the teacher and the students. The teachers were asked to perform a lesson as they would normally teach it. The issue arises that the observer cannot describe how the teacher naturally teaches without their presence to observe it. Similarly the students' behaviour may be either better or worse as they have a stranger in the room. The conclusion would therefore tend to promote covert observation of the classroom. Flick argues against covert observation as it can lead to its own set of issues (Flick, 2003). Flick describes how:

The researchers abstinence from interacting with the fields leads to problems [...] analysing the data and assessing the interpretations because of the systematic restraint on [...] interior perspective.

(Flick, 2003, p.139)

The conclusion therefore is that the addition of an observer in the classroom inherently changes the observations, but the lack of an observer creates a discrepancy from the data being collected. This difficulty must therefore lead to the researcher choosing the most ethical method of data collection. Covertly recording students could be suggested as a method to capture completely natural teaching interactions and lessons. In order to ensure that completely natural lessons were recorded the teachers and students would have to be completely unaware that they were being recorded. This would mean that the participants would not give informed consent as the nature of getting consent would inform them of the recording. This could also be determined as deceptive, as the teachers are not aware they are being recorded. This would also have an impact when discussing beneficence and confidentiality as the teachers would not be aware of the purpose or use of the recordings. Therefore the most ethical method of data collection within this research was overt observations, with the acknowledgement that the observations collected have been influenced in some way by the researcher. Methods were employed to ensure that the addition of an observer in the classrooms had as minimal an impact as possible. In order to satisfy ethical concerns the research methodology was subjected to an ethical committee. The results of this submission will now be discussed.

3.8.2: Ethics of the Methodology

As it can be seen from the methodology this research involves video recording primary school students and teachers. As such it was therefore necessary to submit the research for ethical approval. To this end, a submission of the research methodology and all of the documents involved in the research were submitted to the Education and Professional studies ethics committee in 2009. This submission considered the ethical issues of video recording minors in the classroom, the issue of storage of the physical media collected, placing videos of minors on the internet and the health and safety issue of placing cameras in the classrooms.

The video recording of the lessons was deemed a necessary requirement for the research as it would provide large amounts of data that could be called on at any stage. While sourcing the

teachers, information sheets were created for them and their principals which made it explicit that there would be video recording equipment used in the research process. There was also an information and permission slip created for the students to give to their parents. Any parent/ guardian who wished their child not to be involved in the process had the opportunity to opt out if requested. Provisions were made for this by the teachers and the principals involved.

In order to reduce the risks of placing videos of minors on the internet the first provision that was made was password protecting the intervention. The membership of the intervention would also be completely controlled by the researcher to ensure that only members of the research had access to the videos. No teacher, school or student would be identified by their full name on the website. Also the videos would be uploaded using secure websites which would not release the video to the general public. The confidentiality of the data was the final ethical concern addressed. While this had been dealt with in relation to the website, the location and access rights of the physical media needed to be addressed. To this end, any physical recordings or data on the participants of the research were kept in a locked room to which only the researcher had access to.

Another concern with the addition of cameras into the classrooms was students or teachers tripping over cables and equipment. In order to reduce this risk for the teachers, students and researchers, all of the classrooms were visited prior to the recording of the lesson. This was of particular concern in lessons where the students would be asked to walk around the classroom while carrying out investigations. By visiting the classroom prior to the recording the researcher was able to identify areas to place cameras which would not hinder the flow of the classroom, block emergency exits and control the placement of cables in the classroom. The position of the cameras was also discussed with the teachers to ensure that the cameras created as little disruption as possible.

The documents enclosed within the ethics submission included the tools mentioned throughout the methodology chapter above, the information sheets, risk assessment forms and the acceptance of the University of Limerick Child protection form. The committee deemed that the risks to the students and teachers were minimal and that the considerations made as part of the research were appropriate to minimising ethics concerns.

3.9: Chapter Conclusion

This concludes the description of the research methodology that was employed as part of this research. As it can be seen, the methodologies in this research attempted to ensure valid, accurate and detailed research of factors affecting Irish primary science education. As this research is comprised of several independent studies which are designed to build upon each other in order to inform the development of the intervention.

Chapter 4: Contextual Findings

Education today must help students learn how to learn in powerful ways, so that they can manage the demands of changing information, technologies, jobs, and social conditions

(Barron and Darling-Hammond, 2008, p.2)

In order to understand the nature of the enactment of IBSE by Irish primary school teachers it is important to consider contextual factors in their professional formation that are likely strong drivers of practice. To this end the views of primary science teacher educators were explored in terms of the issues and factors facing pre-service teacher education and the values of the various Irish institutions of teacher education. In order to expand the study, and to explore the methods used to promote IBSE, lectures in one of these primary teacher education colleges were attended. Finally a study of current primary school textbooks was carried out to explore their representation of IBSE given evidence that teachers are relying heavily on textbooks to guide their practice (Waldron et al. 2009).

4.1: Teacher Educator views on Irish Primary science education

The study in this contextual analysis involved interviewing primary school teacher educators to establish their views on elements of teacher education, how they view science in their respective institutions and IBSE. Comparisons will be drawn in this study between the teacher educators' responses and the information identified in the literature on science education. The aim of these interviews is to develop a deeper understanding of the issues and practices surrounding primary school science education in Ireland.

4.1.1: Research Method

These interviews aimed to capture what the teacher educators believed to be the primary issues facing science education. They also provided an insight into the various methods and practices of teacher education in the different colleges. The semi-structured interview technique offered the best method for the collection of this data. It ensured that each interviewee would be able to express their opinion without it being challenged by others in their field. It also enabled the researcher to address any items or elements that the teacher educators discussed if they needed explanation or expansion and allowed for comparison of their responses.

The interviews were carried out with four teacher educators, from four different teacher education institutions. Chapter 1 described that there are 5 primary school teacher education institutions in Ireland, however due to scheduling conflicts one teacher educator declined to take part. The interviews lasted between thirty minutes and one hour and the interviewees were given the interview questions in advance to ensure they could properly prepare their responses. This also enabled them to discuss some of the questions with their colleagues, prior to the interviews, in case an institution had more than one staff member in the science education department. For reference and anonymity, each interviewee was assigned a number between 1 and 4.

The structured element of the interview contained five questions. These questions were:

- What do you believe are the most prominent issues in primary science education?
- Do you believe science should be taught through inquiry? Why?
- How do you teach pre-service teachers to teach through inquiry?
- Do you believe that this institution values science highly as a subject and places enough emphasis on it during teacher education?
- Do you see any value in a set of resources being developed for the promotion of IBSE in primary science?

The first question was asked to identify what the teacher educators believed to be the most common issues in Irish science education only. This would enable the researchers to compare the responses with the issues identified in the literature review. It also afforded the researchers an opportunity to identify issues that may not have been identified in the literature but may be common in Irish classrooms.

The second question revolved around the methodology of inquiry. It was hoped that the teachers would touch on inquiry while discussing ideas and solutions to the first question. If this was not the case, the question would be asked with a brief introduction stating how curriculum and its guidelines were now emphasising inquiry in the science classroom. This question aimed to identify whether teacher educators agreed with the new emphases of the curriculum and whether they believed inquiry is an appropriate teaching methodology within

science education. It also allowed the interviewer to progress more naturally into the third question which related pre-service education to inquiry methodologies.

The third question, thus, enabled the researchers to discover methodologies and practices currently being employed in pre-service education that promote inquiry and IBSE. These practices would also be compared to the literature review on the components and activities within IBSE. The practices could also be placed under consideration for the intervention that was being developed as part of this research.

The fourth question emerged from studies on science education which recommend more pre- and in- service education to be given in science (Varley et al, 2008a). This question gave the interviewees an opportunity to reflect on their institution's practices with relation to science education and to highlight whether science is considered to be an important subject in their institution. It was important in the analysis of the interviews that the various answers to this question would have to be scrutinized to identify any biased views as teacher educators would naturally wish more emphasis be placed on science education as it is their subject. To achieve this key points would be identified in their answer that held comparable elements to other institutions, such as time allotted for science, time allotted for other subjects and methods of evaluation in science.

The final question was added to obtain the interviewees' thoughts and ideas on the method of intervention that was being planned as part of this research.

4.1.2: Prominent Issues in science education

The first interview question was designed to determine the issues that teacher educators' believed to be important in primary teacher education. The answers that were obtained can be divided into two categories. The first category relates to issues in pre-service teacher education and the second category relates to issues in the practice of science education.

While discussing pre-service teacher education, the responses to this question were strikingly similar. According to the teacher educators, the primary areas of concern are a lack of time for teaching, the backgrounds of the students, the balance between skills and content development and developing a teacher's capacity to address misunderstandings in the

classroom. These issues are consistent with the literature on issues in science education (Appleton and Kindt, 2002, Harlen et al., 1995, Murphy et al., 2007, Varley et al., 2008a, 2013, Victor and Kellugh, 1997). Each of the teacher educators felt that the time allotted to science was not sufficient to teach science content and pedagogy to pre-service teachers. This, they believed, resulted in the content knowledge coming second to the pedagogy of IBSE. It is the view of teacher educators in Ireland that, during their pre-service education, teachers should be given the skills required to teach science effectively. It follows then that pre-service teachers must learn the content at a later date but will be proficient in the methodologies and activities to employ IBSE in their teaching.

A lot of teachers wouldn't have and a lot of our student teachers wouldn't have any experiences of science themselves in primary school so one of the key issues is creating that balance between the knowledge and skills what content you are giving

- Teacher Educator 1

This issue was further expanded on by concerns about the experiences of students that are entering pre-service teacher education. Each of the four teacher educators acknowledged that the students currently entering pre-service education are generally students of the humanities. They stated that the majority of students entering teacher education had studied only Biology to Leaving Certificate level, if they had done a science subject at all, echoing a study carried out by Harlen et al. (1995). The teacher educators believe that this results in the students not being proficient in the subjects of Chemistry and Physics when they enter Tertiary education and, hence contributes to their low confidence levels in these subjects.

The final issue that arose, in relation to pre-service teacher education, was that of teaching pre-service teachers how to address misunderstandings in the classroom. Each teacher educator mentioned identifying and addressing misunderstandings as a primary method employed in their teaching of science. All four teacher educators described similar methods used to address misunderstandings in their classes. These discussions revolved around the methodology of investigating a topic. Each teacher educator believed that only by actively carrying out an investigation through inquiry, will students identify and address their own misunderstandings. They believe it is essential to offer pre-service teachers an experiential approach to enable them to identify areas where misunderstandings can be developed and to provide them with the skills required to address misunderstandings as they arise.

As discussed above, the second category of issues within Irish primary science education related to the actual practice of teaching science in the classroom. Teacher educators believe the main issues in science education are; a lack of teacher education, a lack of teacher experience, a lack of teaching time, in-adequate resources and poorly designed school grounds. As argued in Chapter 1 and 2, there are concerns about the amount of teacher education supplied to both pre- and in- service teachers in Ireland (Harlen et.al., 1995). When the teacher educators discussed the lack of experience they combined pre-service education, in-service education and the time spent teaching science. With relation to this the teacher educators believed that the science portion of pre-service education was not, generally, sufficient to equip a teacher with all of the pedagogies and content of teaching science in Primary schools. They also mentioned the lack of in-service education being officially presented to teachers in science since the introduction of the new curriculum. Finally the teacher educators believed that teachers were, generally, not spending the required one hour per week teaching science and therefore not developing their skills in the subject. This results in the exclusion of content knowledge from teacher education, which otherwise could have allowed for the adequate construction of a teacher's science related PCK for entering the classroom.

In schools {...} it would be an issue around resources {...} I think they talk about we haven't got the equipment and I think that it's unfortunate that they would use that {...} as an excuse more than anything else. When you think about primary science they need {...} some mirrors, they need some bulbs, battery holders etc, they need magnets for magnetism, we might need some equipment for sound for light but beyond that we don't need a lot of equipment as such. So to say we don't have the equipment is a bit of an excuse but it is it is a genuine concern of people whether it is well founded or not.

-Teacher Educator 4

Issues also arose with regard to the amount of time spent in extracurricular activities. One interviewee highlighted how subjects such as the safe cross code, extracurricular languages and religious ceremonies are studied in primary schools, all of which are outside of the CoRes curriculum. Interviewee 3 believed that the teaching of extracurricular languages was to start the students studying second level topics prior to starting in second level. This interviewee also highlighted that the NCCA study had evidence to show that even though second level entrance exams do not exist in Ireland, that the final year of primary school is

spent preparing for any exam that the second level school may have (Varley et al., 2008a). This, as stated by the interviewee, results in a concentration on the CoRes three subjects that are usually examined; English, Irish and Mathematics. The result is that teachers are less likely to meet the science curriculum time requirements in sixth class compared to other years. Another point raised by this interviewee highlighted how students felt a lot of time was placed into studies and practices for the Seven Sacraments of the Catholic faith. Within Catholic primary schools, students carry out two of these sacraments, Communion and Confirmation, usually in second class and sixth class respectively. All of these elements combine to take time away from curriculum studies.

All interviewees agreed that there may be a lack of resources for teachers in the classroom. One of the teacher educators described the one time grant awarded to schools for the purchase of science equipment, upon the introduction of the new curriculum (Varley et. al., 2008a). This grant was provided 10 years ago and since then there has been no further funding for science resources or equipment. The interviewee stated clearly that, they believe, there needs to be ring fenced funding for science equipment, especially for consumables and equipment that break through continuous use. Interviewee 3 however, discussed how he thinks a lack of equipment and resources may generally be used as an excuse not to teach science. This interviewee believed that many science lessons can be carried out with everyday equipment and resources and some teachers believe that if they do not have a specific piece of equipment in the classroom then, they cannot carry out that lesson. He believed that this should be challenged in teachers' minds and, where possible, cheap, readily available alternatives should be made known to the teachers so they can effectively carry out the lessons rather than avoiding them.

One final issue that was raised by the teacher educators was the teaching of second level content in the primary school curriculum. Interviewee 4 described how that this practice should be avoided, as the two curricula are completely different in their content and approaches. He believed that while teachers may think covering the second level content will give their students an advantage over other students, the primary school science curriculum is about developing the basic skills necessary to study science. This means that students who carry out second level material will not have developed the basic skills necessary to continue their study of science and will therefore be at a disadvantage compared to the other students. The skills, this interviewee was describing, relate to the science skills as described by the

primary science curriculum, such as observing, classifying, estimating, questioning and measuring amongst others (DES, 1999, 1999a).

4.1.3: Should science be taught through inquiry?

The teacher educators' answers to this question were unanimously positive. They believe that science should be taught through inquiry and, therefore, they aim to provide their students with the skills needed to carry out inquiry lessons. The interviewees all believe that inquiry promoted the epistemology of science and that it is a fundamental component of SESE, which demands thinking, problem solving and knowledge development. It should be noted that there was no hesitation from the interviewees in answering this question. This may highlight a general acceptance of inquiry as the best practice method of science instruction. It could, however, also be a sign that the teachers do not consider other alternatives to inquiry in their instruction.

There were however, some important points raised on this question in relation to nuances within inquiry in terms of how it is enacted. Interviewee 2 highlighted that while inquiry was important, he believed that there is too much of an emphasis placed on "fair testing" in primary schools. While he believed that fair testing was a very important element in science investigations and experiments, he also felt that teachers emphasised fair testing over the inquiry nature of a lesson. He felt this issue could be addressed by using "open-ended" inquiry lessons. His description of open-ended inquiry was an inquiry lesson that was completely dictated by the students. This would provide the students with an opportunity to work on an investigation and discover whether a test was fair or not, without the aid of a teacher. This practice would encourage investigation and thought rather over didactically explaining to students the fair nature of their investigations. While this point was raised, he acknowledged the time constraints of a lesson might not allow for students to carry out all "unfair" tests in every investigation.

The other issue with teaching science, through inquiry, was the emphasis on content knowledge. Interviewee 4 highlighted how there is an emphasis in the curriculum on the content that must be covered. While this is the case, he stated that skills development should be the primary concern of a teacher. While these lessons may not be dictated by the curriculum, they can allow for further content and skills to be developed. It could be argued

however, that based on the results of the literature review combined with question 1 of this interview, if teachers do not have the time to teach the CoRes curriculum, they may not have the time to teach beyond it.

4.1.4: How do you teach pre-service teachers to teach through inquiry?

The question was structured in such a way as to provide the teacher educator with no limitations to describe their practice. As it will be described in section 4.2 a series of lectures were also attended on primary science education. The observations carried out in the lectures will be kept separate from the answers provided in these interviews. Each teacher educator provided a unique answer to this question, showing no consistency across the various institutions of education. For the purposes of this research teacher educators were also asked whether they utilise a specific model or approach to IBSE. None of the interviewees stated that they utilized a model of inquiry for the practice of their lecturing. The interviewees did state however; that they knew of certain models of inquiry such as the 5Es and Predict Observe Explore (POE), both of which were discussed in section 2.2, but that they did not use them by choice.

Interviewee 1 used the list of skills as dictated by the curriculum to develop their lecturing. This enabled the students to see links between the pedagogy, curriculum and the curriculum guidelines. The interviewee was adamant that teacher educators should “practice what they preach” and therefore the methodology of inquiry must be taught to the pre-service teachers through inquiry. She also highlighted that, by using the skills listed in the curriculum as a guide, this generally reduced the amount of misunderstandings that were developed by the students aided them in understanding the lesson content better. The interviewee did not elaborate on this point to describe how misunderstandings were being formed using previous methods of instruction. The teacher educator informs the pre-service teachers of the intentions to teach through inquiry and, prior to teaching lesson content, describes the pedagogy of inquiry to the students. She stated that, by describing inquiry to the students at the beginning of their education they are more aware of the concept and what to attempt to achieve while teaching.

The approach I take with it is to highlight what the key principles of the curriculum are and see what opportunities and what invitations they give [that these] teachers that we want to see.

- Interviewee 2

Interviewee 2 followed a similar pattern to interviewee 1 by describing inquiry to the students in one of the first lessons on the topic. The interviewee described how he used a 3 or a 5 step method similar to the 5Es in his lectures. These steps were not actively labelled in the interview but revolved around the idea of determining prior knowledge, investigating a topic and then assessing the knowledge and understanding that had been developed. The link between this process and the 5E phases can be clearly seen, as this method following a process of Engagement, Exploration and Evaluation.

Interviewee 3 described that she, and her colleagues, generally, followed a “social constructivist approach”. This approach was described as an approach whereby the students would construct their own knowledge on the pedagogy of inquiry through experiencing it. In this institution the students were divided into groups and carried out their lessons through workshops. While there was no model used in this teaching, the workshops did employ different methodologies such as concept maps, thinking, drawing, concept cartoons, misunderstandings, fair tests, investigations, skills development and assessment, all aimed at building a repertoire of inquiry methodologies that could be used in the classroom. The interviewee described how these activities were structured in the lectures to promote the construction of knowledge for the students.

Interviewee 4 stated that he highlighted the importance of developing knowledge through activity. To do this pre-service teachers would be asked to discuss the important points of a topic, follow a series of activities designed to understand the topic and then to develop a series of questions they had on the topic. This provides the students an opportunity to carry out lectures through an inquiry method while still covering the content and allowing the teachers time to ask questions on elements they may not have understood. The similarities between this approach and the 5Es can also be clearly seen with the lecturer accounting for Engagement, Exploration and Explanation. This interviewee described how he attempts to divide the lectures into three separate areas for the pre-service teachers. These areas are; developing content knowledge, developing inquiry skills and lesson planning. A mix of these

three areas would be taught in any one semester and this approach aims to give the students enough knowledge and pedagogies to teach science through inquiry in their classrooms.

4.1.5: Do you believe your institution values science highly?

This question was added to the interview to determine the teacher educators' views on their institutions and how they value science education. The aim was to understand the background of the institutions that the teacher educators were from.

Out of the four interviews that took place, three of the four interviewees stated that they felt their institution valued science highly. The reasoning as to why this was the case revolved around the resources that were supplied for science education, the amount of time spent studying the subject at third level and the different practices that were allowed in the colleges. These three institutions had dedicated science areas where students could carry out experiments and investigations under the guidance of the teacher educators. It must be noted here the links between this description and the guided discovery approach to education (Mayer, 1999). In one of these institutions the teacher educators pointed out that the institution provides awards for the students work in science and contains a science notice board where events, such as science week, can be actively promoted. While one teacher educator believed that there should be greater time awarded to the study of science she also highlighted that, in the study of SESE, students are awarded the same amount of hours in science as history and geography combined. This, she admitted, reflected the institutions dedication to science. As part of this institution the students carry out two primary fields of study, they carry out the teacher education courses and the study of another subject of their choosing. At the time of the interview, plans were also being put together for students to study science as their second subject, again highlighting how the institution were accepting of the subject. The third interviewee pointed out that his institution provides science students with an area to plant and grow vegetables as part of their studies, allowing for the hands-on study of science and the promotion of observational skills.

Well much and all as I would like to say that there is no ill will for science institutionally, however institutionally it hasn't been a proactive or enticed in terms of personnel [or] resourcing.

- Teacher Educator 4

The fourth interviewee stated that while the institution did place science on the curriculum, he felt that their approach and attitude to it was generally neutral. The reason provided for this opinion was described by the amount of time allotted to science in that institution. Here science was not given an equitable distribution as other subjects in the curriculum. This, he felt, resulted in science being considered as less important by the institution compared to other subjects, a view which could be transferred to the pre-service teachers and have a negative effect on their teaching of science.

4.1.6: Do you see any value in a set of resources being developed for the promotion of IBSE in primary science?

Each of the teacher educators felt that there was a need for a tool to be developed to aid in the teaching and learning of science at primary school level that emphasises meaningful learning over carrying out an activity. They suggested that any learning guides should be hosted on the Internet as it would be easily accessible and as stated by interviewee 3: "teachers like using the Internet in their classrooms". They emphasised that resources should not be "ready-made" lesson plans, but instead allow the teacher to create their own lesson from the ideas, content and activities presented to them. The content that was felt should be addressed was that of the physical sciences, with emphasis on the energy and forces and materials strands of the curriculum. This would provide the majority of teachers who have studied humanities subjects or biology to choose lessons that would be of greater benefit to their knowledge of science teaching and learning. The final concern raised by the teacher educators was that any resources developed should aim to address concerns about content knowledge on a subject and help the teachers to build up their own confidence levels in the teaching of science.

4.1.7: Other points raised

When asked was there anything that the interviewees would like to add to the interview, one teacher educator added a point on the use of textbooks in the teaching of science. This teacher educator highlighted that, while they believe textbook can be a valuable resource in science, that current textbooks should be considered only as resource books in a lesson. Interviewee 4 believed that teachers are currently relying on the textbook as a source of lesson plans and, in his lectures, he does not promote the idea of "Opening a textbook at page 59, Ok. So that means we are studying forces". He instead recommends to his students that they buy a few

copies of each textbook to use as reference guides and resource books in their teaching. This actively relates the findings of the NCCA study which found that a large percentage of teachers still use a textbook in their science teaching (Varley et. al., 2008a, 2008b, 2013). The issue of textbooks will be revisited in Section 4.3.

4.1.8 Conclusions from the teacher educator interviews

The aims of the teacher educator interviews were to identify key elements and views from the instructors of pre-service science education. Several conclusions can be deduced from the responses that were given. The first conclusion is that the teacher educators in Ireland describe the issues that Irish primary education currently faces as being in line with the literature on issues in science education. This allows for researchers, teachers and policy developers to analyse or utilise international practices and programs to attempt to address the issues in Ireland. The second conclusion relates to the teacher educators views on IBSE. While all interviewees adamantly promoted inquiry in their discussions there was no consistent method of instruction being employed. This may highlight a lack of communication or agreement across the institutions of Ireland on science instruction. It has previously been described how Irish teacher education institutions provide between 12 and 44 total hours of science instruction, depending on the institution attended. It can therefore be concluded that Ireland currently contains a highly varied and unequal level of instruction when it comes to primary science and that the teacher educators are not consulting with their peers in order to help develop a more consistent approach to science instruction. The third conclusion is that teacher educators appear to understand the role of science within their institution. The reasoning behind the interviewees answer to question 4 contained clear evidence to support their answers. This result also highlighted institutions positive attitudes toward science. Interviewee 2 believed the institution could do more to promote science. The final conclusion that can be developed from this study is that, generally, teacher educators believe that efforts should be put into primary science research and the development of teaching and learning guides as well as supports for teachers.

4.2: Observing teacher education in science

As part of the contextual study into IBSE in Irish primary science three pre-service science lectures were attended in one of the institutions of education listed in Section 1.2. In total three, two hour lectures were attended on the topics of electricity, light and forces. The term lecture is used to describe the class as this is the term used by the institution. It should be noted that the lectures consisted of various approaches and were not limited to a traditional lecture style. While it cannot be claimed that this limited time in a single institution would provide insight that could be generalised to the entire process of primary science education, it was considered a useful opportunity to develop some insight into the learning experiences of pre-service teachers, in particular focusing on IBSE. It was also hoped that these lectures would assist the identification of key areas and approaches for the development of the intervention in this research. Issues with access did not allow these observations to be extended to all of the colleges of education. These observations will be considered under the headings of; the use of inquiry, the various methodologies employed and the issue of misunderstandings.

4.2.1: Research Method

The primary method that was employed for attendance at these lectures was observation techniques. The primary researcher was present at all three lectures. Notes were taken on the observation of the teaching style as well as the responses of teachers. These notes were then synthesised for analysis and this synthesis was proof read by the lecturer to ensure accuracy. The lecturer requested that the lectures were not recorded. The notes were also proof read by the lecturer to ensure accuracy. This enabled a form of error checking and ensured that the lecturer was happy with the notes taken. The lectures were carried out in a classroom which was well equipped for the study of science. Science posters were displayed on the walls and investigation resources were stored around the room. The format of the lectures was consistent and contained several content areas as well as practical investigations for the students to carry out. There were approximately 20 students in each lecture. The lectures contained elements of teacher education theory, practical work and evaluations.

4.2.2: The use of inquiry based approaches

The first area that will be discussed is the interpretation of inquiry as part of the lecture series. For the purposes of this interpretation the 5E method, see Section 2.2, was referred to as an example of an inquiry based process and guide to place activities under. The results of the teacher educator interviews identified that there is no consistent approach to pre-service teacher education between colleges. Generalizations therefore cannot be drawn between these observations and lectures in other education institutions.

Lecture One: Electricity

Within the first lecture a structured approach was taught with the process being:

Stage 1: Finding the context

Stage 2: Finding Ideas

Stage 3: Testing Ideas

Stage 4: Assessing the learning that has occurred

It is clear that there are similarities to this approach and the 5Es model. Firstly finding the context and finding ideas involves the students using their prior knowledge on the subject that is being taught. This would be consistent in the Engagement phase of the 5Es. Testing ideas would be consistent with the approaches described in the Exploration stage of the 5Es and assessing the learning would be consistent with the Evaluation stage.

The process listed above was made explicitly clear to the students as they were carrying out the lecture. The process began with finding the context. This context was introduced by the lecturer displaying a torch to the students and asking guiding questions such as “How does it work?”, “Where is the battery?” etc. These questions had several purposes such as relating the subject of electricity to everyday objects. It called on the students’ previous experiences to explain the torch and how it worked. Again this would be consistent within an engagement activity to elicit students’ prior knowledge.

In Stage 2: Finding Ideas the students had to construct a concept map from several terms. It was important that the students had continual feedback while they were doing this for two reasons. Firstly to see if they could construct a concept map properly and secondly to highlight any misunderstandings they may have had in the content knowledge. The lecturer

explained the distinction between formative and summative maps to the students directly. Formative maps were described as being used to elicit prior knowledge and misunderstandings. Summative maps were described as being used to assess student learning and address misunderstandings. This is again, another example of an Engagement activity whereby the lecturer is determining the level of prior knowledge of the students in the topic.

In Stage 3: Testing Ideas, students were asked to carry out investigations into electricity in groups of three. Students were given activity sheets to carry out which followed an investigation structure. This activity sheet followed the ideas of a guided investigation (Roberts et al., 2010) whereby the students were provided with a problem or question and asked to solve it using a specific list of equipment. Each investigation built on the previous which highlighted a scaffolding process. The investigations that the students carried out had three purposes. Firstly the concept of scaffolding was being used. Secondly the investigations went beyond the curriculum constraints. These investigations were designed to aid the teacher in developing content knowledge for unexpected student questions during investigations. Thirdly it aimed to ensure if students in the future asked “What would happen if...?” the teachers would have an idea of how to approach answering this question. This stage of the lesson would be considered as a combination of exploration and explanation from the reasoning provided above.

In Stage 4: Assessing the Learning, a student from each group was asked to go to the whiteboard and draw their investigation, while a second described it. This showed both their process and their learning. Time was given for other students to ask questions in this section to ensure that everyone understood the concept being presented. This stage of the lesson would be considered as a form of evaluation in the 5Es.

Lecture Two: Light

While there was a structured approach provided for the lecture on electricity, the lecture on light was given a different approach. Here the lecturer explicitly stated to the students that the lecture would mainly concentrate on finding ideas about light. This would be considered stage two of the previous lecture, which consisted mainly of engagement activities. These activities included thinking and drawing, concept cartoons, and the use of the support website www.teachers.tv. The reasoning behind this approach was provided by the lecturer when she

described how light can be a complex topic for primary school students. By providing pre-service teachers with methods to identify areas of confusion or misunderstandings the pre-service teachers could target their content to address these issues directly, rather than carrying out a lesson on light that is not fully understood.

The first section of the lecture used the three activities described above. The first of these activities was a Thinking and Drawing activity. Thinking and Drawing is a specific skill set as described by the 1999 curriculum (DES, 1999). As this was a lecture on the subject of light the teacher asked the students to draw how they see various items. This identified the prior knowledge of the students and identified misunderstandings with relation to transparent items, light sources and light reflectors. The lecturer also combined the answers supplied by the pre-service teachers with typical examples of submissions from primary school students as real world examples. It can be seen that these activities are consistent with the description of engagement within the 5Es.

The video used in section two of this lecture was hosted on the website www.teachers.tv. This video highlighted to the pre-service teachers areas of student misunderstandings, how students develop these misunderstandings and methods to ask the student to re-evaluate their thoughts. This element of the lesson showed how the use of instructional videos can develop thoughts and discussions on a subject with pre-service teachers, and lead to them understanding how misunderstandings are developed and addressed.

The third activity involved the book “Concept Cartoons” by Naylor (2000). Concept cartoons were used to describe a lesson on light. The concept cartoons displayed student interactions on the topic of light and the students were used to initiate discussions. The format of these concept cartoons mimicked typical interactions of students in a classroom. This activity developed ideas of how concept cartoons can be used to promote discussion within a classroom. Again these concept cartoons would be mainly relevant to an engagement section of a lesson whereby students would be using their prior knowledge to identify and describe their concepts on a subject.

Lecture Three: Forces

Similar to the lecture on Light, the lecture on forces did not contain a process but instead concentrated on different stages of a lesson. There were two distinct sections in this lecture; the development of a concept map and a series of investigations into forces.

The first section of the lecture introduced a concept map on forces. There were no terms provided to the pre-service teachers for this concept map only the central point labelled forces. This would be analogous to a summative concept map, as described in the electricity lecture. Discussion was also used by the lecturer to aid the students in developing their maps. This section would be analogous to the engagement or evaluation phase of the 5Es.

The lesson moved to an investigation sheet similar to that described in the electricity lecture. These investigations were designed to scaffold and develop content knowledge beyond the curriculum constraints. The lecturer included issues with fair testing by questioning the pre-service teachers to determine whether tests were fair or not. The students were also asked to present their results to the class. This section of the lecture could be described as an exploration, explanation, elaboration and evaluation of the topic of forces.

The use of inquiry conclusions

There are several conclusions that can be drawn about the use of Inquiry based approaches in these lesson observations. The first conclusion is the lack of the term inquiry to describe the approaches that were employed. This provides an interesting insight into the method of teacher instruction provided in these lectures. While throughout the three lectures the various stages and sections could be applied to the structure of an inquiry lesson, this was not made explicit to the students. It can only be speculated whether these students understood the place of each of the various approaches in the process of inquiry.

The second conclusion was this teacher educator facilitates inquiry in her lessons through guided investigations. By limiting the apparatus for the investigation the lecturer was changing the investigation from open-ended to a guided investigation. Section 2.2 showed how Krishner et al. (2006) determined that truly open ended investigations had few positive published results. The approach also recalls the section 4.1 interviewee who believed that open-ended investigations should be the methodology used in science. However, the lack of

time awarded to science may have dictated that these investigations were not fully open-ended.

The third conclusion is the issue of the process of inquiry in primary science education. The three lectures described above were carried out respectively. The first lecture clearly defines a process that the students will follow, and this process was made explicit to the students. In the second lecture however, this process is abandoned for only two elements of the process, which were not made explicit. Finally the third lesson once again returned to a clearly defined process but this was not made explicit to the students. Again only inferences can be drawn about this approach however the inconsistency could be deliberately used by the lecturer to remove the reliance on a process in teaching. Alternatively it may develop inconsistent knowledge with the students as to what an inquiry based lesson is and how it is carried out.

4.2.3: IBSE Methods described in the lectures

In this section the various methodologies that were employed in the lectures will be described under the headings of the 5Es and serve to identify how the teacher educator used these methodologies in her practice.

Questioning played an important part in these lessons. The questions were designed to cover several aspects of IBSE from introducing a topic to evaluating it. Questioning was also used to relate a topic to everyday life for the students. Questions were also initiated through the use of concept cartoons. All of these questions were designed to discover misunderstandings, determine prior knowledge and begin discussion on various topics. As observed in the context of these lectures questioning can be elements of the engagement, exploration, explanation and evaluation stages of the 5Es.

Discussion also played a large part within this lecture series. Referring to the 5E structure, discussion would have been a large element in all five of the 5E phases. Discussion played a part in developing the teachers' content knowledge and challenging their preconceptions. Both discussion and argument were prevalent in investigations where students had to formulate fair tests and discuss why they believed the test was fair. The lecturer typically used the entire class to discuss elements of the engagement phase. This developed a broad understanding of the prior knowledge of the students. Upon the conclusion of the

investigation discussion was again used to decide the outcome of their investigations and to assess the ideas presented on the concept cartoons. The investigation discussions were mainly based on group work and required the students to discuss and argue their case for a particular method or idea.

As stated previously, there were two types of concept map shown, formative and summative. Formative maps were used at the beginning of the lesson and were used to assess student knowledge and misunderstandings. Upon the conclusion of the lecture the students were asked to create a summative map from what they had learned. In the format presented by these lectures concept maps can be an element of both Engagement and Evaluation.

Investigations also featured heavily in these lecture observations. These investigations involved a large amount of preparation work to ensure that the materials were gathered and together and were suitable to the investigation. The materials used within the Forces investigations were common everyday materials that would be easily attained by the teachers in the school. This process highlighted the various materials and resources, which teachers could use in lessons, without having to rely solely on what is available in the classroom. This is an important point in the development of resources for primary school science as developing resources that use everyday materials that are readily available to the teacher will aid the teacher in their lesson and, according to education change literature, result in the teachers being more likely to attempt the lesson.

Scaffolding was also observed through these lectures, especially in investigations. Investigations were structured so that each investigation built upon the learning of the previous one. In the context of these lectures scaffolding was used throughout all stages of the 5Es.

This concludes the section on the methods employed within the lecture series. It can be seen that the methods cross many stages of the 5Es. Many of these activities will be recalled during the observations of teachers in Chapter 5 and the development of the IBSE framework in Section 5.1.

4.3.4: Subject Misconceptions⁵ Discovered

The lecture observations afforded a method to see where misunderstandings are developed and how they can be addressed. In the first lecture on electricity misunderstandings arose on the subjects of wire colour, closed circuits and relevant terminology. A student who was carrying out an investigation into making a bulb light thought that the colour of the insulation on the wire meant that the wire had different properties. This misunderstanding was also discovered in research by Summers et al. (1998). In this case the method to challenge this misunderstanding was to inform the students that the insulation colour is independent to its use. The pre-service teachers were also curious about the symbols on the equipment (the buzzer being used had a raised V on the bottom). They then tried to associate this V with voltage, when it had no relation to it. This misunderstanding was addressed by the lecturer who explained the issue to the students.

In the second lecture misunderstandings arose on the subjects of total darkness, sources and reflectors of light and directions of light. As stated previously the video displayed to the pre-service teachers involved the development and addressing of misunderstandings relating to light. The video explained clearly several misunderstandings and how to address them for the teacher. The misunderstandings described included; the difference between dark (having a low light source) and total darkness and seeing colour in darkness. These misunderstandings were challenged in the video through investigations using totally dark rooms. Here the students could experience total darkness and describe how it is the absence of light. They also realised that they could not see colour in total darkness. On the subject of light sources and reflectors teachers became confused about what object could be the source and what object could be a reflector of light. This misunderstanding was challenged by discussion. Here the lecturer described a scenario asking whether the moon was a source or reflector of light. The students discussed that while the sun is a source of light the moon reflects the light from the sun. This then aided the students in understanding the phases of the moon. Misunderstandings on the direction of light were identified through examples of primary school students' drawings. Here the pre-service teachers had to explain the direction of a shadow with relation to the source of light.

⁵ It must be noted for the purposes of this research that the word misunderstandings was used throughout the lecture series by the teacher educator. It is acknowledged that the use of misunderstandings as a terminology is generally considered outdated and a more accurate term would be misunderstanding (Smith III et al, 1994).

In the forces lecture, misunderstandings arose on the subjects of mass versus weight and the terminology used in science. There was confusion between the terminology of mass and weight by the pre-service teachers. Explanations were used by the lecturer to describe that this misunderstanding is common due to weight being a generic everyday term but it is generally used to describe mass. The definitions of mass and weight were also described here.

4.2.5: Lecture Observation conclusions

It was hoped that the attendance of pre-service teacher education lectures would add to the contextual study of this research. There were several important conclusions from these observations which will aid in the exploration into inquiry in primary science. The first conclusion that can be drawn is that there is no consistent method of teaching through inquiry utilised by this lecturer. It was hoped that, if there was a consistent method employed by the lecturer, the approach could be analysed for its usefulness and applied within this research. The second conclusion that can be drawn is that these lectures showed how diverse the 5E model can be, with every element of the lectures being able to be attributed to one of the 5E phases. Finally the lecture observations highlighted some relevant misunderstandings and methods to address in any intervention or reform of practice.

4.3: Analysing current textbook resources for teachers

In order to complete the contextual study on IBSE in Irish primary science it was decided that a review of current primary school textbooks would be carried out for two reasons. The first reason stems from the results of the NCCA study, detailed in Chapter 1, which found that 71% of surveyed teachers are using and as a result are carrying out didactic teaching methodologies (Varley et. al., 2008a, 2008b). This study would therefore aim to analyse whether textbooks could be used to support IBSE in the classroom, enabling a teacher to maintain a crutch of their teaching while adapting to the aims of the new curriculum. The second reason was to identify curriculum content and methodologies that were present in textbooks that could be adapted into an IBSE format for the intervention of this research. Concerns about textbooks were also raised about the use of textbooks in primary school science during the teacher educator interviews in section 4.1.

Textbooks in Primary science should be carefully examined by experts in primary science education and monitored by the DES before being put on the market.

[We tell our] students to have a textbook but don't get the students to get [a specific] one as the teacher can end up relying on them, and if parents see that they aren't filling out their textbooks then they worry as to what is being covered in classroom.

-Teacher Educator views on textbook use in school, Section 4.1

To this end, three Textbook Series were chosen for review. Section 4.3.1 will detail the research method used for this analysis. Section 4.3.2 will detail the analysis and results and section 4.3.3 will describe the conclusions that can be drawn.

4.3.1 Research Method

The methodology used in this study is based on a content analysis of the textbooks. This methodology was chosen in order to assign meaning to the various methodologies employed in textbooks and to make inference about their meaning (Krippendorff, 2004, Wang, 1998, Wilkinson, 1999). As teachers are using textbooks as primary resources in their teaching, the activities presented in the textbooks are crucial to understanding how teachers are currently teaching science. In order to analyse the textbooks within an inquiry context an analytical framework had to be created and applied to the textbooks (Wang, 1998, Wilkinson, 1999). For the purposes of this work a framework was developed based on the 5E model of inquiry (Bybee, 2006a). The 5E model is utilised in the teaching of a lesson which meets the requirements of an inquiry based approach as defined above.

The textbooks chosen for analysis were randomly chosen from a list of current science textbooks. No consideration was given to the title or author of the selected textbooks. This method was chosen in order to eliminate any factor of the title or author which could influence the results of this study. Two exclusion criteria were applied to this study. The first exclusion criterion was the textbooks purpose in the classroom. There were several textbooks available that dealt with the subject of Social, Environmental and Scientific Education (SESE) rather than specifically science education. These textbooks were excluded from the selection of textbooks as their purpose went beyond the subject of science alone. This would have had an effect on the analysis as the content would have to have been subjected to an extra section determining whether it was targeted towards geography, history or science. It

was also assumed that the amount of science activities in these textbooks may be reduced as they catered for three subjects rather than one. Therefore, it was decided that these textbooks could not be compared to textbooks that included science alone. It is important to note that the audience of the textbook was also not a factor in the decision for analysis. As it will be shown, if a textbook was selected for analysis all of the textbooks in that series were analysed. This meant that the analysis of the textbook would not be subjected to an unfair comparison if the textbook was aimed at a younger or older year group. This decision also removed the issue that will be shown with Textbook Series C whereby each individual textbook is aimed for use over two years rather than one year. By analysing every textbook in the series, conclusions could be drawn that would compare activities aimed at the same level in schools. The three Textbook Series therefore, were chosen at random, from the available textbooks on science education and were all subjected to the same method of analysis. The second exclusion criterion was the language in which the textbooks were presented. Several of the textbooks available in science education are presented in Irish as well as English. In order to ensure that the textbook could be properly analysed the English only versions were chosen. At the time of the study there were eight textbooks available for use in primary schools. Applying the exclusion criteria meant that six were applicable for analysis. It is also important to note that this study was not designed to classify each the amount of inquiry in textbooks. Therefore the sample size that was chosen for analysis was $n=3$. It was decided that three textbooks would provide enough data to determine whether textbooks could be used to support inquiry in Irish primary school classrooms.

IBSE is focussed on the idea of a process rather than a single activity (Anderson, 2002). This process of inquiry is identified by carrying out all five phases of the 5E model (Bybee, 1989, Bybee et al, 2006a), described in Table 2. Applying the various concepts described to primary school contexts it was decided that a descriptor of inquiry would be used within this research to allow for a certain degree of flexibility to support cases whereby a textbook did not follow the prescribed 5E structure. This descriptor allowed for two assumptions to be applied to the textbooks. The first assumption involved the elaboration phase. Elaboration activities involve the application of what has been learned and may include many elements outside of the context of the classroom. It was assumed that textbooks would supply knowledge and activities but not ask students to apply it to other situations. The second assumption was that the textbook would not place a particular emphasis on evaluating students. It was assumed that if a teacher wished to evaluate the learning that they would

develop their own methods and tools to do so. It would therefore be unlikely that a textbook would supply a teacher with a formal evaluation for the content and therefore the concentration on evaluation would be reduced in textbooks. This meant the descriptor of the process of inquiry would include the first three of the 5Es, Engagement, Exploration and Explanation. This descriptor still allowed a textbook to incorporate all of the five phases if the textbook included them but allowed flexibility in the analysis to see whether textbooks could promote at least the first three phases of the 5Es.

Table 4: The Content Analysis Tool

Subject	Engagement	Exploration	Explanation	Elaboration	Evaluation
Topic matter	Add engage activity	Add Explore activity	Add Explain activity	Add Elaborate Activity	Add Evaluate Activity
Topic matter 2	Add engage activity	Add Explore activity	Add Explain activity	Add Elaborate Activity	Add Evaluate Activity

The next stage in the methodology involved the development of a tool that would enable the various ideas and activities within the textbooks to be placed under the phases of the 5E model. The nature of the 5E model ensured that every activity within the textbook could be placed within one of the 5E phases. A tool was designed in such a way to allow for the easy comparison of topics, books and year groups. Each topic or lesson in the textbook was broken into its various activities and placed under a heading in the 5E model. Each activity was also described under the 5E model heading to enable a comparison of the various activities that the textbooks promote.

Table 5: An extract from a completed framework on the subject of light

Subject	Engagement	Exploration	Explanation	Elaboration	Evaluation
Light	Discuss whether black is a colour or not		Explain how light is a form of energy		
		Discuss the differences between natural and artificial light			
	Discuss whether white is one colour		Explain how white light is made of 7 colours		
		Experiment to mix different colour light		Question and discussion: What colour dog should an Australian farmer get	
				Research how lasers work	Create an information poster about lasers
	Discuss a torch beam in the darkness				
	Discuss the light entering and exiting an aquarium	Experiment to observe and record refraction		Discuss the findings of the experiment	Investigate how lenses affect the beam of light

Table 4 shows the template content analysis tool. Table 5 shows how above tool was used to break down and associate the material and corresponding activities on the subject of light in one of the textbooks to each of the phases/headings of the 5E model and, hence, providing an IBSE-organised lessons structure. The output of the tool also incorporates an order element so, for example, in Table 6, the first activity described in the textbook is a discussion. This is followed by an explanation of how white light is a form of energy. The third activity is an Explore activity, which gets placed on the next line as the table is designed to be read from left to right. Hence, the developed tool categorises an identified activity, describes it and puts in the relevant order that would enhance the inquiry approach of the lesson.

In order to deeply uncover the nature of inquiry in the textbook, a four layer study was developed, as described in Table 6. These layers would each highlight an area of the 5E model structure. Each layer individually could not be used to determine whether the textbooks could be capable of promoting IBSE however the conclusions from each layer and a combination of the layers would uncover this information.

Table 6: The layered structure of the study

Layer	Element	Description
1	Structure of the textbook	Place each activity present in the textbook under a 5E model heading and allow for the structure of the textbook to be viewed under and inquiry lens.
2	Individual Topics	Compare individual topics in the textbooks for patterns and comparisons as to which topics met the requirements of the framework
3	Individual Activities	Highlight whether textbooks are utilising many varied activities or repeating a limited set of activities
4	Pedagogical or Content Orientated textbook	Identify which textbooks promote a large number of pedagogies, a large amount of content or both.

Data analysis was carried out by a single researcher using a blind test method of coding. This method was used to ensure the consistency of data. Additional coders could not be used in this analysis as all coders would have had to have a standard and in-depth knowledge of the construction of the 5Es, as well as the aims and objectives of each layer of the study. Instead a blind coding setup was used where a selection of the textbooks were coded, and then recoded without reference to the first analysis. A comparison of the two analyses highlighted ambiguities in the definitions used during the analysis. These definitions were clarified further, the structure of the tool was adapted and another textbook was chosen for a blind code test. Once the comparisons of the two blind coding tests showed consistent results then the full analysis was carried out.

Table 7: The breakdown of the textbook labels:

	Junior Infants	Senior Infants	1 st class	2 nd class	3 rd class	4 th class	5 th class	6 th class
Textbook A	A1	A2	A3	A4	A5	A6	A7	A8
Textbook B	B1	B2	B3	B4	B5	B6	B7	B8
Textbook C	C1		C2		C3		C4	

The structure of the textbooks also created a difficulty for comparative reasons. Three Textbook Series, designated A, B and C, were analysed as part of this study. Each textbook in series C contained material to be covered in two consecutive years of the Irish primary school system, whereas each textbook in series A and B contained material for only one year. In order to account for this variation in the structure of analysed textbooks, the following labelling system was designed. Each textbook was assigned a unique label comprising the designated letter of its series followed by a number indicating the targeted year of its coverage. Accordingly, a textbook from series A that contains material for Junior Infants year was assigned the label A1, whereas a book from the same series but covers material for first Class was assigned the label A3, and so forth. The textbooks were then grouped according to their corresponding target year, as illustrated in Table 7.

4.3.2: Textbook Analysis Results

4.3.2a: Structure of the textbook

The structure of the textbooks was indicated in terms of percentage figures and shows how much of the activities in the textbook are deemed to support each of the phases of the adopted 5E model. These percentage figures were created by comparing the total number of activities in one phase to the total number of activities in all the phases in that textbook. This created a proportional representation of each 5E phase in the individual textbooks. This highlights whether particular textbooks encourage a particular phase of the activity or whether certain phases are more common in certain years. Table 8 shows the results of this study and displays several important features of the structure of each textbook.

As it can be seen, the structure of each of the textbooks differs vastly depending on the Textbook Series selected. The results showed how Textbook Series A promotes Engagement

and Exploration, with little emphasis on other elements of the 5Es. The emphasis on Engagement decreases as the years increase, however the final two years textbooks still contain a majority of Engagement activities. While Textbook Series B followed this trend it contained less of an emphasis on Engagement than series A. This series also shows a build-up of the process of inquiry throughout all eight years of the schooling. The structure of Textbook Series C emerged as having an approximately equal standing of all phases throughout all of the years. Considering the learning outcomes of IBSE as described by the description provided above, only textbook C provides a consistent process of inquiry of the three textbook series as emerges as having the most consistent features with an IBSE lesson.

Table 8: The Percentage of each phase in each textbook

5E Phase:		Engagement	Exploration	Explanation	Elaboration	Evaluation	Total
Textbook	Class	(%)	(%)	(%)	(%)	(%)	(%)
A1 and A2	J and S	96.74	3.26	0.00	0.00	0.00	100
A3 and A4	1 and 2	81.54	9.15	9.31	0.00	0.00	100
A5 and A6	3 and 4	64.58	18.80	16.62	0.00	0.00	100
A7 and A8	5 and 6	44.35	29.48	25.18	0.66	0.33	100
B1 and B2	J and S	84.18	15.82	0.00	0.00	0.00	100
B3 and B4	1 and 2	41.15	41.28	17.57	0.00	0.00	100
B5 and B6	3 and 4	22.15	37.88	34.25	4.91	0.81	100
B7 and B8	5 and 6	14.83	44.04	37.99	3.14	0.00	100
C1	J and S	25.00	32.39	6.82	32.39	3.40	100
C2	1 and 2	26.73	32.18	11.88	18.32	10.89	100
C3	3 and 4	16.01	26.85	12.56	28.82	15.76	100
C4	5 and 6	16.74	22.48	15.83	29.35	15.60	100

Note: J and S class refers to Junior and Senior Infants

4.3.2b: Patterns in Individual Topics

From the study carried out, it quickly becomes evident how few of topics present in Textbook Series A contain the structures and process of inquiry. Throughout all eight books of this series only five topics contain the structure and process of inquiry as determined by the 5Es. Textbook B includes twenty topics across the book series that meet the descriptors of structure and process. This Textbook Series contains a greater, more diverse set of lessons that meet the framework requirements. This may suggest that the textbook could benefit teachers that are not confident in subjects and across more curriculum areas. As it has been described previously, the textbooks in series C contain a highly structured approach within the textbook that aligns itself well with the 5Es approach. These results are carried through to the process and structures of each of the individual topics. There is no topic presented in Textbook Series C that does not meet the descriptors above.

As it can be seen from these results, there is no discernible pattern across all of the textbooks highlighting which topics are more likely to be presented in an IBSE manner. Textbook Series A aligns with the results of the NCCA study of teachers by showing how Living Things subjects are more likely to be carried out as IBSE but there is an emphasis on Engagement and Exploration only. Textbook Series B, on the other hand, promotes IBSE lessons across more topics and curriculum areas. Textbook Series C displays all of its topics clearly as IBSE lessons and incorporates a consideration of each of the 5Es as shown in section 4.3.2a. It can therefore be concluded that Textbook Series C meets the intended learning outcomes of IBSE to the greatest extent. It also can be concluded that textbook C contains characteristics which are closer to an IBSE structure per topic than the other two textbooks.

4.3.2c: How Activities are Represented in Textbooks

This section analysed what activities were used to present each of the 5E phases in the different textbooks. The descriptions of activities within the Engagement phase can be similarly described across all of the Textbook Series. It is clear that younger student's thoughts and actions are being elicited from their life experiences and older student's thoughts and actions are being elicited from their experiences of their studies. This shows a move from the students' life experiences to the students' knowledge of science. Textbook Series C emerges in the Exploration phase as having the most diverse range of activities all of which are in line with current trends in IBSE. The approach provided in the explanation phase in

Textbook Series C can be viewed as a more student-centred approach to learning. This series asks the student to explain the topic rather than providing them with information to be learned. This displays a more constructivist approach rather than a deductive approach. The only conclusion that can be gained from the elaboration phase is that Textbook Series C promotes the use of this phase in lessons whereas the other Textbook Series contain between zero and five percent of these activities. Again Textbook Series C emerged as having the most varied approaches and activities in the evaluation phase. These conclusions highlight how if a teacher utilizes Textbook Series C they will be provided with many student focussed activities to carry out and can therefore be considered as having the most potential to support inquiry in the classroom.

4.3.2d: Textbook Orientation

The data analysis presented above highlights how each textbook chosen for analysis has a different orientation towards developing content knowledge, developing pedagogical knowledge or developing both content and pedagogical knowledge.

It becomes apparent that Textbook Series A heavily promotes the content knowledge of science. The series, generally, does not contain the structures as determined by the 5E model and where the structure is present it is not in the order specified by the 5Es. The final books' concentration on explaining a topic to a student rather than the exploration of a topic is also apparent. The study of the various activities present in this book did highlight many, varied methodologies in the Engagement and Exploration phases however; these methodologies were isolated to these two phases. The analysis of Textbook Series B identifies that it promotes content over pedagogy. This series was shown to promote mainly Engagement and Exploration phases. It also concentrates on supplying the information to the students and no book in this series contains the process of the 5E model. It becomes evident that textbook C contains the process and structures contained within the 5E model in all of its textbooks. These structures are also accompanied with the promotion of many varied activities and pedagogies for the teacher in each of the 5E phases. The approach of the explanation phase is also heavily student-centred rather than didactic. In relation to the content knowledge of the subject Textbook Series C contains all of the subjects that the other two series contain. It is for this reason that Textbook Series C is being described as promoting both content knowledge in science and the pedagogy of inquiry.

4.3.3: Discussion and Conclusions

The results of this study highlight several interesting nuances within primary science textbooks from which several conclusions can be drawn. Firstly using the definition of IBSE and the framework, it has been shown that textbooks can in fact support the implementation of inquiry in the school by providing teachers with content knowledge and varied, student-centred, pedagogical practices. This means that a teacher who is wishing to adapt their methodologies into an IBSE approach can still, in principle, gain support from a textbook. This research therefore caters for the teacher who centres their teaching on the textbook, but allows them to develop pedagogical practices beyond traditional didactic methodologies. It also provides an argument for the inclusion of the textbook into the classroom as a tool rather than a central dictator of lessons.

Each element of this study highlighted a specific area or ideal related to IBSE. Textbook Series A was shown to contain mostly Engagement and Exploration activities. While this may not have been in line with the descriptors of IBSE attached to this study, the approach taken by these books may be attempting to account for the young age of the students. These textbooks could be promoting science as an interactive subject that can be easily discussed. While this study cannot make a judgement on this approach, it is the findings of this study that these textbooks can only support the specific phases of Engagement and Exploration within the 5E model. A teacher could however build on the lessons present in this textbook by adding in elements of the other 5Es to them. This teacher would have to understand the process of inquiry and have the content knowledge required to add activities in the Explanation, Elaboration and Evaluation phases. A teacher utilising the final books in this series would have to be adept at determining the students' prior knowledge, capturing interest, misunderstandings and evaluating the learning and understanding that has occurred in the lesson based on the structures present in these textbooks.

Similar to Textbook Series A, the books in Textbook Series B do not contain all of the structures present as described by this study. Again younger students are presented with Engagement and Exploration activities promoting science as an interactive subject. The senior books in this series contain a majority of Explain activities. This approach is very deductive in nature and relies on the student memorising large amounts of facts about certain topics without learning them through exploration. These books could benefit the

implementation of IBSE if the teacher is fluent in the process of Exploration, Explanation, Elaboration and Evaluation. Textbooks B7, B8 and B9 could only address the content knowledge required for IBSE lessons but could not be used to develop a complete IBSE lesson due to the lack of varied pedagogies and IBSE structures in the textbooks. A teacher utilising these books would need to concentrate on students' prior knowledge and exploring topics in later years of primary school. The textbook, therefore, would only emerge after the topic had been introduced and the students are allowed to explore it. The textbook could also be used to provide any information which may have been missed in the Explore phase or to identify any misunderstandings that may have arisen through the Explore phase.

Textbook Series C emerged as the series that met the most requirements over all of the elements of this study. It is therefore the conclusion of this research that this textbook is the best suited to the promotion of IBSE in the classroom. All of the books in this series meet the intended learning outcomes of IBSE while containing the features and characteristics of an IBSE lesson. This textbook can aid a teacher in the pedagogy of inquiry while providing them with the necessary content knowledge to support the implementation of IBSE.

These conclusions rely heavily on the PCK of the teacher and the context of their specific classrooms. The conclusions rely on the teacher having the training, information and understanding of the process of IBSE. Without this knowledge a teacher could easily revert to didactic teaching methodologies if they select an inappropriate textbook for their inquiry pedagogy level. The challenge therefore becomes aiding in a teacher selecting the textbook which best suits their level of PCK and their inquiry needs. This study has shown that textbooks currently available to teachers in Ireland can be used to promote IBSE in the classroom to varying degrees and utilising varying elements. This means that the teacher does not have to abandon a crutch of their teaching when trying to carry out IBSE lessons but can in fact gain valuable support from a textbook in their teaching. It must also be pointed out that all of these textbooks were written with the new curriculum in mind and the assumption is that the practice of IBSE was taken into account when they were being written. The different approaches and structures presented in the textbooks could refer to the authors' interpretations of IBSE and its practice. Therefore the approaches discussed by the textbooks could be a result of confusion about the practice of IBSE. Any future confusion could be addressed by the National Council for Curriculum and Assessment through the publication of further guides for teachers and textbook authors as well as the inclusion of professional

development to encourage the use of textbooks as scaffolds of IBSE. This would to aid in the understanding of what the NCCA considers to be IBSE and future textbooks could be written to promote it.

4.4: Chapter conclusions

This chapter has attempted to describe several studies which were carried out to develop a contextual awareness of science education in Ireland. The teacher educator interviews developed an awareness of the views and opinions of teacher educators in Ireland. These views included their views on issues in Irish primary science education, the active promotion of IBSE, the importance of science in their institution and their views that there should be further research and reform in Irish primary science education. The pre-service teacher observations provided insights into the methods and approaches of inquiry that are being implemented in pre-service education. These observations also identified how to identify and address misunderstandings for the intervention. Finally the textbook analysis determined that textbooks can be used to aid IBSE in the classroom and that teachers do not have to abandon a crutch of their teaching if they want to conform to the new curriculum goals and practices.

Chapter 5: Professional Practice

IBSE pedagogy [...] creates opportunities involving firms, scientists, researchers, engineers, universities, local actors such as cities, associations and other kinds of local resources

(Rocard et al. Report, 2007, p.2)

This chapter will detail the study of professional practice of science teaching in Irish primary schools. This study is realised through the development of an analytical framework, a series of discovery observations and an analysis of the Pedagogical Content Knowledge (PCK) of the participant teachers on the subject of magnetism.

5.1: Developing an analytical framework of Inquiry

It was believed that the lack of a definition of IBSE (Anderson, 2002, Abell, 2007, Krishner et al., 2006) would create issues when attempting to analyse any data for elements or processes related to IBSE. It was therefore decided that a tool would be developed, based on the review of the literature and lesson planning techniques, which could be used as a reference point in any analysis. The section on approaches to IBSE (2.3.2) details the primary model of IBSE chosen as part of this research which is the 5Es model. Table 2 in Chapter 2 describes each of these phases.

The exploration methodology of this research ensured that this framework could be field tested with appropriate real world examples of lesson analysis. The framework was applied to the textbook analysis, the discovery observations, the development of the intervention and the intervention observations. The application of the framework to these studies aided in validating the development and usefulness of the framework.

5.1.1: Structure of the analytical framework

Using lesson planning techniques, a series of questions were placed within the 5E headings to develop the individual structure of each 5E phase. By placing each of these points in the framework, any researcher or teacher utilising it would be able to position an activity to the appropriate location on the framework.

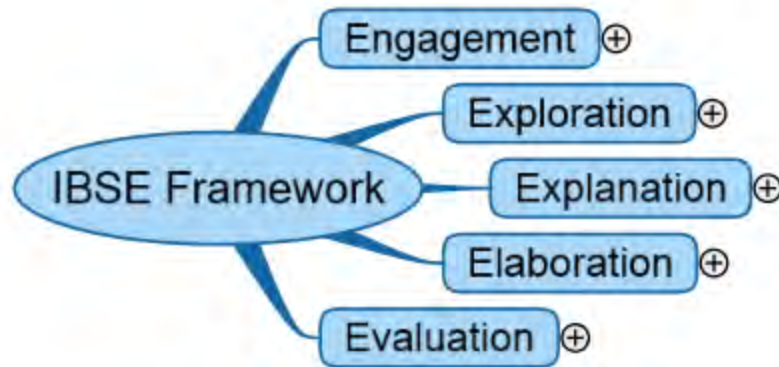


Figure 4: The Base Section of the ISBE Framework

A series of questions were then applied to each phase. These questions included:

- What is the basic concept of that 5E phase?
- What is the desired outcome of that phase?
- What activities can be used to meet these outcomes?
- Who carries out these activities?
- What content knowledge must be imparted to meet the outcomes?

The first question ensures that the basic concepts of the 5E phase are considered before any consideration is given to the content or objectives of a lesson. It aids in clarifying the purpose of the phase as some activities can be carried out in different phases of the 5Es.

Once the topic and 5E phase has been chosen, a teacher would then consider the intended outcome of the lesson. Depending on the phase, the outcomes could be as simple as recalling prior knowledge or experiences of the student to understanding terminology or practices. The third question within the framework involves considering the various activities that could be used to meet the outcomes of the lesson as well as the outcomes of the 5E phase. As stated in the literature review, primary school teachers generally are carrying out teaching activities which promote the activity over meaningful learning (Rocard et al., 2007, Varley et al., 2008a, 2008b). By placing the outcome of the lesson before the activity consideration this framework aims to ensure that any activity utilized within a lesson has a meaningful learning objective behind it.

The fourth question identifies who is conducting the activity. IBSE is described as a student centred approach to teaching (Abell, 2007, Anderson, 2002, DES. 1999, 1999a, Varley et al., 2008a, 2008b, 2013). This question enables the teacher or a research to identify whether the lessons or activities are heavily student or teacher centred. Rocard et al., 2007, stated that didactic methodologies may have relevance in ISBE lessons. This question also affords a research to identify where teacher centred activities are required for learning rather than student centred activities. The framework also identifies whether students are working in groups or individually.

The final question of the framework identifies the content knowledge that will be required for the lesson. This section was added to ensure that there was an element of content placed within the framework as this can be a contributing factor in determining the various activities or methodologies employed. This section also serves to identify links to other curriculum subjects for both the teachers and students.

5.1.2: The 5E Phases

Engagement

Figure 5 details the Engagement element of the IBSE framework. The five questions above were applied to the concept of Engagement in the 5Es.

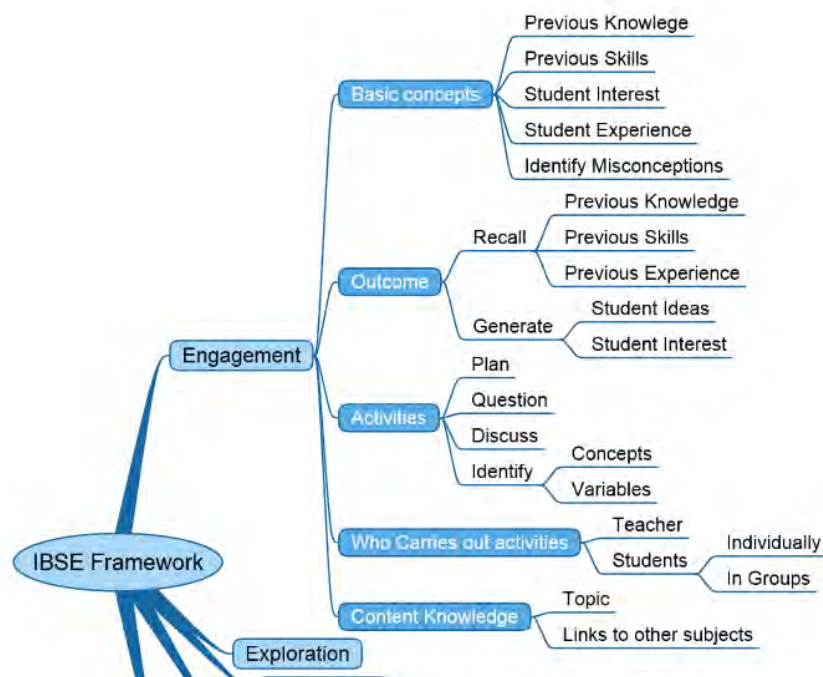


Figure 5: The Engagement section of the IBSE framework

Exploration

The framework for the exploration phase revolves around the development of concepts or skills that a student may obtain through their studies. Figure 6 details this section of framework.

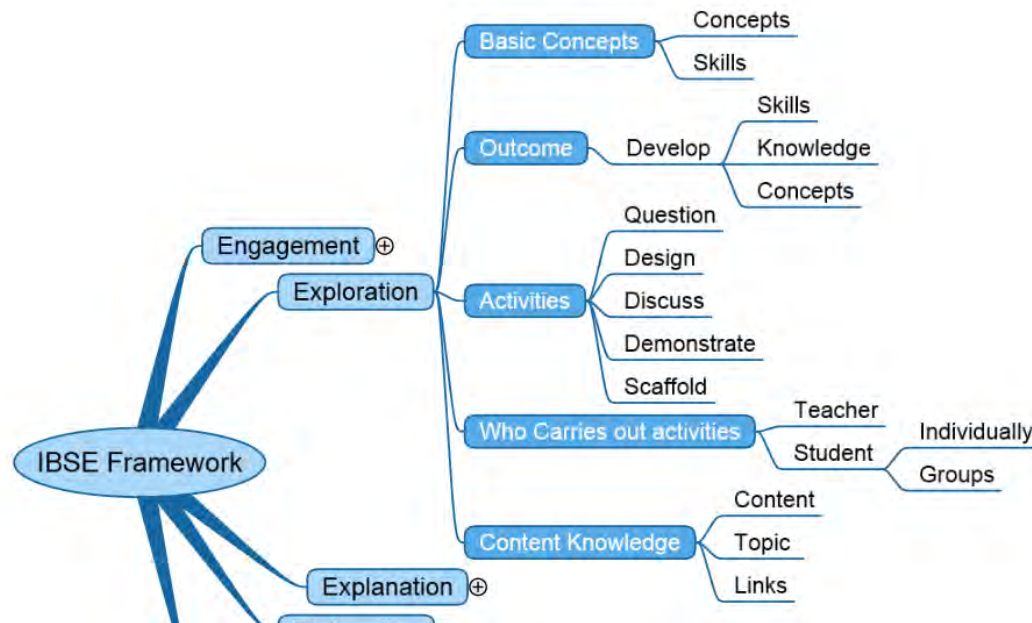


Figure 6: The Exploration section of the IBSE framework

Explanation

Figure 7 details the explanation section of the framework. The main point in the explanation phase relates who is carrying the various activities out. A teacher may misunderstand that the explanation phase is where they add the content knowledge to the subject that the students have been learning. This is however not the description of the explanation phase as described by Bybee (Bybee, 2006). The explanation phase can be carried out solely by the students, where they explain what they have learned to the class or teacher. This allows the teacher an identify elements of students learning and then expand on them if needed. An extra point has also been added to the content knowledge question which includes results from any experiments or investigations that have been carried out.

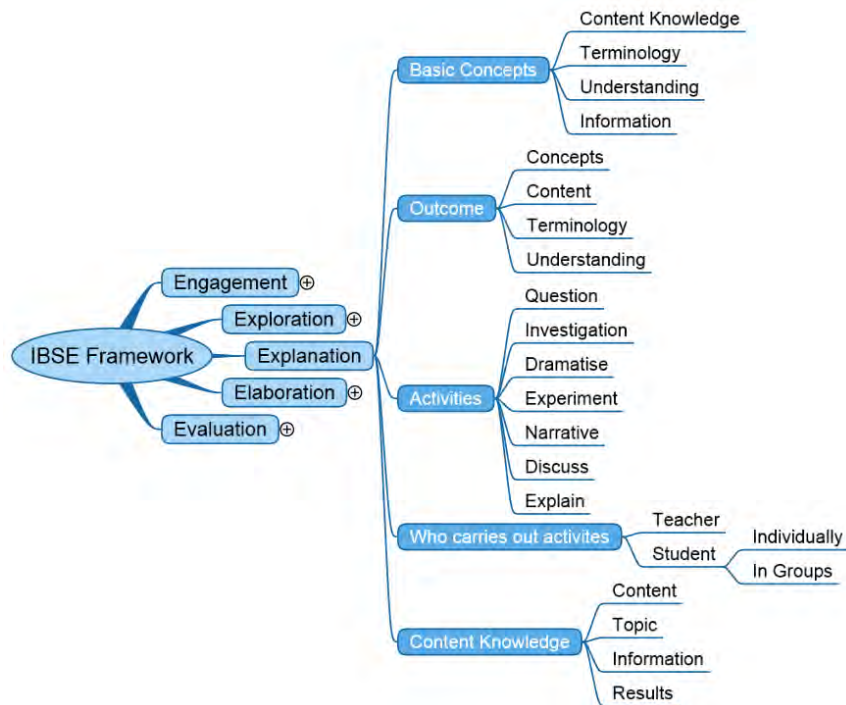


Figure 7: The Explanation section of the IBSE framework

Elaboration

The elaboration phase of the framework involves the student application of knowledge from the lesson and is shown in Figure 8.

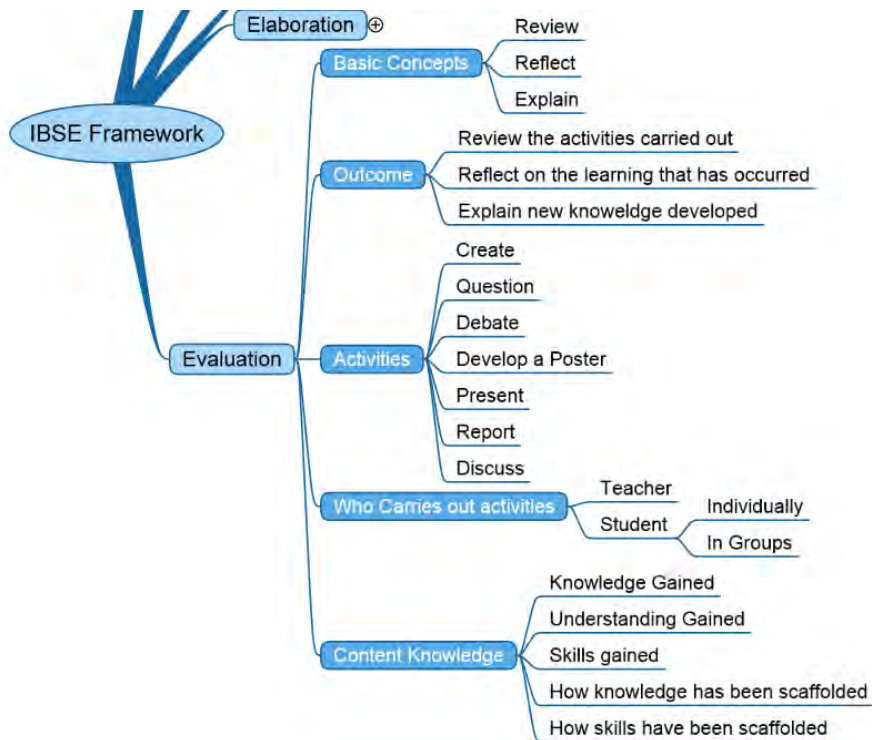


Figure 8: The Elaboration section of the IBSE framework

Evaluation

The final phase of the IBSE framework is the evaluation phase and is shown in Figure 9. The crucial point of the evaluate phase is the content of the activity as this involves ensuring the students understood the content or skills that were being developed throughout the lesson and identifying gaps in understanding or knowledge by the student.

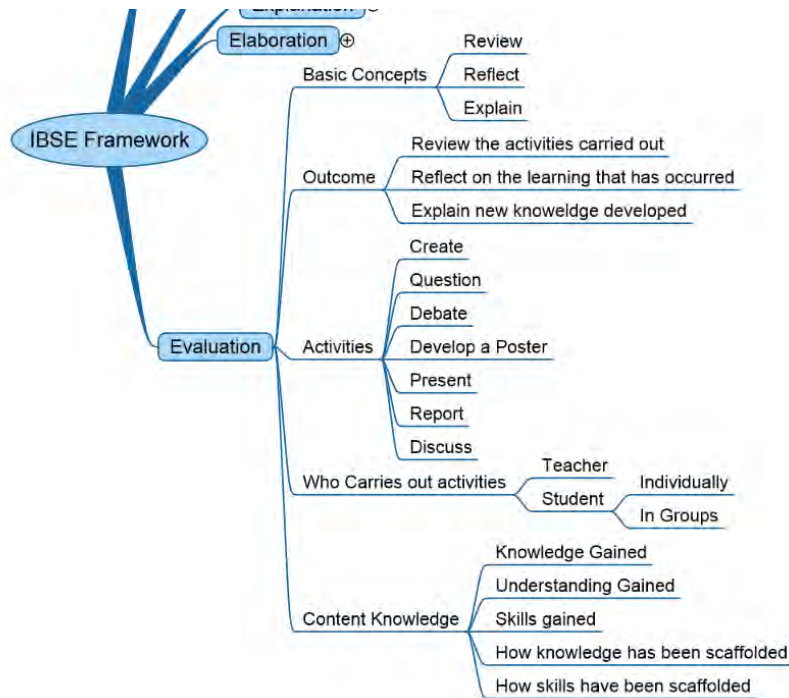


Figure 9: The Evaluation section of the IBSE framework

5.1.3: The Analytical Framework

Combining all of these phases into the analytical framework of IBSE allowed all of the resources, lessons and developments within this research to be analysed using a consistent structure. This framework was developed on the supporting structure of the 5Es. Using the 5Es ensures that the framework was based on sound research that was heavily linked with IBSE.

5.2: Lesson Plan Analysis

As described in Chapter 3, the lesson observations utilised several tools and methods. These included tools on lesson planning, teaching practice and lesson evaluation. This section will detail the results of the lesson plans that were collected. Many of the tools and practices were edited during the course of the discovery observations in order to improve the quality of the data being collected.

5.2.1: Research Method

The pre-lesson tool (see Appendix A) is divided into three sections. The first section is composed of an interview designed to identify contextual elements of the class that is to be observed, due to context playing a large role in a teacher's PCK (Shulman, 1986, Shulman, 1987). These questions identify recent science lessons, the topic to be observed as well as a brief future lesson plan. The interview also asked for any risks the researchers should be aware of before entering the class. The second section of this tool involves the teacher creating a lesson plan using the CoRes tool, see section 3.5.2 (Loughran et al., 2001). This tool was developed to identify elements of a teacher's PCK in science and to discover whether the CoRes would be useful as a lesson planning tool. This use of the CoRes as a lesson planning tool represents a novel application of the tool. The final section of the pre-lesson tool adds any extra notes or teacher lesson plans for the data analysis.

Throughout the course of the observations it became evident that this method did not add any valuable data to the lesson analysis. This was due to the amount of time it took to fill in all of the various tools, the value of the data collected and lack of teacher developed lesson plans and evaluations. Also as the observations were carried out between other lessons the researcher would have to interrupt a lesson to carry out the interviews. Instead the pre-lesson tool was reduced to the CoRes tool alone with the option for the teachers to add their own lesson plans if they wished.

5.2.2: The pre-lesson tool results

The original premise behind the interview questions was to identify various elements of the teacher's scheme of lessons as well as details about the class. The results of these questions did collect some details about the context of the class that was being taught and the school itself. These details informed the descriptions of the teachers in Chapter 3 and aided in the understanding of the contexts of these teachers.

The second element of the pre-lesson tool was the CoRes. In the context of this research it was hoped that the CoRes could be used as a lesson planning tool. This was a new element of practice for the CoRes and it was unknown as to whether the results would provide meaningful insights (Loughran et al., 2000, 2001). Loughran et al. describe how CoRes are developed through focus groups and not through use with an individual teacher. While the participant teachers, in this research, were all provided with information and guidelines to using the CoRes, the feedback from the teachers identified that the CoRes tool was not, generally, beneficial to their lesson planning. Reasoning for this will be provided from section 5.2.3 onwards. The collected CoRes did however provide some beneficial data with relation to the teacher's PCK. It must be noted that Teacher D did not submit a CoRes lesson plan by choice. The CoRes are shown in Appendices

The final element of the pre-lesson tool was a section for the teacher to add any other information for the researchers before the lesson was recorded. This section took the format of a questionnaire to be filled out by the researcher and to be used as a recording tool only. The questionnaire was composed of three questions and ensured that all lesson plans and resources were properly accounted for. The teachers opted not to submit their own lesson plans for the research, but instead used the CoRes tool provided as it was part of the research. This again negated the use of this section so it was eliminated from subsequent lessons.

5.2.3: Lesson Plan Analysis

5.2.3a: Pedagogical Knowledge

In terms of pedagogical knowledge it is not clear the value of the CoRes tool has for individual teachers and lessons. As stated previously the CoRes was designed to be carried out as part of a focus group of more than one teacher and to consider several lessons. The pedagogical knowledge can be ascertained from question 7 and question 8 of the CoRes. It

can be seen that there is a lack of data supplied by these teachers for these questions. This is applicable across all four CoRes collected and while methodologies such as discussion discover, questioning and worksheets are mentioned, no conclusions can be drawn as to how they will be utilised in the classroom. Comparing Teacher C's CoRes to Teacher A and B, the answers provided are much shorter and there are more blank spaces. For example, question 8 relies solely on questioning to evaluate the learning that has occurred. Comparing the answer of question 7 to the previous three CoRes collected it can be seen that Teacher A and B mentioned many activities (see Appendix K) or gave specific descriptions of a methodology they were employing (see Appendix L and M). This may identify a lack of pedagogical knowledge by Teacher C.

5.2.3b: Content Knowledge

Again there is little data identified in the CoRes relating to content knowledge. While the primary objectives and ideas in the lesson are described there is a lack of detail present to form any conclusions. One answer provided by Teacher C however may highlight an issue with content knowledge. In question 3, the teacher states that he knows about displacement in ships but does not intend to teach it. This answer only informs the researchers that the teacher is aware of the concept of displacement but does not provide any insight into the level of knowledge the teacher has about that subject. It also may identify confusion by the teacher as displacement refers to the water that is displaced by the ship, not "in" the ship. The CoRes here may highlight that the teacher is aware of the concept of displacement but has little knowledge of what the concept is.

5.2.3c: Context Knowledge

The CoRes collected from the participant teachers identifies that these teachers may have a large amount of contextual knowledge however the responses to the questions are short and do not provide a lot of detail. Throughout the CoRes there are several considerations of how the students learn and what influences their daily life. This is informed from the answers to questions 4 and 5. Teacher A, for example, understands that her students are impatient when studying science but they enjoy planning and investigation activities in her classroom. Teacher B describes how the students are naturally inquisitive and that a "hands on" approach would be best method to show magnetic materials. She also highlighted how the students, who are at a first class level, should not be given a lot of terminology on magnetism and that

the electricity lesson must be limited to discussions as she cannot demonstrate electricity to students of that age.

5.2.3d: The use of CoRes as a Lesson Planning Tool

The collected CoRes contain elements that would not be considered suitable to be used for a lesson plan. Firstly, by using the CoRes, the various learning objectives are not obvious and if a teacher is using this tool it may lead to an objective being omitted in the class. The benefit of lesson planning is to aid a teacher in effectively developing process which will meet the intended outcomes of a lesson. For example, using question 7, a lesson plan should detail the objective of an observation or data collection. Instead the CoRes only list the activity without consideration to its method and effect. Secondly the structure of the CoRes does not allow for a time factor of the lesson. The effective use of time and timing for teachers was an issue that was highlighted by the teacher educators in Chapter 4. The CoRes does not include any time considerations in it and therefore it makes the timing of the lesson difficult to manage. It has been stated in Chapter 3 that the CoRes tool contains elements which are associated with IBSE. It has been argued previously however that IBSE is a process rather than a set of activities, (see section 2.2). By utilising the CoRes as a lesson plan the process of the lesson is not clear and it cannot be established whether the lesson would follow the structure of an IBSE lesson.

5.3: Discovery Observations

As stated previously there were two sets of lessons observed in this research. The first lessons observations are labelled the discovery observations as they aimed to discover elements of IBSE in teaching in Ireland. While this was the case, the teachers were not made aware of any IBSE agenda. This was important as it meant the observations, from the teacher's point of view, allowed the teacher to teach naturally without any preconceptions as to what was expected of them. Chapter 6 will detail the intervention observations whereby this research actively influenced the teaching of the observations to assess the impact of the intervention.

The discovery observations were used to develop an idea of whether ISBE practice in Ireland was explicit or implicit in teaching. To accomplish this, it was decided that teachers would be recorded practicing science teaching in their own classrooms. This, it was hoped, would create authentic teaching scenarios that would be used in the development of the learning

environment. In total eight discovery observations were carried out. The teachers were asked to teach a subject that they were comfortable teaching, for the first recording. This would serve several purposes. First it was thought that the addition of two cameras and a researcher in the classroom would cause a disruption to the normal running of the classroom. It was also thought that the teacher would be able to reduce this disruption to the classroom if they were comfortable teaching a subject. It would also provide an insight into what subject the teacher thought they would be confident at teaching. As stated previously, research has shown that teachers are generally not confident at teaching the physical sciences (Harlen, 1995, Murphy et al., 2007, Varley et al., 2008a, 2008b, 2013). By asking the teacher to teach a subject they were comfortable with, comparisons between the participating teachers and the research above could be made. Thirdly it was thought that if a teacher chose a subject they were confident at teaching they would be more likely to teach through an inquiry approach rather than a didactic approach. The teachers were not made aware of this idea prior to carrying out the lesson. Table 9 describes the discovery observations for each of the participant teachers. This table also shows the variance of the subjects that were observed.

Table 9: Topics covered in the discovery observations

Teacher	Observation	Subject
A	1	Light and Reflection
	2	Rate of Flow
B	1	Introduction to Magnetism
	2	Introduction to Electricity
C	1	The sinking of the Titanic
	2	The Senses
D	1	Extracting Protein from milk
	2	Acids, Bases and the pH Scale

The second observation was carried out in a similar fashion to the previous one. Here the teacher was again asked to teach any subject they wished in the manner with which they would normally teach it. The teacher was asked to teach a subject that they were not entirely comfortable teaching in order to ascertain what subject the teachers found difficult to teach. The second reason for this was, at that stage, it was hoped both the teacher and the students would be familiar with the video equipment and observer in the classroom. It was hoped that parallels could be drawn between the subjects taught and the subjects that the NCCA found teachers tend to struggle with (Varley et al., 2008a).

5.3.1: Research Methods

This section will describe the during and post lesson tool. The during lesson tool (See Appendix B) was designed to be filled out by the observer during the course of the lesson. This tool was developed from the local systemic change (LSC) observational protocol which was used to record teachers lessons (LSC, 2008). The tool consists of four sections; context, purpose, resources and instruction. The context section was designed to complement the pre-lesson tool but also rate the classroom space and resources for carrying out science lessons. The resources section highlighted any resources the teacher used that they did not mention in their lesson plan. It was hoped that this section would highlight whether a teacher did not use a resource they had planned to use. The final section involved specific lesson details, such as the groupings of students. This section was important as some of the concepts of IBSE relate to student lead instruction through groups (Anderson, 2002, Davis and Smithey, 2008). Also included in this section are references to individual elements of IBSE that have been identified from the literature such as discussions or investigations (Anderson, 2002, Davis and Smithey, 2008, Walker, 2007, Zion et al., 2007).

The post-lesson tool (see Appendix C) consisted of three distinct sections. The first section of this tool was a semi-structured interview with the teacher. The next section involved the teacher filling out a set of Likert scales on the lesson. These Likert scales rated the lesson from 1 to 5, with 1 being a low value to 5 being a high value. 6 and 7 were also added to these scales so the teacher may select “Don’t Know” or “Non-Applicable” respectively. These Likert scales are divided over five sections: Design of the lesson, Implementation of the lesson, Science content, Classroom culture and overall ratings. These scales were also adapted from the LSC observational protocol and attempted to be a quick evaluation of the lesson by the teacher or researcher (LSC, 2008). Elements of the design section related specifically to IBSE activities such as whether the lesson was designed to promote investigations. The implementation section recorded whether the teaching was in line with the practices outlined in their plan and in line with IBSE. The science content rates the teacher’s content knowledge with relation to the topic, but also includes how the teacher catered for the students understanding and prior knowledge in the lesson. The final section deals with the teachers views on their students' understanding from the lesson. The teachers

were also allowed to add their own lesson evaluations if they wished which could be added to the data collection, however, the teachers opted not to submit lesson evaluations.

5.3.2: During and Post lesson observational tool results

After the conclusion of the first discovery observation, carried out with Teacher B, it was decided that both of these tools would not be used in further recordings for several reasons. Firstly the layout of the during lesson tool did not allow for ease of use in the classroom. The structure of the tool meant that the observer had to continuously look back and forth and mark the different answers as they occurred. Also, as the tool was being used during the lesson, the answers were continuously being changed and this resulted in confusion about the different answers that were being collected. The amount of time spent filling in the various questions, Likert scales and going back and forth also resulted in the observation of the lesson being very hectic and the researcher being distracted from the lesson observation that was taking place. The ability to focus all attention on the lesson was required for these observations as it would allow for incidental insights into the teaching. These factors could then be recorded for data analysis later on. Instead of this tool, for recordings after the first one, it was decided that a set of notes would be taken by the researcher. These notes would detail any areas that the researcher should look out for when re-watching the captured video and were referenced by approximate time stamps. This resulted in a much clearer series of notes on the lesson, its constituents and details. It also aided in the identification of specific areas of the lesson to return to in the data analysis.

It was also felt that the data collected by the during and post lesson tools would not aid in the exploration of IBSE in Irish primary science. This was due to the nature of both of the tools. These tools were designed to identify key elements of the teacher's practice that could possibly be developed into the synthesis element of this research. The actual result however was a systemic grading of different elements within the lesson. This was another reason for the abandonment of these tools as it was never a goal of this research to grade the participating teachers. The data would instead be identified through observing the captured video recordings and comparing them to the analytical framework described in Section 5.2.

5.3.3: The Coding Structure

In order to analyse the teacher's lessons, the observations were placed into a coding structure. The method of Theoretical Coding was chosen as this coding structure is used in the development of a grounded theory; see Section 3.2 (Flick, 2002, Glaser and Strauss, 1967). In this approach the interpretation of the data is used to 'make decisions about which data [...] to integrate next in the analysis and how or with which methods they should be collected' (Flick, 2002, p. 177). The coding analysis was designed to consist of both inductive coding and deductive coding. The deductive coding would be described through the specific codes identified within the analytical framework. An inductive coding approach was allowed to occur whereby codes could be added that were not necessarily related to the subject. The method of coding began with the process of open coding which aims to use any collected data to develop the codes (ibid). In the case of this research the open coding began with assessing the analytical framework for a series of codes which would be based on the 5Es. The second stage of coding (axial coding) allows for the most promising codes to be elaborated (ibid). Basing the coding on the analytical framework ensured that the categorizing of codes was structured and informed by the contextual analysis. The final stage, selective coding, elaborates a CoRes category around which all of the other categories can be grouped (ibid). This resulted in the coding structure which can be seen in Table 10 which displays the axial codes under the selective code of IBSE.

The coding structure that was used for the analysis comprised of a series of tree nodes. Each node was developed and then the transcription was placed into the corresponding node. In total there were 4 Primary nodes, 12 Secondary Nodes and 18 Tertiary Nodes.

The Engage comprised of activities which had been identified as a method to engage students, capture their attention and/ or identify their prior knowledge from the literature (Bybee, 1997, 2006). The Explore node had four tertiary nodes attached to it: Investigation student, Experiment student, Guiding Questions and Discussion. The reason the investigation or experiment being carried out by the students is to distinguish between an Explore and an Explain activity. If a teacher is carrying out the experiment and explaining the process and results to the students this cannot be considered an explore activity. Again, as found in the literature on the subject of the 5Es, questions and discussion can also form a major element of exploring a topic. The Explain node had three tertiary nodes attached to it: Teacher

demonstration, Discussion and Teacher Explanation. These nodes distinguish between a teacher led activity and a student led activity. This is to accommodate whether the explaining is done by the students or by the teacher. This idea was developed due to the findings of the textbook analysis, described in section 4.3. The former of these headings is considered a constructivist approach whereby the students are explaining the knowledge and understanding they have gained from the explore phase. The latter is considered a didactic approach, whereby the teacher presents information on a topic to the students.

Table 10: The Coding Structure

Primary Node	Secondary Node	Tertiary Node
1: 5E	Engagement	Questions
		Demonstration
		Discussion
	Exploration	Student Investigation
		Student Experiment
		Guiding Questions
		Discussion
	Explanation	Teacher Demonstration
		Discussion
		Teacher Explanation
	Elaboration	Application of Concept
		Demonstration
		Investigation
		Games
		Narrative
	Evaluation	Questioning
Write-up		
Discussion		
2: Individual or Group Activity	Individual Activity	
	Class Activity	
	Small group Activity	
3: PCK	Teacher Demonstration	
	Off-Topic Science	
	Content Knowledge issue	
4: Student	Unexpected student content knowledge	

The Elaborate node has five tertiary nodes associated with it: applying a concept, demonstration, investigation, games and narrative. The elaborate phase was used to code activities with a lesson that were beyond the constraints of the curriculum or involved the students applying knowledge they had gained previously. Finally the Evaluate node had three tertiary nodes: questioning, write up and discussion. These three nodes were all associated with evaluation in the literature on the 5Es (Bybee 1995, 2006).

The second primary node related to how the activity was carried out. It was hoped that these codes would highlight whether the majority of a lesson revolved around individual students, groups or the class as a whole. For the purpose of the coding if a teacher asked general questions to all groups this was considered a class activity.

The third primary node was a node on PCK. This node was divided into three secondary nodes: Teacher demonstration, off-topic science and content knowledge gap. The teacher demonstration node also appeared in the explain node previously. Elements of teachers relying on demonstrating were attributed to PCK whereby the teacher felt they could not have the students carry out a particular experiment or investigation. This node identified when a teacher relied on explaining a subject through demonstration which would be considered a didactic approach to teaching. The reasoning behind the addition of the off-topic science node was to identify when an activity was not part of the lesson that was being carried out, but was still a science activity. This occurred on a number of occasions in the lessons observed when the students' experiences outside the classroom were called upon. The final node was reserved for elements where it was clear that the teacher had a content knowledge gap about the subject they were teaching. This node was complex and could only be attributed to an element of the lesson with specific circumstances. This code was not limited to a teacher stating they didn't know the answer to a question but when a teacher's actions highlighted they did not know the answer to the question. One example of this was highlighted when a student made a statement about gold not being magnetic; the teacher was observed to hesitate, not provide an acknowledgement of the statement, which was correct, and then attempted to continue on the lesson. Her reaction demonstrated that she did not know about or expect the statement from the student.

The final primary and secondary node was “students” and “unexpected content knowledge from student” respectively. These nodes isolated when a student answered a question or started a discussion that the teacher was not expecting them to know. This code was identified through the teacher’s reactions and whether a student made a statement that was planned for a later activity in the lesson. This served to identify elements of student knowledge that may form an element to the development of the learning environment and resources.

Once this coding structure had been developed it was applied to the first observation and a blind coding method was used to ensure its validity and reliability. This blind coding was only carried out by the primary researcher. It was decided that any other coder would require knowledge of IBSE, the 5Es, the method of research and the IBSE framework in order to develop a similar code to the primary researcher. The blind coding method required the first observation to be coded. Several days later, and with no reference to the first code, the first lesson was again coded. Comparisons between the two coded observations identified where descriptions of the codes needed to be improved. The entire process was repeated and the on the second attempt the codes produced a majority of similar results. In order to further improve the validity and reliability this process was then applied to the second recording. When the results of this coding again showed similar results it was decided that the codes had been sufficiently and clearly described for coding all of the observations. The next section will detail the results of the Discovery Observations under the thematic headings of: the structure of the lessons, the use of guided activities, the use of everyday items as resources, Teacher PCK, the contextual knowledge of teachers and teacher impatience and unwillingness to deviate from their lesson plan.

5.3.4: The structure of the lesson

The first emergent theme for the discovery observations is the structure of the lessons that were observed. This structure was informed through the coding of the lessons by the percentage of each phase, combined with the order in which the activities were presented.

The structure of Teacher A’s lessons were generally consistent with the process presented by the 5Es. The lesson began with a discussion on light and reflection. This was developed into an investigation into the reflection with concave and convex mirrors. Finally a worksheet was

used to evaluate the learning. While this does echo the 5E structure it must be noted that over 54% of the lesson was comprised of engagement activities. The second observation also maintained a similar structure and was carried out on the topic of flow rates of liquids. The lesson included an introduction to flow rates, an investigation, an elaboration activity and an evaluation worksheet. Again this process would be consistent with the 5E process. Exploration made up nearly 65% of the entire lesson with explaining making up another 25%. The explaining in this context was mostly in the form of student explanation of the various flow rates that they had investigated.

Teacher B's first observation on the topic of magnetism contained all of the 5Es. The 5Es are also carried out in the order specified, with the exception of a narrative and fishing game which were carried out at the end of the lesson. There was also a consistent amount of each 5E phase presented in the lesson. The activities in the second lesson, on electricity, are not varied with much of the lesson being comprised of discussion and questioning. The effective use of these questions however meant the teacher was able to identify the students' prior knowledge and use this to progress through the lesson into exploring student's understanding of electrical devices and electrical safety. When classifying the structure and type of the lesson the coding showed an almost equal weighting of her lessons spent on each of the 5Es. This shows a very clear structure of inquiry in the lesson and gives equal priority to each of the phases within the 5Es. The process of the lesson presented is also in the correct order for a lesson carried as specified by the 5Es.



Figure 10: Teacher A observing students during an investigation

It becomes evident when analysing the observations for Teacher C that he has a structure that he applies to his lesson. The structure of the lesson on the Titanic involved a discussion on various aspects of the Titanic and then an experiment to demonstrate the discussed ideas and principles. This format is repeated in the second lesson when, following a discussion on the senses, the teacher initiates an activity related to the senses. In terms of inquiry, the observations did include the process of inquiry as dictated by the 5Es, starting with the engage, moving to explore and explain and concluding with the evaluate phase. While the amount of time spent in each of these stages was very different, the lesson still contained the structure of the 5Es.

The structures and procedures in Teacher D's observations do echo the process of the 5Es. Both lessons consisted of an introduction, followed by an experiment and finally a form of evaluation. There was no element of Elaboration in either of this teacher's lessons. It became clear during the observations that this teacher was using teacher support tools within his teaching. These support tools provided the teacher with the structure and process of the lesson and therefore conclusions cannot be drawn about the teacher's specific knowledge on the topic of inquiry. The teacher also chose to teach subjects which he had planned over the recommendations of this research so again conclusions cannot be drawn about his confidence levels in different topics.

The discovery observations identified teachers who, generally, follow the process of IBSE described by the 5E framework. None of the teachers were informed of the idea of inquiry before these observations so it is notable that these teachers have at least some implicit inquiry in their lessons. The observations of Teacher D showed that, while conclusions cannot be drawn about this teacher's knowledge of inquiry, he is at least aware of support tools for teachers, which aim to promote experimentation, investigation and inquiry in the classroom.

5.3.5: The use of guided activities

From the analysis of the discovery observations it is clear that the teachers use guided activities throughout their lessons. These activities involve the teacher either explaining an experiment to the students or the use of guided questions in order to achieve a correct answer.

There were several instances of this type of activity throughout the observations. Both Teachers B and D were observed to guide students through questioning and discussion in their lessons but Teachers A and C provided the most instances of this type of activity.

The activities carried out by Teacher A usually involved the students working on an activity while the teacher gave prompts on what to do next. This was shown during an activity to show how concave and convex mirrors affect reflection. The students were given guided instructions and continuous questions throughout this investigation. The students were allowed to call out their observations and when the teacher had received several different descriptive words she moved to the next investigation. In total there were four investigations carried out in this manner in the lesson.



Figure 11: Teacher C demonstrating the sinking of the Titanic

The use of guided activities is prevalent in the lessons by Teacher C. This was evident in the experiment on the effect of watertight compartments on sinking ships. The teacher provided the procedure for this investigation to the students before starting the experiment. This idea was repeated in the lesson on the senses whereby the teacher didactically informed the students of the process before they were allowed to carry out the investigation. This teacher was also observed to use guiding questions throughout his lessons in order to direct the students learning.

[Teacher]: Does anyone remember why it sank?

[Student 1]: Because it was so big and so long.

[Teacher]: Not because it was so big and so long, I have a clue there {pointing at drawing of the Titanic}

[Student 2]: The rivets

[Student 3]: The engines

[Teacher]: Not because of the rivets or the engines no. I have a clue there in the drawing now. Alright

[Students]: Oh yea there was so many of them {meaning compartments} and they filled up with water.

[Teacher]: Right so there was 16 compartments. Alright watertight compartments ok.

The teacher guides and aids the students towards the correct answer. In the case above the teacher even supplied the answer to the students but this is only after the students have remembered the purpose of the compartments. The use of guided questions and activities may have been a contextual consideration by this teacher to maintain order and to ensure that the students stayed on topic.

The use of guided questions and activities are accounted for in the process of the 5E framework however how they are implemented in the classroom must be accounted for. Describing activities to students is considered a didactic approach to teaching. Within these observations however there is a mix of approaches used by these teachers. While Teachers A, B and D provide their students with the process to be followed in an experiment, Teacher A and B allowed the students to develop their own conclusions. Teacher A and B promoted discussion throughout the experiments to identify what the students were observing. This is more in line with an inquiry based approach. Teacher D however provided the students with the process to follow but did not ask students to explain or discuss their experiments to the extent of Teacher A and B.

5.3.5: The use of everyday items as resources

The Teacher educator interviews described in Section 4.2 identified that teacher educators believe that there are issues with the amount of resources in primary school classrooms. It was described how, upon the implementation of the curriculum, that schools were given a onetime grant for the purchase of science equipment. This grant was awarded in 2003 and has not been given since. Therefore it is up to the teacher to ensure that they have enough resources for their lessons. This often involves the teacher using everyday objects to meet the purposes of activities. This was observed throughout each of the discovery observations.

Teacher A was observed to use many everyday items in her lessons. These items included torches, spoons, bottles and washing up liquid. These items would not generally be part of

science lessons and, their inclusion meant that the objectives of the lesson could be met. The use of spoons as a replacement for concave and convex mirrors meant that every student could carry out the experiment in the class. This did however create an issue with some students where the spoon was not clear enough to get a reflection. The teacher had planned for this and brought in more spoons that was needed and was able to replace them. In the second observation, the teacher had prepared a set of bottles and caps with the same size holes in them. These were used as the primary apparatus in the investigation. While this may have appeared to be an effective utilisation the bottles, the students had to assume that all of the bottles had the same size opening. This was briefly discussed in the fair testing discussion.

Teacher B also used many everyday items in her classroom. In the magnetism lesson the teacher brought in many items which were both magnetic and non-magnetic. The amount of items meant that each individual student was able to investigate an item during the lesson. The teacher also included candles and an oil lamp in the lesson on electricity. This enabled her to describe a period in time when there was no electricity and show what was used to create light. The teacher was able to use descriptions from her own past to aid the students in identifying what life was like without electricity. The teacher explained how her family's home had no electrical lights and that they used candles to see in the dark.

Both teacher C and D included different food items in their lessons. Teacher C used various foods during an investigation into the senses. Blindfolded students were asked to use their senses to identify what the item was that they were given. By using food the students were able to taste the items as well as use touch and smell. Various liquids were included in Teacher D's second observation. These liquids were analysed for their pH level and then compared to each other based on different characteristics.

The inclusion of these items in the classrooms shows how these teachers have adapted to carrying out lessons with limited resources. By using everyday items in their science lessons it was observed that the majority of students could participate and try the activities.

5.3.6: Teacher PCK

Another theme throughout the discovery observations was the identification of different elements of the teacher's PCK. This section will detail content and pedagogical issues and development. The identification of the teacher's contextual knowledge will be described in section 5.3.7.

It was evident in these observations that the PCK of these teachers is constantly being developed. For example Teacher A discovered that, during the description of an investigation, the method she had planned would lead to an unfair test. The teacher had planned the lesson to compare water vs. washing up liquid. While planning the lesson the teacher believed that she could use one type of bottle for the water and a different bottle for the washing up liquid. The teacher is observed to stop talking mid-sentence when explaining the investigation. It is clear that the teacher has just realised that the flow rates of the liquids could not be compared if different bottles were used as the test would no longer be considered fair. Instead of continuing the discourse the teacher instead opted to ask the students a question on why her lesson plan was incorrect. This shows two things. Firstly this teacher is not afraid to make mistakes in front of her students. Secondly the teacher was able to adapt to the situation at hand to ask the students why they should not use different bottles for the experiment. This allowed the development of knowledge by both the teacher and student at the same time. It also allowed the students to make richer comparisons and develop reasons as to why the times achieved were different.

During the lesson on magnetism it became evident that Teacher B's students had more knowledge on magnets than she was expecting. There were two examples of this. The teacher began the lesson by asking the students what they knew about magnets. One student pointed out that magnets come from the ground and that they have to be dug up. From the reaction of the teacher, it can be seen that she was not expecting this response. The teacher did not dwell on the fact that the student knew this but instead moved swiftly onto another question to change the topic. This reaction appeared to be a lack of content knowledge by the teacher and an underdeveloped schema of how to handle the situation. Secondly, during the investigation, the class were allowed to participate by calling out whether they thought the item was magnetic or not. One student pointed out that a 50 cent coin would not stick to the magnet as it is made of Gold. This student knew that not all metals are magnetic, a point which the

teacher had planned to cover later in the class, but the teacher glossed over the comment and moved onto the next object without addressing it. This again shows an area where the student had more content knowledge than was expected by the teacher and the teachers showed an unwillingness to adapt to the response.

These examples show how the PCK of a teacher is constantly in flux. In the case of Teacher A she was able to adapt quickly to the situation and change the experiment that had been planned. Teacher B however showed that she was unable to adapt quickly and instead ignored the issues within the lesson. It would be hoped that she would be able to plan for these events in future magnetism lessons.

5.3.7: The contextual knowledge of teachers

Another concurrent theme in this observation is the contextual considerations these teachers have about their respective classes. These teachers were shown to make many decisions and actions to account for the young age of the students. The research participants that were chosen in this research taught a range of contexts. As described in Chapter 3, Teacher A had a class that consisted of 4th, 5th and 6th class students, Teacher B taught 1st class students, Teacher C taught 5th class special needs students and Teacher D taught 5th class students, but in a science laboratory.



Figure 12: Teacher A during a discussion on light

Teacher A adapted her lessons to accommodate the range of classes that she had to teach. In the discovery observations she had each class level divided in the room so that they could only discuss with students of their own level. This was interesting as all of the students were

made to participate in the lessons and it did not emerge that the older class group answered the majority of the questions. The teacher ensured that she included every student in the activities that were taking place.



Figure 13: Students experimenting with static electricity

Teacher B had to accommodate for the young age of her students. During the magnetism lesson she made sure to label all of the items that were involved in the investigation. This was important as the students were not able to identify certain objects such as a corkscrew. The teacher also used the young age of her students to capture their attention while demonstrating different concepts to the students. This was evident from the way she demonstrated magnetism working through various media. The students appeared amazed when pins moved with the movement of the teachers arm under cardboard. Here she was careful to remove the magnet from view while moving magnetic items through card and fabric. To the students this looked like the item was moving independently but the teacher, through discussion, was able to describe how the magnet could work without touching the object. In order to make the class on electricity more memorable for the students the teacher decided that the students would each create static electricity using their uniforms and balloons. The teacher, knowing that static electricity is beyond the curriculum for this age group, explained the method to make the balloons statically charged. This allowed the students to have some fun rubbing the balloons off each other and attempting to have the balloons stick to the wall. The teacher did not attempt to explain static electricity or charge to the students but allowed them to investigate what items the balloons would stick to. While it could be argued that this activity had no meaningful learning objective it promotes an interesting concept in the analysis of lessons. The teacher stated that she wished to do something that would enable the students to recall the lesson. Therefore it could be argued that, sometimes, activities without meaningful

learning objectives could be useful to aid students in recalling lessons for future scaffolding rather than allowing the lesson to be forgotten.

Teacher B's contextual knowledge was also being developed in her second observation. The teacher had three columns drawn on the whiteboard with the headings essential, useful or not important. The grouping of the devices by the students surprises the teacher. The students list devices such as a television and MP3 player as essential whereas they try to put the washing machine as useful. It is made clear that the students' priorities were not the same priorities of the teacher. This is evidenced by the following discourse:

[Teacher]: Hands up if you think the Television is important {several students raise their hands} Ok. Hands up if you think television is not important {a few students put up their hands} Ok. So most of you think television is important. {Pauses} Ok so what are we going to do about this one?

Here the teacher is actively deciding whether to accept the students' response or to impose her values on the students. The teacher however makes a compromise between both views and decides to place it in the useful column, informing the students that television is useful in certain circumstances.



Figure 14: The teacher referencing a list of electronic devices on the blackboard

The approach used by Teacher C also shows an acute awareness of the context of his class. The activities presented in the class were all guided by the teacher towards the correct answers.

[Teacher]: We know from our history lesson that the ship took ages to go down didn't it. And when it sank we know it didn't just sink straight down. What way did it sink?

[Student]: It went like this {motion with hands} some of it went down and some of it went up.

[Teacher] {Moving his arms}: So it was like this and then what happened the front of it {Moves arms}
It went like that didn't it?

This is another example of the heavy influence of this teacher on the discourse but there are still elements of the students' prior knowledge being identified. Again the teacher is guiding the discussion but this time he waits for a student to describe their answer before broadcasting it to the classroom. Here Teacher C allows one student to explain it in his own words, but realises that his description may not be exact. The teacher therefore provides a clear description of the events to ensure the other students aren't confused. This point is also observed in the lesson on the senses. The teacher started the lesson on the senses by asking the students directly about their prior knowledge on the senses.

[Teacher]: Ok when you feel something that's touch alright. What else.

[Student 1]: Mouth

[Teacher]: Ok what's mouth and lips?

[Student 2]: Touch

[Teacher]: No it's not touch

[Student 1]: Taste

[Teacher]: Taste alright.

Again the teacher here is patient with the students and will not provide them with the answer until at least one student calls out the correct answer. The student in this case managed to correctly identify that the sense related to the mouth and lips was taste.

The lessons chosen by Teacher D identify how he has adapted his teaching based on his context. The inclusion of a science laboratory in his school enabled him to carry out more experimental lessons with students compared to the other teachers. While these experiments were prescribed for the students they enabled the teacher to extend beyond limitations of classroom science.



Figure 15: Teacher C during the discussion on the senses

As it can be seen the contextual factors have a large effect on the teaching of these teachers. Teacher A has to adjust her lessons to accommodate three levels of class and ensure that the objectives are met in all three groups. Teacher B has to accommodate the young age of her students and ensure that her lessons are not beyond their level. Teacher C has to accommodate the special needs of his class by guiding the students towards correct answers and ideas. Teacher D was also observed to choose more experimental subjects for his classes in the school laboratory. All of the participant teachers have therefore adapted their lessons and teaching style to suit the context of their class.

5.3.8: Teacher impatience & unwillingness to adapt

The final theme to emerge in the discovery observation was the issue of patience by the teacher in the classroom. It was observed that both Teacher A and B are impatient to progress quickly through activities, especially in the Engagement phase. Teacher C appears to be more patient with his students and allows them to attempt to get to the correct answer before helping them.

Teacher A is observed to be impatient with her students in several instances. When the teacher asked the question: “Can anybody remember how light travels”, the students were not forthcoming with answers. One student raised his hand to respond but didn’t respond when the teacher pointed to him for an answer. This caused the teacher to react by instantly talking and switch on a torch which she had in her hand. The teacher did not allow for any period of silence from the student. She appeared unwilling to allow for the activity to delay her lesson

plan. The teacher was eventually able to achieve the response she had wished for by the following discussion:

[Teacher]: Look at the [torch] light, where is it? Is it over there {pointing to a side wall}.

[Student]: No.

[Teacher]: Is it there {pointing to another wall}

[Student]: No

[Teacher]: Where is it?

[Student]: There {pointing to the light}, straight in front of you

[Teacher]: Straight in front of me. Light travels in straight lines.

It can be seen that the teacher appeared impatient for the students to reach the answer that she wanted. Instead what is observed is a series of guiding questions, all which are determined to get the students to state that light travels in straight lines. However, the discourse presented above shows that the students did not actually state that light travels in straight lines. Instead the teacher informed the students this was the case when a student came close to saying the answer.

The second engagement activity involved reflecting light using mirrors. This activity required the students to work in small groups of four where one student shined a torch and the other three had to reflect the light using mirrors. Teacher A initially has difficulty initiating the activity but she eventually viewed one group succeed at bouncing the light off all four mirrors. Once this had occurred, she stops all of the other groups and asks them to watch the group that had succeeded. This removed focus from the activity back to the teacher who then proceeded to demonstrate the activity with the group she was standing at. This again shows impatience as the teacher does not allow each group to succeed at the activity but instead only allows for one group to complete the objective before progressing with the lesson.

Teacher B, like Teacher A appeared to be impatient to progress in the lesson and unwilling to deviate from her lesson plan. One example of this was identified when the teachers asked guided questions about where the students would find magnets at home. When a student states that magnets would not stick a press because it is not metal the teacher appears to become flustered by the student response. It is clear that the students have more prior knowledge about magnets than the teacher had expected and the teacher wishes to continue her lesson as she had planned. The teacher is unwilling to deviate from her lesson plan which

included this concept at a later stage in the lesson. This is also observed when, as described previously, a student responded that a 50 cent coin would not be magnetic. Teacher B, appearing flustered and ignored the comment as it was not part of her lesson plan.

5.3.9 Discovery Observations Conclusion

As it can be seen from the results presented above the discovery observations identified several ideas and themes present in the science classrooms of these teachers. It was shown that these teachers generally, include some structure to their lessons, although this may not be the same as the 5E process. The teachers were also shown to prefer guided activities in their lessons rather than student-directed activities. The use of everyday objects was also prevalent in the lessons. Here all of the teachers included resources that would not be part of a science classroom in order to effectively teach their lessons. Elements relating to the development and issues with teachers PCK were also observed. Teacher A was observed to adapt her entire lesson when she realised an issue within her lesson plan. Teacher B appeared to be unable to cope when students stated content knowledge that she was not aware of. While this is the case all teachers were shown to have adapted their practice based on their context. The observations also identified issues within the classes that were observed. The impatience of Teacher A and unwillingness to deviate from Teacher B's plans were obvious in their observations.

Table 11: The strand units from the 1st and 2nd recordings

Teacher and recording	Energy and Forces	Living Things	Materials and Change
Teacher A Rec 1	X		
Teacher A Rec 2	X		
Teacher B Rec 1	X		
Teacher B Rec 2		X	
Teacher C Rec 1	X		
Teacher C Rec 2		X	
Teacher D Rec 1			X
Teacher D Rec 2			X

When looking at the subjects, that the teachers chose to teach, it became evident that these teachers did again not fall under the generalized categories presented by the NCCA (Varley et al., 2008a). As part of this study the first three teachers chose to teach subjects from the

curriculum area Energy and Forces as both their confident and non-confident subjects. Table 11 highlights this data. The one anomaly to this data collection was teachers B and C who chose to teach the Living Things curriculum strand, as a subject they were not confident teaching. Again Teacher D was excluded from this data set as the subjects chosen by him were to fit the purposes of laboratory work rather than this research. While this may be the case, his lessons revolved around the Materials and Change curriculum strand. The observations also indicated that Teachers A, B and C are all willing and able to employ everyday items in their teaching of science concepts, addressing some of the concerns raised in the teacher educator interviews.

5.4: A PCK snapshot of the participating teachers

This section of the research deals with an analysis of the PCK of the participating teachers as part of this project. As stated above, the CoRes did not prove the study with relevant insights into the PCK of the participating teachers. It was for this reason that a full CoRes and PaP-ERs development session was carried out. This CoRes followed the method as dictated by the literature on the CoRes and PaP-ERS (Loughran et al., 2000, 2001).

5.4.1: Research Method

The first stage in the development of the CoRes and PaP-ERs was as to choose a topic that would be discussed. The subject of magnetism was chosen as it was the subject taught by one of the teachers in the discovery observations. This ensured that at least one of the teachers would have knowledge on the content and pedagogy and could aid the other teachers with verbalising their thoughts. Teacher A and B carried out a group discussion on the subject. Due to time constraints outside the project, Teacher C and D could not participate in the discussion.

This process began with the teachers brainstorming the subject of magnetism to create a mind map of what they consider are the essential Big Ideas in teaching magnetism. Once this mind map had been created, five big ideas were identified and CoRes were developed. It must be noted that the CoRes tool was designed to be used with second level teachers; therefore it was unknown what sort of results would be obtained from primary school teachers who would have different curriculum influences and whose teacher education in science would not have

been as substantive as second level teachers. Section 5.4.3 will detail the results of this study under the thematic headings of Pedagogical Knowledge, Content Knowledge and Contextual Knowledge. It was hoped that the CoRes would highlight the different areas, techniques and ideas that the teachers have in relation to magnetism. Once the CoRes had been completed by teachers A and B they were forwarded to teachers C and D so they could add their own responses. The next stage of this investigation was to develop Pedagogical and Practice Experience Repertoires (PaP-ERs). This process involved the researcher identifying a cell from the CoRes that represented an important idea or needed clarification and the PaP-ERs allowed the teachers' to expand on their point.

5.4.2: Brainstorming results

Figure 16 displays the mind map on magnetism that was developed. The mind map was created exclusively by the participating teachers with only guiding questions being asked by the researchers. The first important element that can be drawn from the mind map is the amount of points that were developed. Prior to creating the mindmap both teachers expressed concern over their ability to develop points relating to the subject of magnetism. The mind map highlights that these teachers have a large body of knowledge on various elements of magnetism. Their concerns may be attributed to a lack of confidence in their ability to teach science which would be consistent with the generalizations in by the NCCA study (Varley et al., 2008a). The second interesting element that can be identified in the mind map is the concentration on skills development and pedagogy over content. This is easily viewed in the 5 Big Ideas that were identified:

- Student must understand magnets through exploration
- Magnets have Poles
- Magnets have fields
- Exploring magnets give an opportunity to develop life and scientific skills
- Encouraging a sense of wonder is important in teaching magnetism

As it can be seen three of these Big Ideas concentrate on the idea of pedagogy and two concentrate on the content knowledge that would be described to the students. Once these Big Ideas had been identified from the mind map each of them was discussed in detail with the participants. Of the content related Big Ideas they centre on the idea of magnetic poles and fields. These topics were viewed as being the main learning objectives on the study of

Table 12: CoRes Captured from Participant Teachers

	Students must understand magnets through exploration	Magnets have Poles	Magnets have fields	Exploring Magnets gives an opportunity to develop life and scientific skills	Encouraging a sense of wonder is important in teaching magnetism
1. What do you intend students to learn about this idea	Nature of science- not all talk doing Fair test Structure to discovery	“North” and “South” Compasses “Push” and “pull” ‘Attract’ and ‘Repel’ Earth has poles	Fields have a range Fields have strength Concept of force Fields are invisible but there	Development of group skills – journey Cooperation and life skills Skills for investigation	Learning by doing Important in Environment Encourage research and ICT
2. Why is it important for students to know this	Knowledge is vague- discovered Life skill- metacognition Epistemology- being a scientist	Key to understanding phenomenon. Starting point Explaining compasses First experience of “invisible forces”	Links to other subjects e.g. Geography Forces can be invisible Understanding cartoons Concrete opportunity to explore the ‘invisible’	Achieving consensus – explaining phenomena Life skills vs. scientific skills – dictated by curriculum- necessary for science Sharing, group skills, cooperating- community Maintaining interest	Skills development Keep interest in science Bring in everyday objects to science Important that it doesn’t become “another Subject”
3. What else do you know about this idea (that you do not intend students to know yet)	“Exploration” not explicit treated- freedom to think, explore/ do	Electromagnets Induction Not “verbalising” forces initially Naming later Earths field initially ‘Do magnets run out?’	Induction See B	Do not make the skills explicit Different vocabulary but same skills	Implicit promotion of science instead of telling students that you are encouraging wonder
4. Difficulties/	Time	Timetabling/	Resources	Previous experience-	Unnecessary repetition

Limitations connected with teaching this idea	Classroom management Relationship Behaviour management Passengers in infants	preparation Tidy-up management and admin Space Resources (?) Language for EAL students	Timetabling Teachers knowledge “seeing”/ understanding the invisible	time to build up skills- develop skill sets –guide development – gone beyond level of teaching plan – different style of skill Aware of group conflict Context Balance Preparation important Resources Teachers knowledge context, sources, access	Lesson structure Bad preparation Students get bored –not learning
5. Knowledge about students’ thinking which influences your teaching of this idea	Happy to make mistakes, check again, accept ‘difference’ Appeals to their nature Needs structure	Too challenging for students to generate Questions/ ideas Tailor level to prior knowledge Matching student language to scientific Limit investigations to classrooms	Must make concrete	Class level and vocabulary How much knowledge you should supply Build on prior knowledge and experience in both Have they done science before Have they much experience of investigations/ worksheets	Prior knowledge to encourage learning Non-academic students can excel at magnetism through picture/ drawing recording “invisible force” Repetition – recap lesson Some students may have a specific interest in the topic
6. Other factors that influence your teaching of this idea	Experience of group work Resource management Developing beyond the content	Incorporating prior experience - scanning Links to geography/ sailors Encouraging students to share/ explain	What are students watching? Brainiac, Mythbusters, Discovery, YouTube videos....	Maintaining interest Everyday science Have they much experience of investigations/ worksheets	Encourage interest and enjoyment New and different activities to reinforce same information Multidisciplinary –

		thinking/ sources Improvisation: substituting resources – sharing with colleagues/ timetable		Are worksheets part of the lesson	History , geography , Maths, Creative Writing, Languages Influence of subject You cannot isolate students in science Emphasise group work
7. Teaching procedures (and particular reasons for using these to engage with this idea)	E.g. field range Guidance building on their results towards ‘correct’ results Resources Teacher objective clear Steps: free play, problem, groups (?), roles, rephrase problem- plan – do – reward- report	Start with free exploration -bar magnets, paper clips, paper ± guidance Name phenomena Compasses: earth’s fields Practical work w/ compasses	Free Exploration: Range of field Strength of field Size of magnets Iron filings to visualize fields Approaching with other magnets Design and make: race track, motors, fish games etc.	Teacher led group work- assign role Insist on discussion and consensus Structured investigation, predict estimate Give challenge at the end of lesson- practical/ home activity -push forward- lead into next lessons Report using graphs and charts- displaying Sharing with other classes	Researching Visual and Picture recording Positive feedback and reinforcement Compose structured groups Good bank of resources Expectation of fun Work vs. doing, but not exclusive
8. Specific ways of ascertaining students’ understanding or confusion around this idea (including likely range of responses)	Observation – feedback Effective groups- focus on learning rather than Content Management Investigation Sheets Reporting Back	Prior knowledge: brainstorming Observation Afl worksheets “What happens if/ TV/ Credit cards/ you drop it”	Discussion: teacher led for juniors Project work: reporting back on session Illustrations School presentations between classes	Observation Questioning Feedback Inter-class discussion Allow questions for clarity	Are students looking forward to the lesson “Can we do magnets again” Questions

5.4.3: Content Knowledge

The first three questions on the CoRes relate to the content knowledge of the teacher. These questions identify elements of the subject that the teacher wishes to teach as well as their knowledge beyond the subject. The questions also ask the teachers to explain why they provide the answers. It is clear from Table 12 that these teachers have a developed content knowledge in the subject of magnetism. This is informed through the consideration of both science as a subject and the topic of magnetism.

Relating to science as a subject the teachers discussed how they must account for studying the wider subject of science and beyond. The teachers highlighted the points that “knowledge is vague but discovered by the students”, that discovery is a “life skill” and that exploration is an element of the epistemology of science. These points would indicate the teachers understand metacognition and the use of exploration as a methodology. They highlight in their answers that science is an active subject and that it should not be "all talk". This refers to the ideas discussed in Chapter 2 whereby inquiry promotes the epistemology and nature of science by working in class as a scientist would (Anderson, 2002, Enfield, 2000, Rocard et al., 2007). Included in this answer is a consideration of the development of interpersonal skills when the teachers relate to the development of group and co-operation skills. This echoes the sentiments in the curriculum which, as was discussed previously, aims to develop life skills through the study of science (DES, 1999, 1999a). The teachers believe that encouraging a sense of wonder can promote how students can learn by doing rather than learning by traditional didactic methods. This recalls a point highlighted in the teacher educator interviews relating the students' experiences of science. Here the teacher educator believed that science was still a “new” subject to students which was held in higher regard than CoRes curriculum subjects. The sense of wonder therefore may be maintaining this idea that science is a “special” subject for primary students.

As it would be expected the answers to this question included the terminology of magnetism such as poles, North, South, attract and repel. The teachers discussed how the concept of magnetic poles is critical to understanding the phenomenon of magnetism, acts as a starting point for further study, explains the use of compasses and that it is the students' first experience of an “invisible force”. These points all relate to the content knowledge possessed by these teachers. The teachers are aware that without understanding the concept of poles the

students will not be able to progress in the study of magnetism. The teachers also state that the subject of magnetism should be introduced early to students and that it should be developed each year. They recognise that magnetism is the first example of an “invisible force” to the students and that this can be used to scaffold learning in other topics where only the effect of a force can be seen.

5.4.4: Context Knowledge

As it has been discussed previously, the participant teachers appear to have a strongly developed contextual knowledge. This is also confirmed in the CoRes that was collected. The teachers appear to understand the many difficulties that can be present when teaching science. These difficulties echo the literature in Chapter 2 and the teacher educator interviews in Chapter 4. There is also evidence of how students’ daily lives affect the classroom.

Answering question 4 the teachers raised points about time constraints, classroom management, resources and the relationship between teacher and students. All of these points echo the concerns raised by the teacher educators and the literature on issues in primary science education, see Chapter 3 and Section 4.1. The teachers also understand that a challenging subject such as magnetism may be too challenging for students to generate their own questions and that they must tailor the lesson to the level of the students. Through their experiences of teaching, these teachers state that, the concept of magnetic poles cannot be constructed by the students through exploration and discovery. Instead they state that a certain level of didactic teaching must be employed to teach this concept. Their experience also directs them to tailor the content that is being covered to the level of their students. Teacher A stated that she would introduce Earth’s magnetic poles but the teacher B thought that this would be beyond the knowledge she would want the students to have at their level. This showed knowledge of the specific contexts of each of these teacher’s classes.

One of the contextual factors that the teachers highlighted was the terminology that is associated with science education. This was not identified as a major issue within the literature and the teacher educator interviews. These teacher's experiences have shown them that they have to be careful about the language and terminology that they use to teach this concept. The teachers also identified with difficulties teaching science to non “English as a

First Language” (EAFLE) students. This was the first discussion of students who do not speak English as a first language in this research. This was interesting as the point was raised by the teachers but not the teacher educators. This could highlight an issue in Irish primary science education that Teacher Educators are not accounting for. It also shows a keen awareness of the classroom contextual considerations that these teachers have to make when carrying out their lessons.

Another factor that identifies with a large contextual knowledge is the teachers’ descriptions of external media such as television shows that the students are watching. Television shows on the Discovery channel such as Mythbusters, documentaries and Brainiac as well as YouTube videos are now seen to be informing the students’ prior knowledge within the classroom. Here the teachers acknowledged that they must be aware of these TV shows as students attempt to relate their learning to what happened in one of these shows. These shows can also be used to evaluate the learning as the teacher can identify whether what was shown in the TV show relates to the concept being taught and if they don’t the teacher can identify where issues arise. The dangers of these media, such as YouTube videos which are deliberately fake were also discussed as a difficulty in teaching

The teachers described how non-academic students can excel at the topic of magnetism as it includes elements of drawing pictures and recording. This ensures that students who may not excel at investigations or experiments can remain active and key elements of the group. This encourages them to participate more in the learning, and stops them getting bored. Issues with lessons that use didactic methodologies were again recalled in this Big Idea. This was also echoed when the teachers discussed the use of many various activities and including multidisciplinary topics to promote wonder.

The detail contained in these answers identify with teachers who have a thorough contextual knowledge of their students. It is clear that these teachers are aware of the challenges that face them in the classroom. It is also clear that they understand where the students’ prior knowledge is being informed from and how they can use this within school lessons.

5.4.5: Pedagogical Knowledge

There is also evidence of a developed pedagogical knowledge with these teachers. The pedagogical considerations are clear from questions 7 and 8 in the CoRes. The teachers mentioned many different methodologies to teach the subject of magnetism. Within these methodologies there was a concentration on the use of guided exploration. Many of the methodologies they describe formed part of a guided exploration process. These teachers would appear to have implicitly placed limitations on the freedom of their lessons to control the learning and to ensure that the students understand a topic fully. The specific teaching procedures attributed to exploration included “Guidance, building on results towards ‘correct’ results”, the use of resources, clear teaching objectives and other teaching procedures. The teachers here displayed an awareness of the idea of guided learning compared to open ended exploration, a concept identified in the discovery observations. The teachers also show their knowledge of the process of exploration in their answer. Here the teachers state they use “Plan, Do, Report”. This method would be analogous to the ideas presented within the exploration stage of the 5Es (Bybee, 2006a) again highlighting at least an implicit practice of inquiry in their teaching.

5.4.6: PaP-ERs submitted by the teachers

Upon the conclusion of the CoRes it was decided that the participating teachers would attempt to fill out PaP-ERs in order to gain better insights into the points they had raised in their discussion. PaP-ERs isolate cells from the CoRes which are expanded in order to provide greater detail from the participating teachers.

The first PaP-ER that was developed was on the subject of “exploring magnets gives an opportunity to develop life and science skills”. As part of the CoRes the teachers listed that it was important for students’ to know this; to achieve consensus, develop life and scientific skills, develop sharing, group and cooperation skills and to maintain interest. Expanding on this point the teachers related to the “absorption” of skills by students. Here the teacher explains how skills are developed by the students implicitly without the need for dictation by the teacher.

Can you imagine the reaction of children if they were told that “Today we are going to learn how to record results of an investigation?” or maybe “This week we will be learning to take turns?”

(Teacher A)

This quote shows the teachers' attitudes to making specific science skills explicit to students. She believes that the students would be resistant to learning if the skills are listed to the students and instead assigns roles for the students to develop their skills as part of that role. Here she expresses how the effective creation of groups provides students with the ability to learn to share tasks, to reach consensus on an answer in a report or to fill in an investigation sheet. These skills are equated to life skills of cooperation and turn taking. Once again the answer revolved around the development of effective groupings in the classroom. This shows the dedication of these teachers towards the effective use of grouping in their classroom. These teachers feel that, when used properly, effective groups can develop learning in ways that teachers do not intend. Groups provide the teachers with ways of promoting peer learning, to improve communication skills, to ensure no student is left behind and reduce classroom disruption.

The second PaP-ER developed by the teachers related to “encouraging a sense of wonder in their teaching” and the difficulties and limitations associated with this idea. As part of the CoRes the teachers detailed; unnecessary repetition, lesson structure, bad preparation and students becoming bored as difficulties associated with this. Expanding on this point the teachers highlight the need for proper lesson planning and structure. The teachers feel that poor planning leads to repetition of activities and learning objectives and this can get boring for the students. The teachers do however raise concerns about the truly open nature of the curriculum. Here one of the teachers describes:

I have heard a teacher of first and second class talking of his pupils lighting bulbs and designing a lighthouse. If these comments were accurate, a disservice was being done in exposing children to learning they were not prepared for.

(Teacher A)

Here she acknowledges that the activity may have been to develop meaningful learning goals but, based on her experiences students of first and second class would not have the knowledge in science to effectively carry out this lesson.

The teachers also describe how, over time, a teacher should build up a folder of lesson plans or investigations that can be drawn on at the introduction of a lesson. These resources may be sourced from various resources such as textbooks, other teachers, workbooks or sharing resources with other schools. This, the teachers believe, will result in resources which can demonstrate a topic or concept to the students while reducing repetition in their studies. The cyclical structure of the curriculum, see Chapter 1, was again raised here as a potential issue in relation to this as students have to recall their previous studies. This may require the teacher to cover a particular topic again and without a large bank of resources may result in the teacher repeating an investigation that the students had carried out before. The large bank of resources may mean that some topics could be recalled using a different methodology. This method may result in the students understanding the topic better the second time around.

The final PaP-ER that was submitted related to the Big Idea that “students must understand magnets through exploration”. The CoRes question that was expanded here was the question: Knowledge about students’ thinking which influences your teaching of this idea. The teachers once again related this to the knowledge that students “learn by doing”. This should not be confused with the idea of active learning, discussed in chapter 2, whereby an activity is being carried out in the curriculum without meaningful learning objectives. Instead the teacher can facilitate learning by following a carefully designed and directed lesson plan. The teachers also allude to discovery based learning. An important element of the teachers’ discussion is directed to the point that they have to develop this type of teaching and learning in their classroom and not base their teaching on what they were taught. One of the teachers highlights that she would have been taught about the concepts of magnetism in a very didactic fashion. Now however; she has to attempt to teach the same topic but utilising a more constructivist approach.

Within the PaP-ERs, Teacher A raised a point about the adoption of constructive methodologies. She stated that she remembers little about the in-service awarded to her upon the introduction of the 1999 curriculum. Instead her source of information and guides on constructivist teaching has come from training with the Irish National Teacher Organisation (INTO). This again relates to the points raised in this research in Chapter 1 as to the nature of in-service and educational training supports in Ireland. It has already been shown that this teacher utilises an inquiry-orientated approach implicitly in her teaching, however she states that this is not due to the official in-service education provided by the Department of

Education in Ireland (DES). This then may raise the question as to the effectiveness of the DES in-service and whether this can be attributed to the issues raised by the NCCA study (Varley et al., 2008a, 2013).

5.4.7: Overall PCK analysis results

As it can be seen through a thorough analysis of the CoRes developed by these teachers, their PCK relating to the topic of magnetism would appear to be well developed. The model of PCK being used within this research which concentrates on three main elements of a teacher's PCK, the Pedagogical Knowledge, Content Knowledge and Contextual knowledge (Magnusson, Krajck and Borko, 1999). In relation to this model the teachers knowledge of the various pedagogies within each of their Big Ideas highlights several important factors; They are aware of the activities that could be used in IBSE, they are aware of the structured nature of IBSE and the process of IBSE. This would hint at a well-developed pedagogical knowledge. In relation to their content knowledge, the two Big Ideas emerging from their mind map show that the teachers are aware of the important content within the subject of magnetism as well as teaching methodologies and practices of how to teach these subjects to their classes. Their contextual knowledge also appears to be well developed as they raise points on knowledge and understanding development by their students. All of these factors point to a well-developed PCK in the subject of magnetism with these teachers.

In relation to the PCK of the teachers in science the CoRes and PaP-ERs would hint that these teachers would have a well-developed pedagogical knowledge in science in general. The teachers continually described many varied approaches to teaching science in and IBSE manner. These approaches were also accompanied with well-argued recommendations on their practice and a discussion on issues that are related to these practices.

The PaP-ERs served to provide further insights into these teachers PCK levels. The PaP-ERs, while they only concentrated on one element from each CoRes section did argue points effectively and provide worthwhile insights. The teachers' views on effective groups, effective lesson planning and preparation and constructivism can be related to these teachers having a developed contextual knowledge. The PaP-ERs also served to raise questions on the validity and effectiveness of DES based in-service that is awarded to teachers. Some teachers

may feel that this in-service was all they required to teach science effectively. Instead an argument is made here that this in-service was “forgettable” and only through the interest and enthusiasm of the teacher has she developed her PCK in science.

It must be pointed out that the other two remaining teachers, teachers C and D, believed that the mind map and CoRes developed with teachers A and B was comprehensive and contained all of the elements and points they would raise if the CoRes was carried out with them.

5.5: Chapter Conclusions

This concludes the chapter describing the practice of science education within this research. The chapter began with the development of an analytical framework to which this practical research could be compared to. This framework was heavily influenced by the 5E model and allowed for the development of a coding structure for the lesson observations. The second element of the chapter dealt with the lesson observation tools that had been developed. These tools were developed prior to beginning the discovery observations and through the course of the observations many changes had to be made. The lesson plan analysis attempted to use the CoRes as a lesson planning tool in Primary science. Some elements of the teachers PCK could be described using the submitted CoRes however the tool was determined to be too limited for use as a lesson planning tool. It was also determined to be a difficult tool to apply to one lesson rather than a subject and lacked some of the necessary elements of a lesson plan.

The discovery observations were carried out in order to attempt to discover the practice of science education in primary schools. As such several conclusions were developed. Of the four participant teachers, inquiry orientated process and ideas were identified in the teaching of three of the four participants. These observations emphasised student centred learning and exploration. The fourth teacher could also be described within this group however his use of pre-developed lessons did not create conclusive evidence to support this. These observations therefore seem to contradict the results of the NCCA, but it could be argued that the participant teachers in this study are in the minority of observed teachers that do practice constructivist methodologies. This therefore awarded the research with an opportunity to use the practices and knowledge of these teachers to develop resources and guides for teachers

who do not carry out IBSE lessons. These resources would then aid in informing and developing the schema of these teachers. As it has been previously argued, teacher reform is more effective when it is based on the experiences of other teachers.

The PCK analysis also provided insights into the PCK of the participant teachers. While this was only carried out with two participant teachers several conclusions could be developed. These conclusions were that even though the teachers admitted to low levels of knowledge in magnetism their responses identified several specific elements of a well-developed PCK in the subject of magnetism.

Chapter 6: Intervention

[A research project] needs to up skill teachers in the inquiry element but also make quite sure they are consolidating ... the science knowledge [teachers] are going to need

(Teacher Educator, Section 4.1 interviews)

The intervention that was developed as part of this research took the form of a learning environment and a series of lesson resources building on the findings and knowledge from all of the previous studies described. This chapter will begin by describing the development process of the intervention. This will be followed by the evaluation of the impact of the intervention.

6.1: Development of the Intervention

One of the key areas of development of the intervention of this research was the design, development and creation of a learning environment and resources which promote IBSE. This section will detail the development of this learning environment and resources developed which had to address all of the issues discussed in the previous contextual analysis. These issues included; making teachers aware of the practice of IBSE, containing all of the resources developed for easy dissemination and hosting lesson planning and evaluation tools as well as information about the research for teachers.

6.1.1: The learning environment

The structure of the learning environment contained eight primary sections viewable in Table 13. As it can be seen these various pages would come together to create a learning environment for teachers of primary science. This environment would provide the teachers with resources, planning and evaluation tools as well as insights from other teachers into how using the resources were affecting their teaching. Once these pages had been decided on the second stage of the learning environment development was to develop a user interaction map. This map would show how all of these various pages would be linked together to ensure the teachers could attain any information they wished while using the environment. All of the information presented on the various pages would synthesis the findings of the research.

Table 13: The Learning Environment

Web Page	Description
Home Page	Welcome visitors and host news
Resources Page	Host the resources developed in Section 6.1.2
Links	Provide links to other educational support services
Project Page	Provide information relating to the research
IBSE page	Provide synthesised information regarding IBSE
Activities Page	Provide descriptions of various methodologies and their place in the 5E model
Lesson Tools Page	Provide lesson planning and evaluation tools

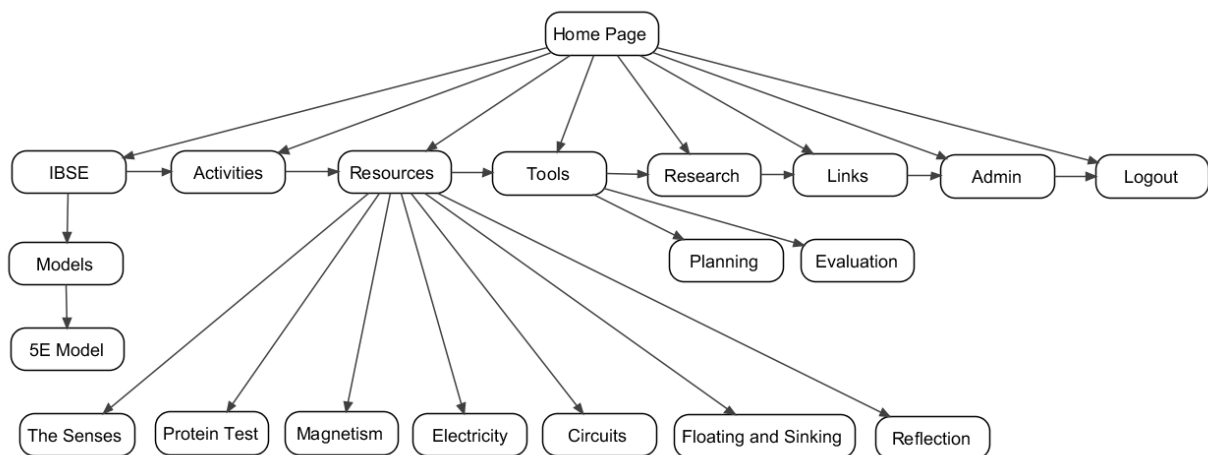


Figure 17: Final user interaction map of the learning environment

As it can be seen, the user interface map ensured that the teachers could access the resources and information as easily as possible. It can also be seen that each resource was afforded its own webpage. These pages would follow the template described below. Figure 18 shows the final homepage developed for the website highlighting each of the various areas described in the previous sections. This page is viewable at the website link: <http://ibse.ul.ie>.

IBSE

Promoting
Inquiry Based Science Education
in Irish primary schools

UNIVERSITY of LIMERICK
OILESCOIL LUIMNIGH

Home
IBSE
Activities
Our Project
Links

Homepage

Welcome to the IBSE project research page. This site hosts resources, links and activities for teachers that will aid them in the teaching and learning of science for the Irish primary school curriculum. This site is continually updated with content developed by both researchers and teachers and is maintained by the research team at the University of Limerick. If you are a participating teacher please log on to access the resources.

Additional functionality available to registered users. Please login to access.

The main goal of this work is to investigate the integration of a set of science teaching resources into the curriculum of Irish Primary Schools that will assist investigation and student understanding. These resources will be rich in audio-visual examples and show areas of good teaching and learning.

Please note that you must have javascript enabled, and a flash player installed to utilise all of the elements available on this website.

If you are a primary school teacher in Ireland and would like access to the website to view and use the resources please contact the following email address with your name, school name and year that you teach:

IBSEIreland@gmail.com

Username:
Password:

Upload Page fixed

<p> The code to our upload page has been fixed. This page will now allow you to upload documents !

[Read full article](#)

Updated the upload Page

<p> The upload page has been updated. For convenience this page now contains the feedback forms fo

[Read full article](#)

Welcome to our new users

Welcome to all of our new users!

[Read full article](#)

Home IBSE Activities Resources Lesson Tools Our Project Links Contact us

Figure 18: The homepage of the learning environment

6.1.2: The Resources

As part of the research seven sets of resources were developed using the template shown in Figure 19. Any text in bold is the template heading while standard text is the description used for that section. The first area of information provides the teachers with the strand unit the lesson falls under in primary science. This is accompanied by an approximate class level for the resource. It is important to note that several of the resources developed can cater for various class levels due to the template structure used. This section also details an approximate duration for the lesson as well as an equipment list. These resources developed were on the subjects of: The Senses, Testing for Proteins, Magnetism, Electricity, Electrical Circuits, Floating and Sinking and Reflection. The resources can be found in Appendices D through J.

This template proved popular with the participant teachers as the structures easily enabled them to create lessons from the resources in the structure of a 5E lesson. The template also allowed a teacher to scaffold their development of their PCK. Through selecting appropriate areas on the template a teacher can develop activities which can cater for areas they determine that their lessons need development. This meant that a teacher could concentrate on their engagement activities, if they felt they had trouble engaging students or accessing prior knowledge.

<p>Strand Unit:</p> <p>Class:</p> <p>Duration:</p> <p>Equipment Needed:</p> <p>Rationale: This section details the rationale behind the lesson. It describes generally the activities that will be present in the lesson as well as details how to make a complete lesson from the resource.</p> <p>At the conclusion of this lesson students should have covered:</p> <p>This section lists the content that should be completed by the end of the lesson.</p> <p>Lesson:</p> <p>This section is divided into headings of the 5Es. Each heading is then subdivided into its various activities. The activities include sample materials such as video clips or images that may be used as part of the lesson. Each activity includes details on the appropriate class level and duration of the activity as well as a rationale to explain why that activity is useful for the students. From the resources that have been developed it was deemed appropriate to include as many different activities in this section as possible. This would enable the teacher to pick and choose different elements of a subject that they wish the student to explore. It would also provide various ways of carrying out different subjects in case the teacher found that a particular activity was not working in their classes.</p> <p>Possible Misconceptions</p> <p>As misconceptions can be developed through the studying of science it was decided that if any misconceptions could be developed thought the course of a lesson they would be described here. This would enable the teacher to watch out for them and to challenge them when they arise.</p> <p>Extra Files</p> <p>This section contains extra files that can be included with the lesson such as worksheets, images or links to external website for research.</p>

Figure 19: The Final Resource Template

The teacher educator interviews, in section 4.1, raised concerns about online resources being lesson plans for teachers. This meant that teachers could download the resource and carry out

the lesson as dictated by the plan, not considering the learning outcomes, activities or their own lesson planning. This template attempts to cater for this issue by providing many more activities than could be carried out in a single lesson. This allowed teachers to develop their lesson planning techniques by only selecting appropriate activities to meet the objectives of their lesson.

The PCK of the participating teachers highlighted that a sense of wonder on the subject of science is lost when students become bored in the classroom. This is especially an issue when the teacher is identifying the prior knowledge of students in later years. The format of these resources provided a teacher with different ways of reaching a learning outcome for students. This would serve two purposes. Firstly an alternate activity could be selected if students were having particular difficulties with a concept or idea. Secondly it ensured that any developed lessons would contain various activity types for the students maintaining their interest levels.

6.2: Intervention observations

As described in chapter 3, there were two types of observation captured as part of this research, the discovery and intervention observations. The intervention observations were designed to discover the effect of the intervention on the classrooms of the participant teachers. This section will present the intervention observations. These observations were non-participant overt observations which asked the participating teachers to develop a lesson using the resources that were developed. There were five observations collected with Teachers A, B and C. Teacher D could not participate in the project further due to external concerns, as was the situation with Teacher C and one recording. Table 14 describes the subjects that were chosen by the teachers. As it can be seen four out of five of these observations were carried out with the resource developed on Magnetism. Teacher B requested that she carry out a lesson based on The Senses resource as she had covered Magnetism with her class already that academic year. The observations were carried out over two terms, with the summer holidays in between. This ensured that 5 different groups of students were observed. The class level taught by the teachers did not change over the summer break. The results of the intervention observations will now be discussed. The primary themes that emerged from the observations are; the structure of the lessons, teacher confidence, teacher adaptability, teacher patience,

Table 14: The Intervention observation subjects

Teacher	Magnetism Resource	The Senses Resource
Teacher A Rec 3	X	
Teacher A Rec 4	X	
Teacher B Rec 3		X
Teacher B Rec 4	X	
Teacher C Rec 3	X	

6.2.1: Intervention Observations

6.2.1a: Structure of the Lessons

The first theme that is evident in the intervention observations is a change in the structure of the lessons by all of the teachers. It is clear in the observations that there is a much more even distribution between the 5E stages in this lesson. While not all stages were presented equally in each observation, every stage of the 5E was present in the lesson and they were in the same order as presented in the intervention.

It is clear from the observations of Teacher A that she attempts an activity in each of the 5Es in the order specified. This appears to have a positive effect on the learning of the students, as recording 4 shows students who are willing and confident providing answers in the subject of magnetism. The teacher also commented how, by recording 4, she was more aware of the structure of the lesson and that it helped her understand why she should plan activities to build upon each other rather than just carry out varied activities. The structure of Teacher B's intervention observations are similar to Teacher A's. In both recordings it can be seen that the lessons appear to be consistent with the process of an inquiry orientated lesson. This is evidenced by the progression from engagement, or identifying student's prior knowledge, to exploration, thorough investigation, explanation, elaboration and evaluation. The 3rd observation by Teacher B must be noted as it was over 60% of the way through the lesson before the teacher mentioned the topic of the senses. Instead she used discussion to develop and identify the students' knowledge of the senses without labelling what topic she was covering. As observed in his discovery observations, Teacher C appeared to have a consistent structure in his lessons. While the approach used by the teacher is consistent with the discovery observations the structure of the lesson has been changed. When coding this lesson

it is clear that the teacher manages to include all 5Es in the lesson and that they are in the order specified in the intervention. This is in contrast to the discovery observations where there were 5E sections missing and there was no clear delineation between certain phases of the lesson. It became evident, as part of Teacher C's use of the magnetism resource, that the resource added many elements to his teaching. It is observed that the class is less disruptive compared to the discovery observations. This could be attributed to the larger amount of activities present in the lesson. In the two previous lesson observations carried out with this teacher there was a maximum of five activities per lesson. It was assumed that this was due to the nature of the special needs students within the class. This observation however showed the teacher including nine different activities in the lesson, which all met the learning goals.

It is clear, therefore that these teachers have adapted their practice using the intervention observations. These observations align more closely to an IBSE process than the discovery observations. It must be noted that, while discussing the 1st intervention observation, Teacher A remarked how she thought there were too many activities present in the resource to carry out in one lesson. This resulted in her rushing through some of the elaborate experiments to ensure they were all completed. In order to aid the teachers the fact that a teacher should pick and choose what activities to carry out was made more explicit in the intervention.

6.2.1b: Teacher Confidence

Another theme which is identified in the intervention observations is an apparent increase in the confidence of Teachers A and B. Teacher A is observed to introduce activities by stating objectives clearly and concisely. For example the first activity is introduced as follows:

[Teacher]: Now the very first thing I want you to do now. I want each group to have a talk for a few minutes and I want you to write down words. Any words that you can come up with that have to do with magnetism OK.

[Students]: {Begin to talk}

[Teacher]: Then we will talk about those words in a few minutes. But who's the recorder. You will be writing the words down.

In Recording 3 the students do not respond to Teacher A's introduction of the lesson leading her to have to adapt the activity. This time the teacher introduces the same activity but edited it slightly to maintain focus by the students. The students are now expected to record their discussions. The students are also able to immediately begin the activity as they are already in

their groups and have their materials prepared. Figure 20 also shows a more confident teacher who can now leave the student groups to carry out the activity with no influence from her. The teacher was observed to stand quietly for several minutes while the students discussed magnetism.



Figure 20: The teacher allowing the students to freely discuss magnetism

It is also apparent that teacher B is more confident in her intervention observations. The teacher began the 4th observation by formally introducing magnetism and asking the students what they knew about magnetism.

[Teacher]: This morning we are going to do a lesson on magnetism. Now does anybody know anything about magnetism? Or know anything about this. OK. Yes.

[Student]: It sticks to something metal.

[Teacher]: Now what sticks to something that's metal? What sticks?

[Student]: A magnet

[Teacher]: A magnet. Ok.

This type of questioning recalls the discovery observations of this teacher. The difference is that this time the teacher appears to be more confident in the subject. Comparing the observations it can be seen that the teacher is attempting to scaffold questions to identify the students' knowledge. In the previous recording the teacher appeared to be less confident and prepared when the students provided her with answers she was not expecting. This time however the teacher wishes to get the students to make exacting statements about magnetism.

It is also evident that the teacher is more confident during the investigation that is being carried out. She is observed to readily accept that certain items are not magnetic even though they are metals. With relation to classroom management it must also be noted that the students were much less disruptive in this recording when compared to the discovery observations by this teacher. This could be attributed to the fact that the teacher appears to be more confident in the lesson and the structure of the activities present.

6.2.1c: Teacher Adaptability

It is also obvious in the intervention observations that these teachers are willing to adapt the intervention resources to their purposes. Throughout the observations there are several instances where the teacher changes or adds something to an activity to make it clearer or more relevant. This is particularly relevant as the intervention was designed to provide the teacher with a resource but the teacher is still required to develop it further to suit their needs.



Figure 21: Teacher collecting the responses to the first activity

Teacher A's adaptability is observed during an activity on magnetism when the following discourse takes place:

[Teacher]: You can't talk without making noise

[Students]: {no talking}

{...}

[Teacher]: Ok hands up then, what words can you think of?

[Student]: {immediately raises his hand} Metal

In this particular instance the teacher afforded the students the opportunity to talk. The students however remain silent and do not even attempt to look at each other. After about fifteen seconds the teacher then changes her mind and asks the students to raise their hands. This elicits an immediate response from the students and the activity progresses. In the 4th recording it became evident that the students began to list items that they believed to be magnetic. The teacher uses this to her advantage and adapts her plan to allow the students to test the various items that they had described later in the lesson. This showed that the teacher was also aware that there was no point in students listing items without them investigating whether they were magnetic or not. Teacher A also included a free play activity which was not present in the intervention. This activity was comprised of several elements all of which were designed to have the students openly explore magnets. This allowed the students to actively explore and discuss magnets without having to meet an objective. This activity was introduced as follows:

[Teacher]: I just want you to play with them for a minute. And I just want you to see [...] what's going to happen.



Figure 22: Students during a free play activity with two magnets

There were some other notable elements in the intervention observations. The development of Teacher A's PCK was observed in the 3rd recording. The teacher stated that the students had to carry out an investigation into whether magnetism worked within water or not. The students had to plan, predict and carry out their own investigation in this section. One student was viewed to place a magnet in water to take a paperclip out. The teacher realised that the activity that she had planned did not meet the learning outcome she intended.

[Teacher]: {loudly} What was that? What did you just do? What did you do there?

She expected the students to use the magnet on the outside of the glass of water to take the paperclip out. This she realised that the activity was showing that magnetism worked through glass and water. Instead, the student had come up with a procedure which showed magnetism working through water alone.



Figure 23: Teacher A demonstrating magnetism working in water

In the discovery observations Teacher B used shoeboxes to sort out the items that were magnetic and non-magnetic. In the intervention the teacher adapts the activity and placed two hula-hoops in the centre of the classroom. The students desks were then arranged around these hula hoops. During the investigation the teacher stated that the hula-hoop on the right would contain magnetic items and the hula-hoop on the left would contain non-magnetic items. This allowed the students to easily sort, compare and discuss the items compared to the discovery observations.



Figure 24: The teacher discussing various magnetic and non-magnetic items

Teacher C also added a form of evaluation to his lesson on magnetism. This evaluation was not part of the resources and involved a write up of some interesting ideas that the students had been discovering during the lesson. The method was known as a 3 2 1 evaluation.

[Teacher]: We are going to do a 3 2 1. So the first thing I want you to write down is three interesting things you found out today about magnets ok.

{...}

[Teacher]: So we are going to do two things I did not know

{...}

[Teacher]: And I want one question you still have about magnets ok.

This approach enabled the teacher to evaluate the students learning from the lesson and also to present a recording exercise in an interesting manner. The students appear to be less resistant to this form of writing exercise than the writing exercise observed in the discovery observations. The students were also able to record their own answers to these questions. This appeared to spark discussion and debate in the students who found different ideas interesting.

It can be seen that while the intervention provided the teachers with many activities to try in their classroom they all adapted the lesson to suit their own needs. All of these adaptations were added to the intervention activities to attempt to promote different ideas and to make the intervention as flexible as possible.

6.2.1d: Teacher Patience

It is also apparent in the intervention observations that Teachers A and B appear to be more patient progressing through the lesson. Teacher A, in the 3rd recording, is observed to wait approximately fifteen seconds for students to respond to a question. This is in stark contrast to the previous observations where the teacher did not allow a student to pause before answering a question. This patience allowed her to consider the activity and to adapt it to her needs.

In the 4th recording there is also evidence that this teacher is more patient. Figure 20 shows Teacher A standing waiting while students discuss magnetism. The teacher is observed to be calmer and to allow the students to talk for a much longer time before interrupting. This is also evidenced during the investigation into magnetic objects. During this activity the teacher

is observed to have more control over the classroom and the activity compared to the previous observation.

In the discovery observations Teacher B was shown to be impatient with items she believed would be magnetic but were in fact non-magnetic. This was evidenced when the teacher placed an aluminium can in the magnetic box even though it was not attracted to the magnet as she was frustrated with the result. In the 4th observation the teacher appears to be more accepting of metals that are non-magnetic.



Figure 25: Teacher B holding a magnetic and non-magnetic knife

The following discourse exemplifies this:

[Teacher]: Now did anybody try out this teapot {picks up metal teapot}?

[Student]: I did. It didn't stick

[Teacher]: Did it not stick?

[Student]: No

[Teacher]: {tests the teapot} you're right. So it's

[Student]: Non-magnetic.

{teacher places teapot in non-magnetic hula-hoop}

Here the teacher readily accepts that the metal teapot is non-magnetic as not all metals are magnetic. This also the case when the students tested different types of cutlery. Some of the spoons and forks tested were magnetic and some were non-magnetic highlighting that, even though they looked the same, they were in fact different. Figure 25 shows the teacher holding a magnetic knife (in her right hand) and a non-magnetic knife (in her left hand).

[Teacher]: You see they are different selections, different kinds so this one doesn't stick.

It would appear therefore that the structure of the intervention observations allowed the teachers to be more patient in their lessons and to allow students to discuss and experiment more freely than in the discovery observations.

6.2.1e: Misunderstandings

The intervention observations also highlighted the ease at which misunderstandings can be passed from the teacher to the students in the classroom. During the lesson on the senses Teacher B attempted to get the students to associate the sense of touch with the skin. The students however made three attempts at responding but still didn't provide the correct response. The teacher decided that this amount of questioning was enough and that the students were close enough with the fingertips so she supplied the students with the final answer of the skin. The teacher however becomes distracted and records the fingertips on the blackboard as being associated with the sense of touch. Throughout the rest of the lesson the students identify the fingertips with touch rather than the skin.

{near the end of the lesson}

[Teacher]: And what do you touch with your?

[Student]: Fingertips

[Teacher]: And it is the skin of your fingertips.

In the recap of the lesson it is very clear that the students have concluded that the sense of touch is associated with their fingertips. The teacher also does little to alleviate the error that has developed. This shows how easily misunderstandings can be developed in the classroom. This misunderstanding was added to the intervention in order to highlight it to teachers.

6.2.1f: Intervention Observation Conclusions

As it can be seen, the intervention appears to have several impacts on the teaching of the participant teachers. Firstly it can be stated that the structures of the intervention lessons is more consistent with the 5E process. Each of the intervention observations contained the 5Es and they were in the order specified. In the 3rd observation Teacher A attempted to cover all the material provided in the resources. This appeared to make the teacher uncomfortable and showed the lesson as rushed. In the 4th observation she was aware that she should choose

particular activities to carry out. This made her appear more confident and more competent in the lesson. There is also a notable increase in the confidence of Teachers A and B by the final recording. Both teachers had attempted the magnetism lesson twice and on their second attempt they are observed to be more consistent and patient during the class. All of the teachers also showed a willingness to adapt the lessons that were presented on the intervention. These adaptations were catered for the context of the teacher's classrooms and were all added to the intervention. Finally the intervention observations displayed how easily misunderstandings can be transferred in the classroom. As evidenced by Teacher B who will have to attempt to change the students understanding that the sense of touch is associated with their fingertips.

6.3: Teacher opinions of the learning environment and resources

A feedback form was provided to each of the participant teachers to collect their opinions and views on the learning environment and the resources. The questions were:

- Do you feel taking part in this research has affected your teaching in anyway? If so How?
- Did you find that this research changed your knowledge on Inquiry Based Science and if so, how?
- Did you think the website was an appropriate way to obtain the resources and find information?
- Would you recommend the process and/ or resources from this research to another teacher?

The responses from each of the teachers will now be discussed.

Question 1:

The primary effect that the teacher highlighted about participating in this research related to the practice of lesson planning and preparation. The teachers stated that they could plan lessons better and be better prepared using the resources. One teacher highlighted how seeing the students' reactions on the videos allowed her to prepare for similar reactions in her classroom. One of the teachers expressed how he now understood the value of prior knowledge within a lesson, both for him and the students and that this would now form an element of his lessons from here on. One of the teachers also stated that taking part in this research has reawakened her interest in primary school science by equipping her with more ideas to enhance her resources and teaching. The use of the learning environment also served

to remind her that science is both “a body of content knowledge and a way of learning”. This statement is particularly striking as the teacher appears to be alluding to the epistemology of science. While it was never a clear goal of this research to promote the epistemology of science, IBSE has been shown, in its nature, to support the epistemology of science. Therefore it can be concluded that this research has supported this teacher developing this idea within her teaching.

Question 2:

The teachers’ response to this question stated that, with the exception of one of the teachers, participating in this research has added to their knowledge on IBSE. The other teacher stated that his school had been striving to teach through inquiry for a number of years now and had carried out initiatives with respect to this. The teachers who said it had affected their knowledge stated that participating in this project has changed the way they approach lessons as they now make them more inquiry based whenever possible. One teacher stated that while the term “inquiry based” was new to her, the method followed her teaching approach closely anyway. This point raises questions again about the in-service and curriculum documents, both of which aim to promote inquiry but yet a teacher stated that she was not aware of the term. She also stated that the method also signals a move away from textbooks which would be “welcome”. Again this research has shown that the textbook does not need to be abandoned entirely, a prospect which would be daunting for some teachers, but instead the use of the textbook needs to be redressed in primary science.

Question 3:

All of the teachers agreed that the website was an appropriate way to obtain the resources and find information. They also highlighted how the use of the website allows for the videos of practice to be seen which will be “useful to teachers of all ages”.

Question 4:

All of the teachers again said they would recommend the processes and resources from this project to other teachers. They believe that the resources would benefit teachers who do not have a personal interest in the subject or do not have the confidence to teach science. The feedback also stated that the approach and structures make the subject easy to understand for teachers and that the investigations are clearly explained with background information to fill in content knowledge gaps.

These responses show the positive attitudes and opinions of the participating teachers on the learning environment and resources developed as part of this research. While this would be expected, due to their inclusion in the development phases, they do raise points about teacher confidence, clear investigations and promoting IBSE which may infer to the relevance of these resources. The next section will detail an evaluation of the effect of the resources on the PCK of pre-service primary school teachers.

6.4: Impact of the intervention on pre-service science teachers

The study into the effect of the resources on the PCK of pre-service teachers was carried out in a similar fashion to the PCK study with the participant teachers. As stated in Chapter 2, this study was carried out with three volunteering pre-service teachers from one of the teacher education colleges detailed in Chapter 1. It must be noted that these teachers had not yet carried out any teacher training so their insights were not based on teaching experience, only their education and interaction with the intervention. Two different CoRes were developed with the pre-service teachers. The first one served to be a baseline snapshot of their PCK on the subject of magnetism. The students were then given access to the intervention and a second CoRes was developed. Once again a mind map was developed through discussion and guiding questions by the researchers. This mind map was then used to develop the Big Ideas on the subject. The topic of magnetism was used to ensure that comparisons could be drawn between the PCK of pre-service teachers and the participant teachers in this research.

6.4.1: Prior to access to the intervention

The first stage of this study was to develop a mind map of the pre-service teachers' thoughts on the subject of magnetism and use this to develop the Big Ideas that would be expanded on. Figure 26 is the mind map constructed by the pre-service teachers prior to their access of the intervention. As it can be seen the three primary Big Ideas that are identified in it are:

- Magnets in students everyday lives
- Discover Learning and play
- Magnetic poles and fields

These Big Ideas are analogous to the Big Ideas developed by the participant teachers. Prior to the CoRes being developed the pre-service teachers stated that they felt they would not be

confident teaching magnetism. The full CoRes developed from this mind-map is viewable in Table 15.

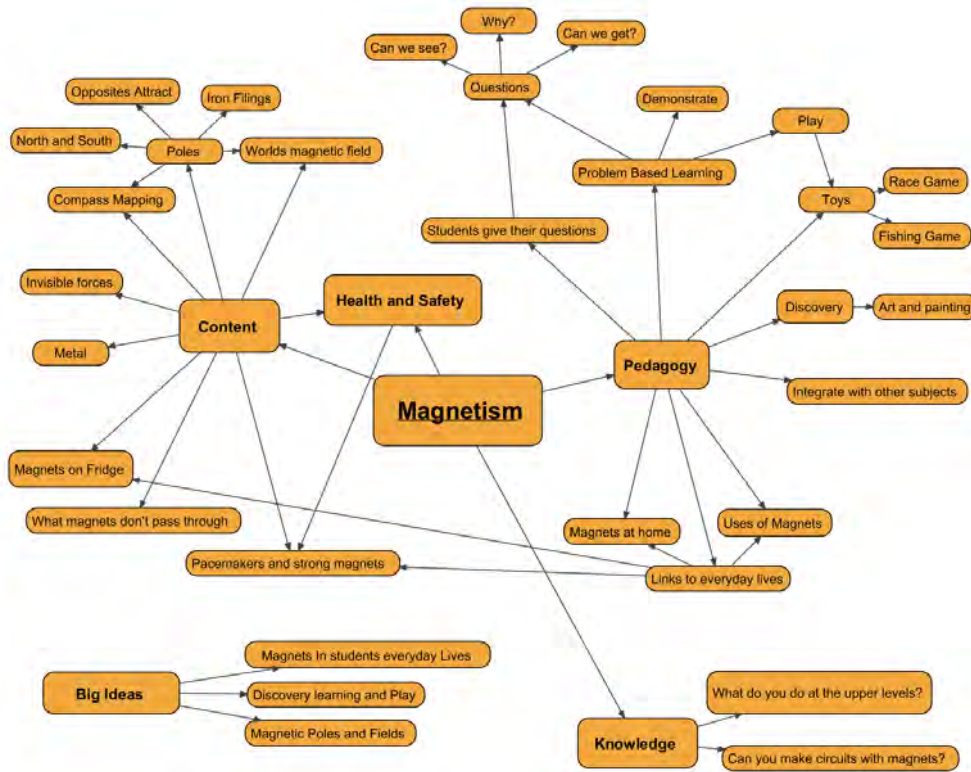


Figure 26: Pre-service teachers mind map prior to intervention access

Table 15: Pre-service Teachers CoRes Prior to learning environment access

	Magnets in the Lives of students	Discovery Learning and Play	Magnets have poles and fields
1. What do you intend students to learn about this idea	<p>Magnetism is a force</p> <p>Uses of magnets</p> <p>Advantages and Disadvantages</p> <p>Repelling</p> <p>Opposites and attracting</p>	<p>Poles attract and repel</p> <p>Do not make the process of discovery learning explicit to the students</p> <p>Develop a progress of science study with the students</p>	<p>Understand the concept of poles and fields</p> <p>Implications of magnets having poles and fields</p> <p>Visualise the effects of magnets</p> <p>Show how magnets work – not including the theory of magnetism</p>
2. Why is it important for students to know this	<p>No Wonder</p> <p>Discover magnets</p> <p>Important to understand the usage of magnets</p> <p>Important to relate science to everyday lives</p> <p>Make sense of the world around them</p> <p>Show innovation</p> <p>To promote thinking scientifically</p>	<p>It's the students natural instinct to play and discover</p> <p>They internalise it better through discovery and play</p> <p>Consolidate their learning easier</p> <p>They use their own “relaxed” language to explain what is happening</p> <p>The students enjoy the lesson</p>	<p>So that students can see it and know what is going on</p> <p>So students can develop a broader knowledge</p>
3. What else do you know about this idea (that	<p>North and South should be taught by 3rd class to develop scope for 5th class</p> <p>Junior Certificate Vocabulary to do with magnetism</p>	<p>There are resources available to aid the lesson (such as Discover Primary science)</p> <p>“it works”</p>	<p>The technical side of magnetism</p> <p>Know the previous teaching of the class to build a lesson on</p>

you do not intend students to know yet)	Worlds Magnetic field should be taught in later class levels	Discover learning and play can cover everything easier as the students experience it It is structured It can scaffold a lesson It brings the topic to the level of the students	
4. Difficulties / Limitations connected with teaching this idea	Carry out research to expand content knowledge Resources available in the school Useful resources relating to the subject Utilising the immediate environment Carrying out planned experiments	Students can go off task and require guidance You must have a structured classroom The students may ask questions that the teacher cannot answer as it is open exploration You must guide the students bit by bit Questioning levels may be beyond the level of the students Class numbers may be preventative	Ascertaining the students prior knowledge Have to learn ideas and theories in magnetism to answer questions Place unanswered questions in a question book
5. Knowledge about students' thinking which influences your teaching of this idea	Students ask lots of questions You have to evoke curiosity Prior knowledge sharing Hone the basic ideas of science study Students are visual and tactile learners	Students prior knowledge Students love play It is a springboard for more learning It appeals and develops to the strengths of the students Develops motor skills It uses the students imagination	The students will have prior knowledge of magnets as most will have them on their fridge and have use them before The introduction of the lesson must build on varied levels of prior knowledge

		Aids them in remembering the lesson as they enjoyed it and it makes the lesson special	
6. Other factors that influence your teaching of this idea	<p>You have to develop the students learning</p> <p>Guided discovery</p> <p>Find “Wow” resources for capturing interest</p>	<p>Students find mind maps “boring”</p> <p>Making it more visual</p> <p>Gives students freedom</p> <p>Students appreciate the primary experience</p> <p>They enjoy discovery</p> <p>Gives students the resources to recall the discovery in later life</p>	The experience of previous lessons teaching magnetic poles and fields will affect how the lessons is carried out
7. Teaching procedures (and particular reasons for using these to engage with this idea)	<p>Guided discovery</p> <p>Questioning and observing</p> <p>Time given to observing and discussing this observation</p> <p>Class discussion</p> <p>Section on language development and new words</p> <p>Oral language development and integration</p> <p>Subject link to geography and Art</p>	<p>Scaffolding is essential</p> <p>You must have a clear layout and plan</p> <p>You could reorganise the classroom into groups, but create the groups carefully</p>	<p>Make the lesson visual for the students to see the effects of magnets and poles</p> <p>Utilise discovery channel documentaries on magnetism to add to the wow factor of the lesson</p> <p>Students must carry out an experiment on magnetism in the lesson</p>

<p>8. Specific ways of ascertaining students' understanding or confusion around this idea (including likely range of responses)</p>	<p>On-going assessment students throughout the lesson Get students to label 5 magnetic and 5 non-magnetic items in the classroom Name and Write down the above Create a poster presentation Use flash cards of items to find whether the students know if they are magnetic or not Sort and test using hula-hoops, for prediction and categorisation, then test predictions and compare original to the end of lesson hula-hoops Peer teaching, asking students to explain what they have learned to a younger class</p>	<p>Continuous observation Questioning Listening is important to identify the learning and to keep the students on task Probing the students for what they have discovered Offering time to free play to help the students develop their knowledge Take a step back to give the students freedom to learn</p>	<p>Identify gaps in knowledge for the questions the students ask Listen to the classroom discussion to identify areas of misunderstanding Ask the students to write about poles and fields to get their knowledge Students carry out an interview, one being journalist and one interviewee having studied magnets This interview could be recorded Use games like snakes and ladders and relate them to the subject Students sort out sentences into true false groups Students draw a cartoon strip on their studies and what they have learned, scaffolding it with the title and limiting it to three things that have been covered</p>
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6.4.1a: Content Knowledge

When analysing the CoRes of the pre-service teachers it is evident that while there are similarities between these CoRes and the ones presented in Chapter 5, these CoRes lack the detail and specificity that the previous CoRes contained. This would be expected of pre-service teachers who do not have as much knowledge or experience. While that is the case the CoRes do identify several important points.

Relating to content knowledge it is clear that these pre-service teachers have a set amount of knowledge with relation to magnetism. They are able to highlight the idea that magnetism is a force, the uses of magnets, and repulsion and attraction. The pre-service teachers are also aware of the concept of scaffolding magnetism from the idea of a push and pull to attraction and repulsion. While discussing the implications of magnets the pre-service teachers were referring to the real world effects of magnetism. This was described by the pre-service teachers as helping the students understand how magnets play a role in their everyday lives by describing the use of pacemakers and electromagnets in scrap yards. Another interesting element of the CoRes was presented when the pre-service teachers raised the points of making magnetism visible to students. This point is also referenced throughout the CoRes in Chapter 5.

When responding to the question “What else do you know about this idea?” the pre-service teachers identified several areas of the content of the curriculum. Here the pre-service teachers described how the concepts of North and South Poles should be developed in students prior to 3rd class to allow scope to be developed in magnetism for 5th class. This shows that the pre-service teachers are already constructing schemes of work for their teaching that will ensure that magnetism is scaffolded throughout the students' primary education.

The pre-service teachers also identified with a sense of wonder in the classroom. This was a Big Idea as presented by the participant teachers and the pre-service teachers believe that if the topic of magnetism is removed from the lives of everyday students that they will not have a sense of wonder when studying it and this will lead to difficulties in teaching. The pre-service teachers believe that relating science to everyday life will aid in the promotion of scientific thinking which is a life skill, a point which was also raised by the practicing teachers.

6.4.1b: Context Knowledge

As stated previously it would be expected that these pre-service teachers would not have as detailed a contextual knowledge as the practicing teachers. This is apparent from the CoRes collected but the pre-service teachers do show some appreciations of the context of the classroom. The difficulties and limitations for the subject are not as detailed as the participant teachers CoRes however; there are influences of the classroom identified such as a lack of resources. They also show an awareness of students based on their own experience of being students. From this they describe how students ask a lot of questions, the teacher has to evoke curiosity, prior knowledge sharing, science skills and how students are visual and tactile learners. The pre-service teachers also show a consideration of their own lack of content and context knowledge. They describe how they could ask the students to research a topic both so the students could develop their learning and so the pre-service teacher could expand their knowledge based on the findings of the students. This removes some of the pressure from the teacher as they develop knowledge in their teaching.

The pre-service teachers also considered how it was difficult for them to enter the classroom as they would have no knowledge of what previous teachers have covered. The pre-service teachers described how ascertaining the students' prior knowledge would be a difficulty when they enter the classroom. Here they list the problem as “not knowing what the previous teacher taught”. This is of particular concern to pre-service students and they highlighted that they would have to concentrate on identifying student's prior knowledge when starting new topics.

Finally it is evident that the pre-service teachers, like the participant teachers are aware of the students watching TV shows that promote science and that they should consider these in their classes. They describe using Discovery Chanel documentaries. This recalls the CoRes as developed by the participant teachers and highlights elements of the pre-service teacher's knowledge of student's thinking, lives and the classroom context.

6.4.1c: Pedagogical Knowledge

The final theme to emerge from this study was the pedagogical considerations of these pre-service teachers. Within the CoRes the pre-service teachers presented their knowledge on the pedagogy of constructivism and inquiry. The teachers also stated that they would have a separate section of their science lesson dedicated to language development for new

terminology and oral language development. This shows a dedication to the introduction of new terminology within the subject of science and catering for non-“English as a First Language” students, a point raised by the practicing teachers.

Under specific ways of ascertaining students understanding or confusion the pre-service teachers listed; on-going assessment, poster presentations, sorting out activities and peer teaching. These points were also echoed throughout the CoRes of the participant teachers. The pre-service teachers did describe some of the specific activities they would carry out. Another interesting development from this CoRes was the pre-service teacher's description of an investigation carried out in the magnetism resource. Here a teacher described how she would use “something large like a Hula-Hoop” to sort out magnetic and non-magnetic items to make the groups more visible to the students. This activity was only added after the pilot stage of the magnetism resource but shows how the pre-service teachers thinking is in line with that of practicing teachers.

As it can be seen, the pre-service teachers PCK appears to be well developed in several areas. Using the three elements of PCK model in this research it is clear that the pre-service teachers have a large bank of methodologies they wish to employ in their classroom, that their content knowledge appears to be lacking in some elements and that they are basically aware of the concepts that influence their classroom context. Once the CoRes had been developed the pre-service teachers were granted a username and password to the learning environment so they could access the resources for a week before the second CoRes session.

6.4.2: Post access to the intervention

The process for developing the second CoRes with the teachers was the same as the first CoRes. After the pre-service teachers had been given access to the learning environment for a week they were asked to develop another mind map through discussion. Figure 27 shows the mind map that was developed by the pre-service teachers.

As it can be seen the Big Ideas that can be identified within this mind map are not vastly different from the previous mind map. A development in the understanding and thinking of the pre-service teachers can be shown however. It can be seen that the pre-service teachers

have developed their knowledge from the idea of magnets in students' everyday lives to visualising magnetism. This shows a refocus of their ideas which moves from the uses of magnets, a subject which was linked under the heading of magnetic poles and fields previously, to the importance of making magnetism visual for students, which only formed a point in the previous CoRes. It can also be seen that the pre-service teachers have refocused their thoughts on discovery learning and play into evaluating how students work scientifically. This seems to highlight a more broad definition of how students learn science rather than describing it through discovery. The pre-service teachers also maintain their thoughts on the importance of magnetic fields which was a previous Big Idea. Once again the eight questions of the CoRes were asked to the pre-service teachers. Their responses will be described below. The full CoRes developed can be seen in Table 16.

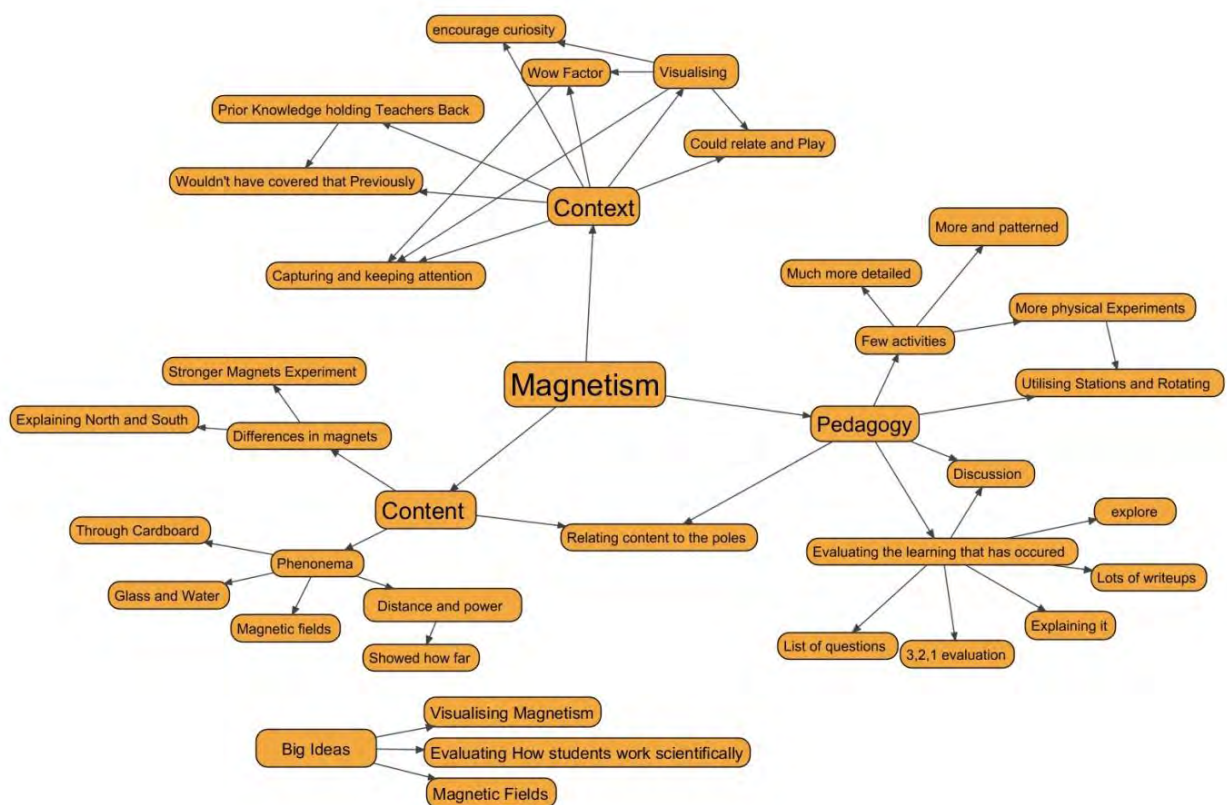


Figure 27: Pre-service teachers mind map post access to the intervention

Table 16: Pre-service Teachers CoRes post access to Learning environment

	Visualising magnetism	Evaluating how students work scientifically	Magnetic Fields
1. What do you intend students to learn about this idea	To recognise that there is a field around a magnet Students can't see the field but can imagine it	That they can self evaluate They can see if the topic is clear to them That they shouldn't be afraid to ask questions which makes a difference in other classes as well How to work scientifically That they are meant to and it is OK to ask questions How to consolidate their knowledge How to link what they have learned into their knowledge How to reassess their knowledge to look back over it	How to visualise magnetic fields That students can imagine it without mapping it out Recognise that it is invisible but there
2. Why is it important for students to know this	Turning abstract into fact Seeing real life concepts Awards a variety of exposure for the students	So students don't get lost in the topic How to build on their foundations of learning So students can Assert themselves through questioning That they know they can ask questions → Needs to be introduced early in a child's learning Students have a right to ask questions It is a skill set to develop for the student	So there is a purpose to the activities Link the subject of magnetism to everyday life Create a broad understanding which can be applied when needed Capture the interest of students Lead to more questions about magnetism and build on this
3. What else do you know about this idea (that you do not intend students to know yet)	They won't have seen the field Know the content of poles repelling Different materials allow for magnetism You can make things magnetic You can see the strength of the force lessening in some experiments	The skills they learn in evaluation carry through to other subjects That evaluation is a lifelong skill It makes the student comfortable and creates a relaxed atmosphere Students will get better and go further in their learning	The worlds magnetic fields → Applying a small scale model to the world → separate geographical and magnetic poles Subject links to geography → Creates a good inclusive lesson for 5 th and 6 th classes

		<p>“This is how I improve” It draws attention to a students’ prior knowledge and can aid them in recalling</p>	The various activities to show magnetic fields
Difficulties/ Limitations connected with teaching this idea	<p>Magnet resources including ones of different strength and size Require a lot of planning to ensure magnets can be visualised Students not getting the concept and spending more time trying to get it New unplanned for ideas that the students come up with and adapting to them Both the teacher and students prior knowledge The lesson is messier → classroom management issues Difficult to keep the students focus You cannot lecture the students</p>	<p>If students have difficulties with the basic concepts they cannot build on that foundation of knowledge Ensuring students develop their scientific method properly A teacher must recognise the substance of the activity rather than just carrying out an activity There is a place for overall assessment of the class to see how well they are learning as a whole You can identify individuals with issues by knowing them and if they are quiet A teacher should keep a record of the evaluations</p>	<p>Difficulties with magnetic fields Teacher must have structured leading questions Make the learning explicit for the students otherwise there could be confusion Separate the geographical and magnetic poles The fact that the north Geographic pole is a south magnetic pole</p>
5. Knowledge about students’ thinking which influences your teaching of this idea	<p>Students are curious and stimulated by lessons like these Introducing different types of learning Making magnets tactile They are more interested in active lessons Varying teaching methodologies captures interest Students will be keen to do it again</p>	<p>Students love to talk to each other Students love to ask questions and respond to them Students enjoy group work and working in pairs They are influenced by others around them The student who participates the most will not be isolated but instead each member of the class can participate Students self actualisation will be built upon “we can do it as well”</p>	<p>Confusion with geography Could be left out if the class is weak in magnetism Would have to watch peer learning as misunderstandings can be passed easily Eliminate small group learning to ensure that every student identifies the correct information</p>
6. Other factors that influence your teaching of this idea	<p>Difficult to keep focus and not go on tangent</p>	<p>“it feels good” when you understand the subject Evaluating through discussion and questions encourages expression Continuous assessment ensures that the</p>	<p>The teachers desire for learning can drive the lesson A teachers own interests may aid in the learning Teachers cannot be afraid to teach the</p>

		<p>students know they are following the subject and learning from it which gives them greater confidence continuing forward</p> <p>It leads to easier recalling of content</p> <p>It provides teachers with a different methodology and promotes experience</p> <p>It teaches students how to learn from their peers</p>	<p>subject otherwise it could lead to errors</p> <p>If there is a bright student and the teacher supplies extra information/ studies to them the parents could influence the teaching by asking that the student not be singled out like that</p>
7. Teaching procedures (and particular reasons for using these to engage with this idea)	<p>Activity stations</p> <p>Hula hoops for consolidation</p> <p>Write results on board for students to refer to</p> <p>Create good, mixed ability groups</p> <p>Peer teaching → students aren't as worried about discussing subject amongst themselves</p> <p>Hands on</p> <p>Discussion and Questioning</p> <p>3,2,1 evaluation</p>	<p>Ask students to do their own evaluations and then compare them with other students</p> <p>Utilise leading questions</p> <p>Creating proper groups for evaluating is important</p> <p>The teacher can answer questions or problem later if the students doesn't understand after exploring it</p> <p>It should be continuous in the classroom</p>	<p>Mapping the magnetic field</p> <p>Distance experiment</p> <p>Ask students to describe their learning to the teacher to ensure it is correct</p> <p>Provide extra materials (books etc.) for students to study if they want</p>
8. Specific ways of ascertaining students' understanding or confusion around this idea (including likely range of responses)	<p>If students keep referring to the none thing then they are confused</p> <p>Teacher will know by the reactions of the students</p> <p>Listen to what the students are saying → try to pick up where the misunderstanding or problem is</p> <p>Questioning session can aid in identifying groups that have problems</p> <p>3,2,1 evaluation idea</p>	<p>Comparison of students evaluations with other peers</p> <p>Discussion and questioning</p> <p>Do not make the evaluation explicit to the students</p> <p>Partner techniques</p> <p>Teach students how to listen, talk about a subject and evaluate it</p> <p>Develop a routine of evaluation</p> <p>Do not rely on the dominant child but ask others to explain the topic to their peers</p>	<p>Understanding the context of the classroom will aid the teachers in finding misunderstandings or students that do not understand</p> <p>Specific focussed questions</p> <p>Ask the students to write up their learning</p> <p>Carry out a news report to explain the abstract study</p> <p>Relate a subject (such as poles in geography) a few weeks later to recall what had been learned</p> <p>Ask the students to describe the story of their investigation</p> <p>Carry out a discussion</p>

6.4.2a: Content Knowledge

With relation to the content knowledge that is contained in Table 16 it is notable that the pre-service teachers' answers more closely mirror the practicing teachers CoRes. For example the pre-service teachers allude to the knowledge that magnetism may be an “invisible force” and visualizing magnetism. The pre-service teachers described how they were aware that the concept of magnets and magnetic fields would be difficult for students to understand if didactic teaching methodologies were employed. Instead the concepts demonstrated within resources afford them with the ability to display the effect of the invisible force. They also state that it is important for students to see real life concepts and creates a variety of exposure for the students. This point was raised by the practicing teachers in their CoRes and became a primary element of the development of the resources with the inclusion of the investigation on magnets and the several elaborate activities that were added.

The pre-service teachers, when describing what their knowledge, responded that; students will not have seen a magnetic field, that different materials allow for magnetism, that items can be made magnetic and that the strength of the magnetic force can be reduced. Each of these points shows a development in the content knowledge of the pre-service teachers as they had not been described before. It is also clear that the pre-service teachers view the idea of magnetic poles as a launching point for the study of magnetic fields and making fields visible.

It is clear, when describing the difficulties with teaching magnetism that the pre-service teachers have understood and thought through some of the difficulties associated with employing the resources within their classroom including; the difficulty with the magnetic strength investigation, the importance of planning, spending more time to develop understanding, adopting to new ideas and prior knowledge. The pre-service teachers show that they are aware that misunderstandings can arise when carrying out the activity on the strength of magnets. They also describe the importance of lesson planning and structure in their science teaching. Lesson planning was only briefly mentioned in the previous CoRes, Table 15, however; through access to the resources, the pre-service teachers seem to view it as a more important element of their teaching.

6.4.2b: Context Knowledge

The contextual knowledge that the pre-service teachers describe mainly refer to the structure and activities present in the resources. These include how students are curious and stimulated by active lessons, the resources introduce a new way of teaching, it makes magnetism more tactile and that students will look forward to doing a similar lesson. The CoRes highlights the pre-service teacher's opinions of the resources by thinking that students will respond positively if a teacher employed them in the classroom. The pre-service teachers also state that it is important for students to know how to evaluate their own learning in order for them not to be “left behind”, a sentiment which echoes the practicing teachers CoRes. The pre-service teachers also state that evaluation is a foundation of learning, that it can aid the students in asserting themselves if they do not understand something and that the skill of evaluation must be introduced early in a students’ learning. They state that the idea of exploration should not be made explicit to the students as it will ensure that the students construct their own knowledge and understanding of evaluation. This is analogous to a constructivist approach to learning, see Chapter 2.

One of the most interesting answers to the question on difficulties and limitations was;

A teacher must recognise the substance of the activity rather than just carrying out an activity

This shows an appreciation of the importance of learning goals and objectives when carrying out an activity compared to the previous CoRes. As a primary aim of the resources, designed to address the concerns in the literature (Appleton, 2005, Davis et al. 2006, Varley et al. 2008a, 2013, Zembal-Saul, 2009) and discussed with the teacher educators (See section 4.1), it becomes clear that this idea is represented and visible in the resources. The pre-service teachers also raised points about; how, if students have difficulties with basic concepts, they cannot build on it and evaluation is a key component of the scientific method.

6.4.2c: Pedagogical Knowledge

Again the teaching procedures of the pre-service teachers seem to have been effected by their exposure to the resources. The Teaching procedures are much more detailed and heavily based on the activities within the resources. Here the teachers describe that the various activities presented within the resources have helped them understand: the importance of

developing effective groups, that lessons based on the resources would be more active and that they had not encountered the method of 3-2-1 evaluation before. The teachers also stated that they believe that the 3-2-1 evaluation would be an effective method for evaluating the students learning without resorting to carrying out write-ups. This moved the conversation onto the final CoRes question where the pre-service teachers reiterated the points within the previous Big Ideas such as; if students keep referring to one thing then they are showing confusion, the importance of student's reactions, listening to the students while they work to ensure no misunderstanding is developed and how questions can be used.

The teaching procedures associated with evaluation also appear to be more developed, as viewed in the previous Big Idea. Here the teachers describe some more of the activities presented in the learning environment such as the use of leading questions and the use of student based evaluations. This point is also echoed in the ways of ascertaining students understanding or confusion whereby the answers are more detailed than the previous CoRes and emphasise a process and peer learning and support.

6.4.2d: Post Access to Intervention Conclusions

It is clear from the second CoRes that the pre-service teacher's PCK is developed in the subject of magnetism but that it is still not as developed as that of the participant teachers, a conclusion which would have been expected. The pre-service teachers do echo the answers provided by the participant teachers in several areas showing that they do have a basic level of awareness of pedagogy, content and contextual knowledge for their teaching. The next section will now compare the two CoRes that were developed by the pre-service teachers. Once again it must be pointed out that the CoRes only provides snapshots to the PCK of teachers and therefore only inferences can be made, rather than strict descriptions of the effects.

6.4.3: Effect of the Resources and Learning environment on the PCK

As it can be seen the exposure of the pre-service teachers to the resources seemed to have several effects on the CoRes of these teachers. Firstly when comparing the Big Ideas, it becomes evident that the Big Ideas have been refocused in the minds of the pre-service

teachers. Other points can be raised on the teachers' intentions of teaching, the pre-service teachers content knowledge, the difficulties and limitations associated with teaching magnetism, the knowledge of students' thinking and the teaching procedures.

It can be seen, upon inspection of the second CoRes developed, that the pre-service teachers are more aware of the idea of visualizing magnetism. It was a major point raised by the participant teachers, that magnetism is the students' first example of an "invisible force". This concern is obviously made explicit within the resources with the amount of varied activities present. The pre-service teachers now view this as one of the most important elements of teaching magnetism in primary school. By making the fields visible the pre-service teachers believe that the students will have a foundation of knowledge that can be built upon through further study.

It also becomes evident that the content knowledge of the Earths' magnetic field plays a larger role in the pre-service teachers' ideas on teaching magnetism. This topic is developed from one point in the previous CoRes into a full discussion within the "magnets have fields" Big Idea. It is viewed as an idea to promote the visualisation of magnetic fields, a tool for introducing magnetic fields and as a major source of difficulties and misunderstandings by the pre-service teachers prior to their viewing of the resources.

It is also clear that the difficulties and limitations associated with teaching the subject of magnetism are more developed in the second set of CoRes. This result is attributed to the amount of points that the pre-service teachers raised in their second CoRes. These difficulties were also more developed and, based on what they had viewed in the intervention, were better identified as to where they could occur within a lesson.

This point is also more evident through the question on the pre-service teachers' knowledge about students thinking. In the second CoRes the pre-service teachers were able to identify ideas that they had suggested in the first CoRes that may cause issue upon viewing the resources. A specific example of this is the idea of teaching magnetic fields to small groups. While the resource may allow for smaller groups the pre-service teachers recognised that this may not be the best approach after viewing the resources.

Finally it becomes evident that the pre-service teachers' knowledge about teaching procedures has been developed through exposure to the resources. It is clear that the procedures are more process orientated than previously described. The importance of planning and having clear learning goals and objects is also more evident in the second CoRes.

All of these points highlight a development in the thinking and ideas of the pre-service teachers after they had been granted access to the resources. The points they raise in the second CoRes are analogous to the issues and problems facing Irish primary science as discussed throughout the contextual analysis and the literature review. It can therefore be surmised that the learning environment and resources have a positive impact on the teaching and learning of pre-service teachers. While this one study cannot form definitive conclusions about the effect of the intervention it can infer that the intervention created positive influences. Further study into the impact of the intervention is needed to conclude whether the ideas, structures and guides presented in the intervention are the most effective way to promote IBSE in Irish primary science.

6.5: Chapter conclusions

This chapter presented the development and evaluation of the intervention that was developed as part of this research. The evaluation consisted of three primary studies. The intervention observations were a comparative observation with the participant teachers. Here Teachers A, B and C each took part in further observations whereby conclusions about the effects of the learning environment and resources could be drawn. The second method of evaluation was to collect feedback responses from the participant teachers. These responses aided in understanding the learning environment from the teachers' perspective rather than the developers. A final study comparative study was also described showing the effect of the learning environment on the PCK of pre-service teachers. The intervention was inferred to have a positive effect on the teaching of the participant teachers as well as the PCK snapshot of the pre-service teachers. The feedback from the participant teachers also identified positive attitudes towards the structures and ideas presented in the intervention.

Chapter 7: Discussion and Conclusions

I think we are so concerned in this country with subject knowledge [...] we will never be at the point where people are fully engaged with the process rather than [the] content

(A Teacher Educator discussing IBSE, part of section 4.1 Interviews)

This chapter will present the discussion and conclusions that can be drawn from this research. The chapter will be developed through the research questions and objectives that were detailed in Chapter 1. Section 7.5 will describe the addition of new knowledge to Irish science education that was developed as part of this research. Following this, conclusions that can be developed which were beyond the research questions will be discussed. Finally a personal reflection by the primary researcher will be given on the research process and development.

7.1: The Nature of IBSE and science education in Ireland

Research Question 1: What is the nature of IBSE and how is primary science education practiced in Ireland?

Objective 1: Analyse the literature to determine best practice in epistemic approaches to science teaching

Objective 2: Explore existing methodologies of Inquiry Based Science Education (IBSE)

Objective 4: Identify elements of IBSE in Irish Primary Science Education through a 5E lens

7.1.1: The Nature of IBSE

The nature of IBSE is realised through the literature review carried out in Chapter 2. It is clear within this review that IBSE is a complex subject which has been developed from a constructivist approach to teaching but is supported through the research and the Irish primary science curriculum (Akerson et al., 2008, Anderson 2002, DES, 1999, Marek et al, 2003, Minner et al., 2010, Rocard et al., 2007). The nature of IBSE is described through the application of a specific description of IBSE, knowledge of the various components, approaches and models for IBSE as well as the advantages and disadvantages of IBSE.

It was described in Chapter 2 that there is no specific definition of IBSE within the literature (Anderson, 2002). This lack of definition allowed researchers and policy creators to develop their own definition of ISBE and apply it to their own research (ibid). Rather than creating a definition of IBSE which could only be applied to this research, this research instead decided to take a governing science education document, namely the Rocard et al. report (2007) and identify a description of IBSE from it. This document was chosen as there was no definition or description of IBSE provided in Irish documentation. Therefore the search was expanded to the next closest context, Europe. This description is presented as:

The intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments

(Rocard et al., 2007, p.9)

This description then enabled the research to progress into an understanding of what the components of an inquiry-orientated lesson were. Some of the principle components of IBSE were identified as questioning (Anderson, 2002, Davis and Smithey, 2008), “diagnosing, critiquing, planning investigations, researching, debating and arguing” (Rocard et al., 2007), Explanation construction (Allen, 1997, Zembal-Saul, 2009) and the idea of scaffolding learning (Hmelo-Silver et al., 2007, Walker, 2007, Zembal-Saul, 2009).

While these components of an inquiry-orientated lesson are quite specific, it was discovered that an inquiry-orientated lesson is considered as a lesson which follows a process of inquiry rather than individual inquiry elements (Anderson 2002, Hapgood et al., 2004). Therefore in order to enact this process several models of inquiry were identified and analysed. These models included the 5Es (Bybee 1997, 2006, NCCA, 2004, PrimaryConnections, 2009), the Predict Observe Explore (POE) model (White and Gunstone, 1992) as well as models developed by individual researchers (Walker, 2007). As the 5Es method aligned closely with the description of IBSE as presented above it was chosen as the primary model for supporting IBSE in this research.

IBSE was also described in terms of the advantages and disadvantages of the methodology. It was shown that research by Krishner et al. (2006) identified that there was no research which stated definitively that IBSE produced positive results in terms of learning and development

by either student or teacher. On further consideration it was discovered that the definition of inquiry used by Krishner et al. (ibid) was that of open inquiry (Blanchard et al., 2010). It is discussed throughout the literature that open ended inquiry may be difficult to implement and that scaffolding could be used to develop a student and teacher towards open inquiry (Blanchard et al, 2010, Hmelo-Silver et al., 2007). Indeed other research has shown positive results with the implementation of inquiry-orientated teaching, rather than open-ended inquiry, (Geier, 2007, Hickey et al., 2000, Hmelo-Silver et al., 2007, Kahn and O'Rourke, 2004, Lynch et al., 2005, Roberts et al., 2010) in terms of skills development, the effects of investigations on learning and scaffolding.

This literature therefore answered the first research question; What is the nature of IBSE by describing how IBSE is a constructivist process of teaching which can be carried out through many, varied, activities all with the intention of scaffolding learning.

7.1.1a: The Analytical Framework

This research also considered the nature of IBSE by using what had been learned to develop an analytical framework of IBSE. This analytical framework, see section 5.1, was developed as part of the methodology of this research as a tool to aid in the qualifying and quantifying of the various IBSE elements and observations throughout the studies. The analytical framework provided a level of consistency to this research which aid in its utility and reliability. It can be seen that the framework of IBSE had an impact throughout the various research studies carried out.

While in its planning stages the analytical framework had an impact on the textbook analysis. The 5E structure allowed specific activities described in the textbooks to be placed into one of the 5E phases. This allowed for the determination that textbooks could, in fact, be used to support IBSE, depending on the PCK and needs of a specific teacher. As part of this research, the tool also provided an easy comparison structure to compare both the discovery and intervention observations. The framework allowed the observations to identify the process of the lesson, the various activities that could be attributed to IBSE and the elements of the lessons that could be edited into an IBSE lesson. This process involved using the analytical framework to develop a coding structure within the software package Nvivo, described in

Chapter 5. This was also a positive result for the analytical framework as it was shown to be easily applicable for a coding structure to identify elements of IBSE in Irish primary science.

The analytical framework was also used as a tool to develop a template for the development of the resources to support IBSE. Here the analytical framework provided the process for lesson resources as well as descriptions for where the various activities could be placed within the process. By dividing the observed lessons into their constituent activities these could be used to develop a new lesson plan, based heavily on practice, which could account for the literature on IBSE lessons. These resources were shown to have a positive effect on the lesson processes as well as the confidence levels and attitudes of the teachers. As such, many of these positives can be applied to the underlying scaffold of the analytical framework.

The development of the analytical framework was originally intended to be an analytical tool as part of this research. While meeting this purpose, the analytical framework however, was also instrumental in providing a scaffolding framework for the development of the intervention in this research. Therefore it is suggested that further studies be carried out into the uses of the analytical framework. These studies could identify its strengths or weaknesses at identifying IBSE, its use as a lesson planning tool and provide suggestions for improvements to the framework. The research into the strengths and weaknesses of the analytical framework would mean applying it within further research studies, to teacher education and to teacher lesson observations. As it was also stated in Chapter 5, the analytical framework was developed with lesson planning theories in mind. The use of the analytical framework as a lesson planning tool is suggested. This study may employ teachers to use the framework in the development of their lessons and then to evaluate their lessons to see whether they utilised the components and processes of IBSE in their teaching. Both of these research studies could be used to suggest further developments, additions or eliminations from the framework.

7.1.2: The practice of Irish Primary science

Perhaps one of the biggest findings of this research was the discovery that there may be a form of IBSE present in schools. It must be noted that there were only four volunteering teachers in this research, however, it was discovered that all carried out inquiry in some form

in their classes. Upon the outset of this research it was assumed that there was relatively no IBSE present in classrooms throughout Ireland. Based on the generalised findings of the NCCA study it was assumed that the practice observed in the classrooms would be mainly didactic in nature (Varley et al., 2008a, 2013). What was observed however; contradicted this assumption. Of the four teachers observed in the classrooms within this study all four were found to include IBSE elements within their teaching. While one of these teachers was shown to use resources developed by the PPDS and DPS within his teaching, this still showed a teacher who is aware of the practice of IBSE and is attempting to utilise it in his classroom.

This resulted in three teachers who, using the analytical framework as a comparison, were shown to implicitly teach science through inquiry. This provided the research with an opportunity to develop the resources using the experiences and knowledge of these teachers to ensure that the resources developed were based on best practice as well as teacher experiences. It also showed that there may be a community of professional science teachers within Ireland that are enthusiastic about science teaching enough to attempt to promote the practice further for teachers who are not confident teaching science.

This research has also shown that IBSE does have a place within Irish Primary science education. All four of the teachers were shown to have positive opinions of IBSE both in terms of teaching and learning. These opinions were expressed in their PCK and feedback on the subject. It must be noted that these teachers were not approached with the aim of carrying out IBSE lessons in their classroom but have implicitly developed the skill throughout their experience. This also developed another worrying conclusion to this study. As stated by one of the participant teachers, the reasoning behind her teaching IBSE is not from the in-service awarded to her by the Department of Education. She stated that she could not even remember what was covered in this in-service. Instead she developed her awareness and practice through her own initiative and attendance at external in-service centres. It can therefore be concluded that the in-service awarded to teachers was not sufficient to promote their practice and the responsibility of adapting to IBSE is placed on the individual teachers enthusiasm for professional development. This is where research projects such as this one may play a major part in the adoption of IBSE. By ensuring that contextual factors, teacher education and teachers' experiences are considered in the development of future methods to promote IBSE, this can help teachers develop the skill of IBSE with little effort and classroom disruption accommodating for the concept of Educational Change (Fullan, 2007, Metz, 2009).

Another suggested future research area is in the development of a database or collection of teacher experiences that could be accessed by teachers to aid in their practice. It has been discussed that the addition of video elements to the resources greatly aided pre-service teachers in viewing how activities are carried out and the effects of these activities. These experiences may not be in the form of videos, as was the case of this research, but could be collected through interviews or feedback. The impact of these teacher experiences could then be evaluated efficiently as a method to develop the practice of science teaching.

One of the impacts of this study raised the question as to the role of the teacher in Irish primary science. The NCCA phase 2 report painted a picture of Irish science teachers shying away from teaching science (Varley et al., 2008a). Those that did engage in the activity were also described as didactically providing information to students rather than carrying out inquiry-orientated teaching. What was observed in the discovery observations challenged this finding, as the participant teachers were shown to be creative, enthusiastic and energetic in their science lessons.

7.1.2a: The role of the teacher

The observations described in Chapter 5 were designed to discover elements of IBSE in Irish primary school teaching. These observations identified key elements from all four participant teachers which showed that their teaching was inherently inquiry-orientated. While this was the case, the lessons were not considered entirely inquiry-orientated but the argument for didactic teaching in IBSE has already been provided by the Rocard et al. report (2007). Therefore was this research lucky enough to identify four teachers who happen to carry out inquiry-orientated teaching, from a sample group of four?

It would be far more likely that the source of the information regarding teachers in Ireland did not analyse the teachers with the same rhetoric and guidelines imposed by this research, which could have led to very general results. Indeed, it has been previously stated that the NCCA study was developed through a series of survey and interview questions (Varley et al., 2008a, 2013). It can be seen that the method followed by this research, the discovery observations, enabled researchers to identify key facets of teaching, to understand why a

teacher taught the way they did. It also allowed the research to identify when a didactic teaching method was actually a part of an overall inquiry orientated activity. It has also been described how, throughout the literature on the subject, that there is no consensus on a definition of inquiry based teaching. As a direct quote from one of the participant teachers, see Section 6.3, “The term inquiry based is new to me”. Therefore, if a teacher does not understand the term, how can they understand whether they are carrying their lessons out through inquiry or not to answer a survey question? And can Irish teachers not be considered as professional teachers if they do not understand or carry out inquiry based teaching?

The concept of a professional teacher is not “universally agreed or understood” (Goodson and Hargreaves, 1996). It would be hoped that the description of “flexible professionalism” (ibid) could be applied to teachers whereby a teacher’s practice could be developed through shared professional communities and cultures of collaboration. This sharing of ideas could lead to the development of a professional community of teachers who can effectively teach many varied contexts effectively. Based on the NCCA Phase 1 results it could be assumed that, generally, teachers are not professionals in their field (Varley et al., 2008, 2013). A professional could not be described as unconfident and avoid the teaching of their field (ibid). As described in Chapter 2, Darling-Hammond argues for the introduction of an entirely inquiry based curriculum (Darling-Hammond, 2008). It could be argued that the Irish primary science is inherently inquiry based, as it is described as experiential and emphasises the epistemology of science. The teacher guidelines also actively promote inquiry as the methodology that should be adhered to (DES, 1999a). Therefore, why, if Irish teachers have an inquiry curriculum, are they found to be not teaching through inquiry by a large population study? Is the role of the teacher not adequately described in the Teacher Guidelines?

This research attempted to support the development of an inquiry habitus (Bourdieu et al., 1978) through the implementation of a scaffold of teaching (Hmelo-Silver et al., 2007). This scaffold was shown to have beneficial results in terms of the process of lessons as well as the confidence levels of teachers, see Chapter 7. Could it then be argued that, in order to develop the generalized population of Irish teachers into professionals we must use a form of scaffolding to develop them into facilitators of learning? This research cannot answer this question but can instead offer the scaffold developed as a tool in the development of professional teachers for further research and analysis.

7.2: Contextual Factors in Irish Primary science

Research Question 2: What contextual factors play a role in Irish primary science which can affect the implementation of IBSE in the classroom?

Objective 3: Carry out a contextual exploration into current Irish primary school science

Objective 4: Identify elements of IBSE in Irish Primary Science Education through a 5E lens

7.2.1: Teacher Educators' Views

This study, described in section 4.1, provided several interesting and important outcomes in relation to teacher education. The NCCA study, which has been described as the primary source of information in this subject area, collected the views of teachers and students (Varley et al., 2008a, 2008b, 2013). While relevant, these studies only mentioned the structure of teacher education in Ireland. This study therefore developed an awareness of the opinions and views of the teacher educators in Ireland.

The results of the interviews highlighted several important points. Firstly teacher educators in Ireland were shown to have a keen awareness of the issues facing Irish primary science education. In these interviews the teacher educators recognised a divide between the issues in teacher education and teacher practice. While some issues were shown to overlap, this division provided greater depth to the opinions of the teacher educators than had been shown in the literature on teacher practice. Each of the teacher educators stated that science should be taught through IBSE, providing another element for the arguments presented in this exploratory study. The interview questions also showed how teacher educators are actively trying to promote IBSE in their lectures and the methods that they are employing to do this. These methods were compared to the analytical framework which improved its viability as a tool within this research. Finally each of the teacher educators described why they thought their institution supported science through different methods and projects. When comparing the descriptions provided by the teacher educators however a worrying picture emerged. It was described how one institution is actively seeking the development of a long term science study element as part of teacher education while a different institution was described as only having science education as part of one semester's study, a total of 16 hours throughout the entire teacher education process.

Another result of this research was the discussion on reform of teacher education. As stated in Chapter 2, the literature suggests that teacher education is ineffective if the process of learning, the pedagogies of teaching are not accounted for and that the investment of teacher educators is a key factor (Korthagen, 2010, Labaree, 1992, Lanier and Little, 1986). It is suggested that teacher education reform studies be initiated that take into account both the teaching and learning of pre-service teachers. This reform should therefore look to include elements of PCK in pre-service teacher education, rather than the concentration on pedagogical knowledge that currently exists.

The conclusions to these interviews identified that the grouping of teachers, as described in Chapter 1, may not be applicable through the development of the intervention. It was described that there were two groups of teachers, the first group had been practicing teaching upon the implementation of the curriculum and the second group were new teachers. The first group here would only have completed the Department of Education in-service course in science education while the second group would have completed a formal science education course as part of their teacher education. The result of the interviews identified that, if an intervention was to be developed as part of this research, that it could not assume that the second group of teachers all had a standard level of education and would therefore have to accommodate teachers with very different skills and knowledge sets.

7.2.2: The use of textbooks

Throughout the literature on the practice of IBSE it becomes evident that the textbook does not play a large role in constructivist methodologies (Rocard et al., 2007). The textbook was however shown to be a crutch of teaching in Irish primary science in the NCCA study (Varley et al., 2008a, 2013, Waldron et al., 2009). These studies concluded that the teachers who are heavily reliant on textbooks are teaching through didactic methodologies rather than constructivist ones. This negative opinion on textbooks was also echoed throughout the interviews with the teacher educators in section 4.1. One teacher educator even stated that he teaches that the textbook should be used as reference book only, that each student shouldn't have a textbook and the teacher should buy a few of each textbook to be used as a reference

tool. A quote from the PaP-ERs captured from the participant teachers also echoed this sentiment:

[This research] signals a move away from textbooks, which would be welcomed

(Teacher 1 Feedback on learning environment and resources)

A study was also carried out to see whether the textbook could be used as a tool in the promotion of IBSE. This study, once again, used the analytical framework to identify elements of IBSE practice and process. The results of the study proved surprising as the textbooks were shown that they could be used to support IBSE, using the definition applied in this research. It was shown that Textbook Series A and B, both contained many activities that could be placed within an IBSE process but that they lack this process in their structure. Textbook Series C emerged as promoting both a wealth of varied activities as well as displaying an IBSE process. Therefore it was the conclusion of this study that a teacher needed to understand their PCK on the subject of science education and IBSE. A teacher, armed with this knowledge, would then be able to select a textbook to use in their teaching that best complements the development of their PCK and IBSE practice.

7.2.4: Challenging Misunderstandings

Another trend in the literature, contextual analysis and findings on the practice of science teaching in Ireland was the concept of misunderstandings (Akerson, 2005). Each teacher educator, in the teacher educator interviews carried out in section 4.1, mentioned identifying and addressing misconceptions (misunderstandings) as a primary focus of their teacher education classroom. But why is there such a focus on misunderstandings and how does this impact the classroom?

Misunderstandings were shown to have implications in the development of a teacher, see Chapter 4. Expanding on the findings of the teacher education interviews, the teacher education observations found that identifying misunderstandings were a primary focus of the teacher education class. This appears to stem from a fear that, if pre-service teachers have misunderstandings that they will pass them onto the students. The teacher education observations also provided insights into how one teacher educator attempts to address misunderstandings. One example of this was when a pre-service teacher described a

misunderstanding about electrical wires. She believed that copper electrical wires contained electricity at all times, even when not attached to a power source. She thought that if she touched the copper part of a wire she would get electrocuted. This made her hesitant about carrying out investigations using wiring. The teacher educator quickly explained to the pre-service teacher that this was incorrect and that she can touch copper wire that is not attached to a power source. Another misunderstanding arose when a pre-service teacher described how she thought that the colour of the insulation on wires made the copper wire fundamentally different. In fact the propagation of misunderstandings was also shown to have an impact within the discovery observations. This was identified when a student stated that a magnet was not attracting an aluminium drink can. The teacher associated this with a weak magnet and placed the aluminium can in the “magnetic box”. The students then, during a recap, stated that an aluminium can was magnetic.

The question can therefore be asked; how does a teacher challenge misunderstandings? In terms of the teacher education lectures the lecturer, upon identifying the misunderstandings, worked with the students to challenge them. In the case of the two misunderstandings detailed above the first student’s misunderstanding was challenged by explaining the concept of electricity to the student and then showing her when a wire is not attached to a power source it can be freely touched. Challenging the second misunderstanding however; provided a difficult scenario for the lecturer as, other than displaying that the copper in all of the wires looked the same, she could not show that they were fundamentally the same. In order to overcome this, the lecturer explained the misunderstanding to the student. Therefore the methods suggested to overcome misunderstandings would be to either challenge the misunderstanding with evidence, or, if this is not possible, attempt to explain the misunderstanding.

As it was seen in the teacher observations it becomes evident that misunderstandings can be easily passed from a teacher to a student in the classroom. The evidence, based on the lecture observations, would identify that the best source to stop the progression of misunderstandings is to target a teacher. If a teacher is aware of the misunderstandings that can arise in a topic then they can actively work to address them before they develop. This results in the students instantly challenging and addressing their misunderstandings. This idea was shown to have an effect within this research. The teacher, described above, carried out a second lesson on magnetism. Using the resources developed she was aware that not all metals were magnetic,

and that aluminium cans were not magnetic. During the second class on magnetism the teacher was shown to test the aluminium can, state that it was not magnetic and place it in the non-magnetic group. This would suggest that any method of reform of practice should include highlighting misunderstandings for teachers to understand. These misunderstandings should be accompanied with methods to prove that the misunderstanding is incorrect which could, therefore, result in fewer misunderstandings being developed and propagated in science.

7.2.5: Promoting Pedagogy or Content knowledge?

Another interesting element from this research raised the question; should pre- and in- service teacher education concentrate on pedagogy or content knowledge? It was shown, in Section 4.1 that pre-service teacher educators in Ireland actively promote pedagogical knowledge in their classes as they do not have sufficient time to cover the content knowledge. The content knowledge is left for teachers to develop themselves as a form of self-study. Looking at the time allotted to science in-service, awarded by the Department of Education in Ireland, would suggest that the two days provided could not have provided a teacher with the content knowledge required to teach a subject to eight different class levels.

In an ideal situation there would be enough time to provide a teacher with both the pedagogical skills and the content knowledge required to teach science to all levels in primary schools, a sentiment echoed by the teacher educators. This however cannot be the case. There is however, one solution that could be offered. It has been argued that the Pedagogical Content Knowledge of teachers is a key factor in their development, in how they teach and how they can adapt to new teaching scenarios (Shulman, 1976, 1977, Loughran et al., 2000, 2001). Therefore it could be argued that instructing a teacher in how to develop their own PCK would provide the teacher with the knowledge of how to develop their pedagogical practices, how to develop their content knowledge and how to develop an awareness of their context. This would place the emphasis of learning onto the teacher, but would provide them with the knowledge and tools necessary to develop their PCK to a level where they are a confident and competent science teacher in Ireland.

The analysis of the PCK as part of this research provided many insights into the benefits of using PCK, and specifically the CoRes and PaP-ERS tool. The participant teachers initially described themselves as unconfident in the subject of magnetism. The focus group to develop big ideas however showed teachers, who not only have a relatively strong content and pedagogical knowledge of magnetism but also a contextual awareness. The CoRes tool has been mainly used to assess second level teachers PCK. This research applied the same principles to primary level and the results identified more holistic views by the teachers compared to their second level counterparts. These teachers wished to promote concepts such as wonder and discovery over content. Therefore not only has it shown that PCK can be applied to this level of education but that it may provide interesting comparisons between the values of primary school teachers compared to second level teachers.

7.3: The Development of a form of Intervention

Research Question 3: What kind of intervention can be synthesised to support and encourage the ideals of IBSE while accounting for the issues and factors in Irish primary science education?

Objective 5: Devise a form of intervention to address the issues in science education and to support IBSE

Chapter 6 detailed the development and evaluation of an intervention which aimed to promote IBSE. This intervention was developed on sound educational ideals based in the literature, accounted for teacher education issues and included the experiences of practicing teachers across different contexts in Ireland. This ensured that the learning environment and resources were unlike any other resource available to Irish primary school teacher today. The learning environment was developed based upon current research in science education. This ensured that teachers accessing the learning environment were provided with a window into current research and thinking. These resources were easily accessible for teachers, included consistent structures for ease of use, aided in the development of lesson planning techniques and contained videos and experiences of practicing teachers. The resources also aimed to provide teachers who were not confident at teaching with resources in the curriculum strand of Energy and Forces. This, as described in Chapter 1 and 3, would ensure that the resources

accounted for the areas of the curriculum which have been identified to be the greatest challenge for teachers in Ireland (Varley et al., 2008a, 2013)

It can be seen that the resources developed had a significant impact on the teaching of the participant teachers. In the discovery observations there were elements of a process of scaffolding observed. Within these observations, generally, there was little emphasis placed on the engagement section of the lesson. This was particularly evident with Teacher A and B who appeared to be impatient to progress through the lessons and supply students with answers whenever there was a delay. Teacher C appeared to place more of an emphasis on engagement and recalling prior knowledge than the other teachers. The majority of the discovery observations consisted of engagement activities. These activities consisted mainly of teacher directed activities but still had elements of knowledge construction. Teacher B's observations had a concentration on the elaboration element of her lessons which asked the students to apply knowledge rather than to explore it. Within the intervention observations the lesson process was much clearer and well defined. Teacher A and B appeared to place more of an emphasis on identifying prior knowledge and appeared much more patient in this section. There was a roughly equal weighting of the engagement and exploration by these teachers in the intervention observations. This is paired with more of an emphasis on elaboration by Teacher A. Also there is a significant shift between the teachers explaining a concept to the students being asked to explain a concept in the explanation phase. Teacher C's lessons did not change in structure drastically, but he appeared to place more emphasis on exploration rather than the engagement phase. It is therefore the conclusion that a professional development tool that concentrates on scaffolding a process of education may have an effect on the teaching and learning of science. It can also be concluded that the teachers were able to develop knowledge about their teaching process from the material presented to them in order to inform their teaching. This is particularly notable with the results from Teacher A and C who had not encountered the lesson magnetism previously. These teachers were able to access the resource, plan a lesson using set activities that met the aims of their lesson and account for their own classroom context to the lesson.

As this research was developed as an exploratory study the full impact of the learning environment and resources was never intended to be fully evaluated. Instead through a series of observations, the feedback and opinions of the participant teachers as well as the development of the PCK of pre-service teachers the impact of these resources are shown to

have a positive influence on teaching through IBSE. It is therefore proposed that further evaluation be carried out into the effects of the learning environment on the teaching of science. This evaluation could concentrate on the development of teachers PCK, as described by the study carried out with pre-service teachers. The analytical framework could also be used to analyse lessons carried out using the resources to describe whether a large number of teachers teach through inquiry when using the resources developed. Finally the teachers' knowledge of the practice of IBSE can be identified after using the learning environment through questionnaires and comparison with the analytical framework.

These processes of evaluation may allow for further observations of the practice of primary school teaching to be carried out. The second recommendation for future studies based upon this research is to expand the resources into other subjects of the curriculum. If further resources are to be developed they should utilise the method presented on the development of the current selection of resources. This will ensure consistency in approach and make them easier to use by teachers. It would also be recommended that any resources developed be based on observations of lessons, with video recordings.

7.4: Other Conclusions

7.4.1: PCK and CoRes

One final conclusion that can be made from this research was developed from the study of the concept of PCK and the use of the CoRes and PaP-ERs. It was shown in Chapter 5 that one of the exploratory elements of this study was to identify if the CoRes could be used as lesson planning tool. This study aimed to use the benefits of reflection, which are embedded in the CoRes tool and to place them into lesson planning to aid a teacher to develop more meaningful lessons. The result of this study concluded that the CoRes tool was not useful as a lesson planning tool for several reasons. It was concluded that the CoRes tool did not meet the lesson planning requirements such as accounting for pedagogical practices and the organisation of lessons. The CoRes presented teachers with an analysis of their thoughts on the lesson they were going to teach rather than a plan of approach for their teaching. While the CoRes was not developed with lesson planning in mind (Loughran et al., 2000, 2001) it is not a failing of the CoRes but rather a confirmation of the usefulness of the CoRes. Therefore

another future research project is suggested with could analyse the development of a lesson planning tool that maintains lesson planning structures, but requires a teacher to evaluate their thinking on their practice like the CoRes tool.

It was also discovered, throughout the course of this research that four of five science teacher educators in Ireland concentrate on promoting the pedagogy of IBSE. While this may be appropriate to the amount of time allotted to science education in Irish institutions, it may result in the findings of the NCCA study where teachers with low content knowledge may have low confidence levels (Harlen, 1997, Varley et al., 2008a). This conclusion then shows there is a need to promote both content and pedagogical knowledge within science teacher education. While the structure of teacher education will only be changed by the particular institution the concept of PCK is offered as a tool in teacher education. By making teachers aware of their levels of PCK it will aid them in identifying the elements of their knowledge that they need to develop. Knowledge of this can then be used to provide students with areas and resources which target their lacking area of PCK to improve their teaching. As PCK has been linked to confidence levels, explicitly developing PCK as part of teacher education may aid in the development of teacher confidence levels (Harlen et al., 1995, Murphy et al., 2007, Varley et al., 2008a).

7.5: Contribution to New Knowledge

This research has made several contributions to new knowledge in the field of Irish primary science education. As it was discussed in Chapter 2 and 3, this research marks the beginning of the concatenation process for studies into IBSE in Irish primary science. As such there were several studies which all contributed to new knowledge in various ways in this research. The studies include the teacher educator interviews, the textbook analysis, the IBSE analytical framework, the discovery and intervention observations, the development of the intervention, the snapshots of PCK of primary school teachers and the snapshots of PCK of pre-service teachers. It could be argued that these studies only began to uncover data within each of their areas but, as discussed previously, this research is described as an exploration. It was therefore never a goal to analyse each research project thoroughly but to discover whether there were elements that required further study and development.

The first addition of new knowledge to the field is the opinion and thoughts of teacher educators. As the primary source of knowledge on the subject of Irish primary science the NCCA phase 1 and 2 study did not analyse teacher education in depth. Teacher educators are key stakeholders in the development of teachers and, as described in the literature review, their methods may have effects on the teachers' confidence and competence. The teacher educator interviews discovered that teacher educators generally agree on the issues currently facing Irish primary science education. The teacher educators were also in agreement that Inquiry should be promoted in science education and that their respective institutions, generally, appreciate science. These results, while not surprising, may identify this group as the subject of further study to identify the ideas and thoughts that they have to address some of the issues in science education. As important stakeholders in their field, their support of inquiry may also be a sign that the NCCA should push forward with the application of inquiry in Irish science classrooms.

The next subject of new knowledge was the textbook analysis as evidenced by the article which was published on this study (Dunne et al., 2013). This study identified that textbooks may be used in the support and promotion of IBSE. Recalling the teacher educator interviews, there was a negative connotation placed on the textbooks by one of the teacher educators. Indeed, it was shown with the small sample set analysed, that the textbooks vary widely in approach, ideals and content. This imbalance could be resolved by the teacher if they chose to use a textbook that contains elements of their PCK in which they are lacking. Then the textbook can be used to support the teacher in developing interesting, inquiry based lessons.

The next addition of new knowledge that this research offers is the IBSE analytical framework. This framework, described in Chapter 5, was formed from the literature review and textbook analysis and served to be an analysis, scaffold and planning tool throughout this research. The analytical framework is presented as a new idea to the field for further study to assess its effectiveness and to improve upon its usefulness. The framework aided this research in maintaining a consistent approach to analysis and aided in validity and credibility.

While the NCCA phase 1 and 2 studies did gather data on Irish primary schools they did not observe the practice of teaching. The NCCA data was captured through student and teacher questionnaires which may have been open to interpretation or confusion. Therefore the

observations that were captured in this research are offered up as new knowledge. This methodology enabled intricate observations of the practice of science teaching. Throughout the research, fourteen observations were captured and each of them were analysed, in depth, for the approaches and methods of primary school teachers. While it cannot be said that these observations create a complete picture of Irish primary science they did aid in understanding how the participant teachers taught science. The method also enabled the observations to be used within the research participant group as professional development tools.

The intervention is offered as new knowledge to this field. Currently, the primary sources of internet-based resources for teachers are hosted by the Primary Professional Development Service (PPDS) and Discover Primary Science (DPS). While these resources are useful, they provide recipe based resources which aim to capture attention and promote knowledge but do not promote the development of the teacher. The intervention therefore is unique in that it offers context specific, professional development to teachers, which was developed with the aid of practicing teachers rather than by a third party.

Finally this research added the field of Pedagogical Content Knowledge (PCK). Previously the CoRes tool had been used mainly to take snapshots of second level science teacher's PCK. This research used the CoRes tool in the unfamiliar context of primary science education. It cannot be stated that the CoRes tool had not been used in primary level prior to this research, but there were no published studies of Irish primary school teachers PCK. Therefore this research showed that the CoRes tool could be used to obtain snapshots of primary level PCK as well as second level. The NCCA studies alluded to low PCK levels of primary school teachers but there have been no further studies into this. This research therefore provides a unique insight into the PCK of the participating teachers. The PCK levels were found to be developed in the participant teachers with them describing areas of content knowledge, different pedagogical practices and having an in-depth knowledge of their teaching contexts. The research cannot claim that these were high levels of PCK but, based on the NCCA studies; it was assumed that these teachers would not provide such developed answers. The study into the PCK of pre-service teachers also showed that while pre-service teachers were not as detailed in their responses as the teachers, there were a surprising amount of parallels in the two datasets.

All of these studies contained unique elements that had not been carried out or published in the Irish context. The combination of the methodology and results of this research are therefore offered up as new knowledge to enable the concatenation process of research into IBSE in Irish primary science education.

7.6: Research Conclusion

This research aimed to explore IBSE in Irish primary science and through a thorough and wide ranging methodology many conclusions were developed which were based on educational literature the experiences of teacher educators, and the experiences of teachers themselves. This research therefore described both the nature of IBSE and captured snapshots of the practice of science teaching in Ireland. It also considered many contextual factors that inform and influence science education. Finally this methodology allowed for the development of a form of intervention which utilised all of the above to promote IBSE practice and to evaluate the impact of such research on the practice of teachers. It aimed to support teachers adapting to science teaching through inquiry and, hopefully, create more confident and more competent science teachers.

7.7: Personal reflection

This research has enabled me as a researcher to experience primary science, a subject I didn't even know existed until I began studying it. Upon studying the curriculum, its aims, objectives and content I came to understand that primary school science was also inherently inquiry based in its nature. I applauded this as a second level teacher, as it should ensure that students have an inquiry skill set upon beginning their second level education. It was therefore dismaying when I encountered the NCCA study which found teachers having difficulties in the new subject, that they were still using traditional methodologies and that in certain cases they were avoiding teaching science altogether (Varley et al, 2008a. 2008b, 2013).

As my background is in science education, rather than research, the entire experience of research was new to me. I have to admit I found it difficult to adapt to as it often meant working on my own initiative without any clear indication of what I would find. My development, as a researcher is clear to me however. I realise now that I was developing

skills that would aid me throughout my career, whatever form it would take. These skills of decision making, questioning and adapting to situations will be helpful wherever I go from here. I look back on the process of this research and, only through writing it down can adequately link all of the various studies together. I think that that is the greatest personal development that I have achieved through this research; the ability to consider every facet of a subject, in an effort to develop a strong and clear understanding of it.

The research process was not without its faults however. After one full year of research, funding and staffing issues caused the entire research to shift focus to the IBSE exploration. I also had many difficulties identifying participant teachers. I will also always recall contacting a school on the phone and hearing the quote:

No, I [The principal] don't think we will participate, our students aren't very bright this year so we have decided to concentrate on physical education and art with them

This was soul destroying to hear, especially as an educator, that a principal had given up on all of his students and he was dictating their futures through arbitrary decisions. Various holidays, breaks and mid-terms also had a major impact on the research schedule and sometimes delayed lesson observations by as much as 3 months.

There comes a point in any project where a researcher must decide whether to continue or not. The large amount of difficulties described above probably should have made the decision to quit for me. However; there was one element of this research which helped me not to quit. The support of the participant teachers encouraged me to follow through with the research. Not only that, but for them to allow me, a stranger, into their classroom to observe and utilise their lessons was greatly appreciated. Observing classroom lessons is an experience like no other. One cannot truly understand the joy of teaching until they get into a classroom.

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Appendices

Appendix A: Pre-Lesson Tool



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Promoting Inquiry Based Learning in Primary School Science through Inquiry Based resources

Pre-Lesson Exemplar teacher Observational Protocols

27/04/2009

Section 1: Pre-Lesson

Pre-Classroom interview Questions:

Background information:

Teacher Name: _____

Date of Interview: _____

School: _____

Time of Interview: _____

Teacher No. _____

Questions:

- What has this class been doing in science recently?
 - What Area are you working on
 - What instructional methods are you using
- What do you anticipate doing in the science class on the day that I will be observing
 - What do you hope the students will learn as a result of the work you have planned
- What is the next step for the class
- Is there anything in particular that I should know about the group of students that I will be observing
 - Learning styles

CoRes: Content Representation Tool (Loughran, Mulhall, and Berry, 2004)			
Ideas/Concepts:	Idea 1	Idea 2	Idea 3
1. What you intend students to learn about this idea			
2. Why is it important for students to know this			
3. What else you know about this idea (that you do not intend students to know yet).			
4. Difficulties/ limitations connected with teaching this idea			
5. Knowledge about students' thinking which influences your teaching of this idea			
6. Other factors that influence your teaching of this idea			
7. Teaching procedures (and particular reasons for using these to engage with this idea)			
8. Specific ways of ascertaining students' understanding or confusion around this idea (including likely range of responses).			

Extra Information section:

(To be completed by the researcher)

Please Circle:

Has the teacher added any extra lesson plans? Yes No

Was there any extra resources used in the class? Yes No

If yes please list below:

Are there any other comments in relation to the lesson planning section?

Appendix B: During Lesson Tool



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Promoting Inquiry Based Learning in Primary School Science through Inquiry Based resources

During Lesson Exemplar teacher Observational Protocols

27/04/2009

Section 2: During lesson

Adapted for the Local Systemic Change observational protocol

Background information:

Teacher no. _____ Date _____
 Time: Start: _____ End: _____
 Subject: _____ Topic: _____
 Class: _____ Observer: _____

Section One: Contextual background and activities:

I. Context of the Classroom:

- A. What is the total no. of students: _____
- B. What is the teachers' Gender: m f
- C. If applicable, what is the teacher aide's (SNA) gender m f
- D. Rate the adequacy of the physical environment:
- Classroom Resources:
- | | | | | |
|-------------------|---|---|---|-------------------|
| 1 | 2 | 3 | 4 | 5 |
| Sparsely equipped | | | | Rich in resources |
- Classroom Space:
- | | | | | |
|---------|---|---|---|----------------|
| 1 | 2 | 3 | 4 | 5 |
| Crowded | | | | Adequate Space |
- Was the lesson carried out in a laboratory: Y N

II. Purposes of lesson

- A. What was the major content area(s) of this lesson or activity:
- _____
- B. Indicate the Primary intended purpose(s) of this lesson or activity based on the pre- and/or post- observation interviews with the teacher.
- Identifying prior student knowledge
 - Introducing new concepts
 - Developing analytical understanding
 - Reviewing science concepts
 - Developing problem-solving skills
 - Learning science processes or procedures
 - Learning vocabulary/ specific facts
 - Developing appreciation for CoRes ideas in science
 - Developing students' awareness of contributions of scientists

- Assessing student understanding

III. Resources:

A. Is this lesson based on instructional materials Y N
 If so what materials:

B. Did the teacher use the materials described in the lesson plan: Y N

IV. Classroom Instruction

A. What were the major way(s) in which student activities were structured.

- As a whole group ▫ As Small Groups ▫ As Pairs ▫As Individuals

B. Indicate the major way(s) in which students engaged in class activities.

- Entire class was engaged in the same activities at the same time
- Groups of students were engaged in different activities at the same time

C. Indicate the major activities of students in this lesson.

- Listened to a presentation
 - By teacher ▫ By Student ▫ By Guest

Guest: _____

- Engaged in discussion/ seminar
 - Whole group ▫ Small groups/ pairs

- Engaged in problem solving/ investigation:
 If so How: _____

- Engaged in reading/ reflection/ written communication
 - Read about science
 - Answered textbook/ worksheet questions
 - Reflected on readings, activities, or problems
 - Individually ▫ As groups
 - Prepared a written report
 - Wrote a description of a plan, procedure, or process
 - Wrote reflections in a notebook or journal

- Used technology/ AV resource
 - To develop analytical understanding
 - To Learn or Practice a skill
 - To collect data
 - As an analytic tool
 - As a presentation tool
 - For word processing or as communications tool

- Other activities
 - Arts and crafts
 - Listened to a story
 - Wrote a poem or story
 - Other (please specify) _____

Comments and Notes about the class:

Appendix C: Post Lesson Tool



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Promoting Inquiry Based Learning in Primary School Science through Inquiry Based resources

Post Lesson Exemplar teacher Observational Protocols

27/04/2009

Section 3: Post Lesson

Rating system adapted from the Local Systemic Change Protocol

Post-Classroom interview Questions:

Background information:

Teacher Name: _____

Date of Interview: _____

School: _____

Time of Interview: _____

Questions:

- Did this lesson tell you anything about what your students are learning and still need to learn in science?
 - How do you plan to further assess the students' learning
- What challenges have you faced in encouraging your students to be actively engaged in this science class?
 - How have you approached these challenges?
- What is the next step for this class?
 - Intent to cover rest of lesson if area missed?

Continue as planned

Post Lesson Rating system:

Note: 1: Not at all

5: To a great extent

6: Don't know

7: N/A

I. Design

- | | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1. The design of the lesson incorporated tasks, roles and interactions consistent with investigative science | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2. The design of the lesson reflected careful planning and organization | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 3. The instructional strategies and activities used in this lesson reflected attention to students' experience, preparedness and/or learning styles | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 4. The resources available in this lesson | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

contributed to accomplishing the purpose of the instruction

5. The design of the lesson encouraged a collaborative approach to learning 1 2 3 4 5 6 7

6. Adequate time and structure were provided for “sense-making” 1 2 3 4 5 6 7

7. Adequate time and structure were provided for “wrap-up” 1 2 3 4 5 6 7

8. Design for instruction takes into account what transpired in the lesson 1 2 3 4 5 6 7

9. _____ 1 2 3 4 5 6 7

Comments:

II. Implementation

1. The instruction was consistent with the underlying approach of the NCCA 1 2 3 4 5 6 7

2. The instructional strategies were consistent with investigative science 1 2 3 4 5 6 7

3. The teacher appeared confident in their ability to teach science 1 2 3 4 5 6 7

4. The teachers’ classroom management Style/ strategies enhanced the quality of the lesson 1 2 3 4 5 6 7

5. The pace of the lesson was appropriate for the developmental levels/ needs of the students and the purposes of the lesson 1 2 3 4 5 6 7

6. The teacher was able to “read” the students’ level of understanding and adjusted instruction accordingly 1 2 3 4 5 6 7

7. The teachers’ questioning strategies were likely to enhance the development of student analytical understanding/ problem solving 1 2 3 4 5 6 7

8. The lesson was modified as needed on teacher questioning or other students assessments 1 2 3 4 5 6 7

9. _____ 1 2 3 4 5 6 7

Comments:

III. Science Content

1. The science content was significant and worthwhile 1 2 3 4 5 6 7

2. The science content was appropriate for the developmental level's of the students in this class 1 2 3 4 5 6 7

3. Students were intellectually engaged with important ideas relevant to the focus of the lesson 1 2 3 4 5 6 7

4. Teacher-provided content information was accurate 1 2 3 4 5 6 7

5. The teacher displayed an understanding of science concepts 1 2 3 4 5 6 7

6. Science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation analysis and or proof/ justification 1 2 3 4 5 6 7

7. Elements of science abstraction were included when it was important to do so 1 2 3 4 5 6 7

8. Appropriate connections were made to other areas of science and/or real world concepts 1 2 3 4 5 6 7

9. The degree of "sense-making" of science content within this lesson was appropriate for the developmental levels/ needs of the students and the purposes of this lesson 1 2 3 4 5 6 7

10. _____ 1 2 3 4 5 6 7

Comments:

IV. Classroom Culture

1. Active participation of all was encouraged and valued 1 2 3 4 5 6 7

2. There was a climate of respect for students' ideas, questions and contributions 1 2 3 4 5 6 7

3. Interactions reflected collegial working relationships among students 1 2 3 4 5 6 7

4. Interactions reflected collaborative working relationships between teacher and students	1	2	3	4	5	6	7
5. The climate of the lesson encouraged students' to generate ideas, questions, conjectures and/ or propositions	1	2	3	4	5	6	7
6. Intellectual rigor, constructive criticism and the challenging of ideas were evident	1	2	3	4	5	6	7
7. _____	1	2	3	4	5	6	7

Comments:

V. Overall ratings of the Lesson

A. Impact of instruction on students' Understanding of Science

Note: 1 to 5 is from negative to positive. 3: Neutral, 6: Don't know, 7: N/A

1. Students' understanding of science as a dynamic body of knowledge generated and enriched by investigation	1	2	3	4	5	6	7
2. Students' understanding of important science concepts	1	2	3	4	5	6	7
3. Students' capacity to carry out their own inquiries	1	2	3	4	5	6	7
4. Students' ability to apply or generalize skills And concepts to other areas of science, other disciplines and/ or real-life situations	1	2	3	4	5	6	7
5. Students' self-confidence in doing science	1	2	3	4	5	6	7
6. Students' interest in and/or appreciation for the discipline	1	2	3	4	5	6	7

Comments:

Extra Information

(To be filled in by the researchers)

Has the teacher added any extra lesson evaluations?	Yes	No
Was there any extra resources used in the class?	Yes	No

If yes please list below:

Are there any other comments in relation to the lesson evaluation section?

Appendix D: Introduction to Reflection

Topic: Reflection

Class: 5th

Duration: Approx 40 mins

Equipment needed: Torches, concave/ convex mirrors or Spoons, Planar mirrors, worksheets.

Subject Links: Mathematics; centre of symmetry.

Rationale: In this lesson students will be introduced to the topic of reflection. Using everyday objects students can investigate mirrors and light in an effective manner. A teacher must ensure that they have covered the ideas of light sources and reflectors, as well as light travelling in straight lines, before trying this lesson. This lesson can be combined with a discussion on centre of symmetry in Mathematics. A teacher does not have to do all of the activities in this lesson but instead choose one or two from each 5E phase.

Engage Phase:

Class: 4th /5th

Duration: 5 - 10 mins

Rationale: In the Engage Phase of this lesson students recap their previous lessons on light. Questioning and discussion are used to extract out a students' previous knowledge. Students will also be introduced to the planar mirror where they can see how light is reflected. This basis will then be expanded in the explore phase.

Discussion

In order to introduce the topic of reflection a discussion can be had on what are sources of light and what reflectors of light are. This discussion relies on the students knowing what reflection is (The bouncing of light off a surface). From here the teacher can introduce several examples and ask the students whether they are sources of light or reflectors of light. Some questions that may start the discussion are:

- What do you know about light?
- What do you know about reflection?
- What is reflection?
- What causes reflection?
- Give some examples of where you would see mirrors.

Students may not know the difference between a light source and reflector. In order to explain this to them a teacher could turn on an off the lights to show a light source. Then place a mirror (if they know a mirror reflects light) in a dark room to show that it doesn't light the room by itself.

Sorting out activity

This activity can be done by either placing pictures on the board and asking questions or handing out a worksheet. The activity involves students describing whether an object is a source of light or a reflector of light. Alternatively pictures of: the sun, the moon, a torch, a mirror, a candle and a light bulb etc can be used.

The difference between a reflection and the opposite:

In this activity the students will learn that the reflection in a mirror is not the same as an opposite. Dividing students into groups of two, one student must first copy the other student. For example if one student raises their right hand the other must raise their right hand. Once the students have tried this ask one of the students to become a reflection. They should find that when they raise their right hand the other student raises their left, thus emphasizing the difference between reflection and opposite. The video below shows a teacher demonstrating the opposite to the students.

Explore Phase:**Class:** 4th /5th**Duration:** 5 -10 mins

Rationale: In this Explore phase students will investigate various types of mirrors and the reflections they produce. As these are investigations, students will not be given any prior information about what to expect but must record the results for the explain phase later on.

Planar Mirror activity:

In this activity students should find out how light travels when it is bounced off a planar mirror. Give the students a small torch, a planar mirror and a few sheets of paper. Ask the students to bounce the light from the torch off the mirrors. If students do this on a table with the planar mirror perpendicular to the table they should be able to draw the path of the light as it gets reflected off the mirror. This highlights how light travels in straight lines and how light reflects off planar mirrors. Older students may be able to compare the various angles of the incoming light with the reflected light to the mirror to discover if there is any link between the angles of reflection and the angle from the source.

Target Activity:

In groups of 3 or 4 students must bounce light off mirrors to hit a target. In the group one student must hold a torch and the other students hold the mirrors. In order to do this the students must first plan how they are going to hit the target using all of the mirrors. This will show the teacher whether the students know that light travels in straight lines or not. In the video below the teacher does not use a target however, the concept is still seen.

Centre of Symmetry:

Print out the worksheet below containing all of the letters in Capitals. Get the students to find which letters maintain their shape when there is a mirror placed half way down and across the letters. Letters with a centre of symmetry such as B, O and K amongst others should be found by the students. The students should also investigate which letters have a centre of symmetry.

Write a secret message:

Using the worksheet below ask students to write a short secret message. Then use the mirror to create its reflection. Students must try to then work out what the message says looking at it, and finally decipher it using a mirror to see if they were correct.

Concave Mirrors:

Give the students a clean tablespoon. Using the spoon the students must draw or describe their reflections when they have the upper side (or concave part) facing them at arms length. They must then describe their reflection when the same side is close to their face.

Convex mirrors:

Ask the students to turn the spoon around so the convex part is facing them. Ask the students to discuss their reflections in the concave mirror when it is close to their face and when it is at arms length and to draw the results.

Comparing spoons:

Once the students have discovered what concave and convex mirrors are, a teacher could ask them to investigate the differences between soup spoons and table spoons using the methods above. This should highlight how the shape of the mirror affects the reflection. The video below shows a teacher explaining the spoon activity to her students and getting some responses about the students' reflections in the spoons.

Explain Phase:**Class:** 4th/5th**Duration:** 10 mins

Rationale: In the Explain phase students are asked to find out for themselves the names of the two types of mirror in a spoon.

Research:

Ask the students to describe the two types of mirror that they have used. This research can be carried out using their textbook or an information sheet provided by the teacher. This information sheet should describe the types of reflection that is produced by both types of curved mirror. The students must then link their descriptions to the type of mirror that was used to produce them. Here the students should find out the terms concave and convex mirrors, and that the inside of a spoon is concave while the outside is convex.

Evaluate phase:**Class:** 4th/5th**Duration:** 5mins

Rationale: In this phase questions and a write-up are used to assess whether the activities have produced meaningful learning during the lesson. This phase may also highlight any misunderstandings that students could have developed throughout the lesson.

Questions:

Once the previous activities have been completed a teacher can ask students questions to evaluate their learning. Asking questions about the uses of mirrors, where are mirrors found, what type of mirrors do you use every day and why, can all highlight the various effects of mirrors in reflection.

Write up of activities

Students can evaluate their learning by writing up the experiments that they have carried out including sections on the various activities that they carried out and the results of the experiments.

Appendix E: Magnetism

Strand Unit: Energy and Forces

Class: Elements of this lesson can apply to all class levels.

Duration: A complete lesson should take approximately 1hr, however a teacher carrying out all of the activities on this page may require up to 2 hours.

Equipment needed: 2 Shoe boxes, various magnetic and non-magnetic items, magnets, Aluminium drinks can, Dog Food tin, Sheet of Cardboard, Compasses, Worksheets/ Copybooks.

Rationale:

In this lesson students will investigate the use of magnets through structured investigations and play. There are several activities listed on this page. Some of these activities show similar ideas and therefore a teacher can select activities that cater for their own lesson objectives. The activities are divided into their 5E category to help in the planning of a lesson. It is recommended that a teacher select at least one activity from each 5E stage for a complete lesson. If time allows, more than one activity per phase can be used, however a teacher should select ideas which show different concepts. If students appear not to understand an activity then an alternative activity may make the concept clearer.

At the conclusion of this lesson students should have covered:

- An introduction to magnets
- An investigation into items that are magnetic
- An investigation into magnets
- Ways to sort magnetic and non-magnetic items
- Materials magnetism can work through

Engage Phase:

Class: All **Duration:** 5 - 10 Mins

Rationale: The engage phase can be used to introduce the topic of magnetism and magnets to the students, students should have encountered magnets at some stage so should be able to come up with words associated with them. If they are having trouble guiding questions could be used such as; what do they do, what do they look like, where do you see them?. This section mainly comprises of discussions and questions aimed at accessing the students' prior knowledge. This section can also highlight any misunderstandings that students may have (see misunderstandings), the teacher can then adjust their lesson to challenge the misunderstanding.

Assessing Prior Knowledge:

Ask the students to write down 5 words that they associate with magnets. Students can do this individually or in groups of 2. The object of this exercise is to see what students associate with magnets. Once completed the teacher can write the words on the board to compare them and get the students to describe why they associate a word with magnets.

Following on from this a teacher may ask for a list of items in the room that they believe are magnetic and non-magnetic. This list may form part of the investigation later on as students can test out the items they believe are magnetic or non-magnetic.

Some of the words that were given during the pilot scheme were: metals, glue/ stick, fridge magnets, physics, cutlery and paper clips. The students concentrated on items that were magnetic instead of descriptive words of magnets. If this occurs a teacher can then ask the students to divide the words they have given into magnetic and non-magnetic.

Discussions and Questions:

In this section students are asked leading questions about magnetism and what they know about it. Sample questions are listed below. These questions aim to engage the students with the topic and extract out their previous knowledge and misunderstandings on magnetism.

- What are magnets? or What do magnets do?
- Where do you find magnets?

It would be expected that students would know that magnets push and pull metals. This would be sufficient background knowledge to move onto the next question. The students should be aware of everyday magnets such as those found on a refrigerator. They may also be aware that magnets are found in the doors of refrigerators and ovens. Younger students would not be expected to know the terminology such as: attract, repel, magnetic and non-magnetic. These terms can be introduced while carrying out the investigations below.

Explore Phase:

Class: all

Duration: 5 - 15 Mins

Rationale: In the Explore phase students will build on what they have discussed and mentioned in the engage section. It is important that any misunderstanding that has been identified in the engage section be addressed here. The time these activities take will depend on the amount of objects the students are investigating. Young groups of students should have more, varied items to give them a complete picture of what items are magnetic or non-magnetic.

Investigation into magnetic materials:

This investigation can be done in a number of ways. The investigation involves using many everyday items and having the students predict whether they will be magnetic and then test their prediction. These items can also come from the lists they have created in the engage section. Either give groups of students several items or have the items in front of the class. Ask the students to predict whether the items they have been given are magnetic or not. Let the students test their prediction with magnets. Have the students sort out the items into the two groups, one with magnetic items and one with non-magnetic items. If the whole class is doing the investigation then the teacher can lay down hula-hoops in the centre of the room to divide out the magnetic and non-magnetic items. This provides a large area for the students to see, divide up and compare the two types of objects. Students can be broken into groups or work individually. Students may also write up the experiment as they do it (see Evaluate Section).

Investigation into magnets

In this investigation students will examine the properties of magnets. To do this the teacher will require several types of magnets. More information on the various types of magnets can be found here. Students should investigate two similar types of magnets first to find out whether the size of the magnet affects the distance the magnet pulls at. The distance can be measured by placing a magnetic item from the previous investigation at the 0 point on a ruler. Then the students can gradually reduce the distance of a magnet to see at what distance the item gets attracted to the magnet. From here different types of magnets can be used to see whether similar size magnets made out of different materials can increase or decrease the distance at which the object is attracted to the magnet.

One way to promote the concept that the power of a magnet is not related to its size is to first test a number of magnets to ensure that one group does show that a smaller magnet is more powerful than a large

magnet. Attempting this activity with a class where all of the results show that larger magnets are more powerful will develop a misunderstanding for the students.

Explain Phase:

Class: all **Duration:** 10 Mins

Rationale: In this section the students will explain what they have learned from the previous two sections. This should provide a picture of how much the students have taken in about magnets and highlight possible misunderstandings that they may have developed.

Description of magnetic materials:

Ask the students to describe any similarities between the magnetic or non-magnetic items. A teacher may highlight any objects which went against students predictions and ask the students to explain why in this section. The students may also record the types of material that was magnetic and non-magnetic.

Elaborate Phase:

Class: All (Activities on Magnetic fields should be kept to higher level classes) **Duration:** 10 - 40 Mins

Rationale: This section builds on the basic knowledge of magnets and develops it further for the students. This section consists of simple short activities that are designed to highlight a particular phenomenon. Each activity should take no longer than five minutes to carry out and explain. As a facilitator of learning the teacher should supply the students with any equipment need and ask them how they would prove the idea described. In order to aid the teacher some scenarios that can be used have been described.

Various types of metals:

In the elaborate phase ask the students to predict whether an aluminium can (eg. Coke) and a Tin can (eg. Dog food can) are magnetic. Ask them to test the hypothesis. The students should find that the aluminium can is not magnetic. Ask them why this is the case. Should students have difficulty with this the teacher can explain how not all metals are magnetic.

Magnetism can pass through paper/ card/ wood:

Take a sheet of cardboard and a paper clip. Place the card between the magnet and paperclip. Show the Students the paperclip on the cardboard and move it around the surface of the card. This can also be done with a paperclip on a desk. A real world use of this technique is when people use magnets to attach notes to refrigerator doors. This can be explained to the students to improve the understanding of the concept. If the students are trying to move a paperclip through wood they could add more wood between the paperclip and magnet to test whether this affects how easy it is to move the paperclip.

Magnetism can work in water:

Ask the students to test whether magnetism works in water. A simple method to do this is to place paper clips in a glass of water and then ask students to extract the paperclip. Students should put the magnet in the glass to see whether the paper clips are still attracted.

Magnetism can pass through glass:

Put some paper clips in a glass of water and ask the students to remove them without touching the water with their hands or the magnet. Get a student to place the magnet at the bottom of the glass and then slowly bring it up the side of the glass removing the clips from the water

Magnetism can be used to separate magnetic and non-magnetic materials:

Spill the paper clips on the table and ask a student to try pick them up and then ask if there was an easier way of doing this. Spill the paper clips again and have one student use the magnet to pick them up. This can be used to show the idea of a magnetic field or sorting out non-magnetic items from magnetic ones (for example if you mixed paper clips with shredded paper etc)

Some metal objects can become magnetic:

Ask the question "Is a paperclip magnetic?". Attach one paperclip to the magnet. Use the end of the paperclip (not the magnet) to try and chain several paper clips together.

Magnetic Fields:

Higher Classes should study magnetic fields and their effects. One simple investigation to highlight magnetic fields is to use a compass. Firstly collect all magnets from the students. Ask the students to find the direction that north is in using the compass. Then give the students magnets and ask them what effect the magnet has on the compass. The students should realise that the material in the compass is magnetic and that it is responding to a larger magnetic field when no near a magnet. They should understand that there is a magnetic field surrounding us at all times. A teacher can discuss why not all metals are affected by the Earth's magnetic field. The students should realize that the metal in the compass is light and free to rotate so it is affected by the Earth's magnetic field.

Once the topic of a magnetic field has been introduced a teacher can ask at what distance the magnet affects the compass at. This activity is similar to the investigation into the strength of magnets above. The students should measure the distance at which the magnet changes the direction of the compass needle. If a teacher has different types of magnets this can show that not all magnets are the same strength and that larger magnets may not necessarily be stronger than smaller magnets.

A deeper investigation into magnets:

This investigation requires magnets that have the two magnetic poles, North and South, labelled on them. Students can use the compasses to find which end of the magnet is north and south and label the magnet themselves. This activity will however require the students to have covered the Earth's magnetic poles. Once they have two bar magnets labelled ask the students to investigate the effect combining two poles has on the magnets (for example what happens when two North poles are placed together, two south poles and a north and south are placed together)

Evaluate Phase:**Class:** 1,2,3,4,5**Duration:** 10 Mins

Rationale: The final element of this lesson comprises of the students recording the results of their investigations. The students should be recording their investigations as they carry them out. Once they have completed the recording a teacher should assess the recordings to find out whether they highlight any

more misunderstandings. Younger students, who may not be able to write up investigations can still be evaluated by using simple questions that get the students to explain what they did, what they expected and what they found.

Write up of experiment:

In order to evaluate the learning students can write up the experiment that they carried out. Not all items must be listed but there must be a mixture of magnetic and non-magnetic items. The following table should be included. A worksheet has been attached below to print out.

Table that can be drawn on the blackboard:

Item	Description	Prediction	Was it Magnetic

In the video above we see a teacher going through the list of non-magnetic items with the class. This is an evaluation of the class and asks the students to record what they carried out or their results. For younger classes a teacher may be required to ask the students what they found and then write them on the board. Later classes doing magnetism should be able to recall what they covered without as much teacher input.

Write up investigations:

Ask the students to describe what they did in their investigations, what they predicted to happen and what happened. In order to simplify this with younger students a teacher can put the headings on the board of the investigations that they carried out.

Simple Recall Questions:

One easy way to quickly evaluate the learning that occurred in the lesson is to ask students questions. These questions should get the students to give as much detail as possible about what they did, such as "Does magnetism work through wood?, How did you test that? Did you find anything when you added more wood between the magnet and the paper clips?"

A teacher may conclude a lesson by asking the students if they have any questions on the topic of magnetism. If students have valid questions that weren't covered in the lesson then this could be covered in the start of the next lesson in order to finalize learning of the students. If a teacher is attempting this they should carry out a very brief discussion about magnetism at the start of the next lesson to remind the student of what they covered.

3 2 1 Evaluation:

Another way to evaluate the magnetism is to use the "3 2 1 evaluation method". Here the students are asked to record some of the details of their lesson using points. They are asked for

- 3 interesting things that you found out about magnets
- 2 Things I did not know about magnets
- 1 Question I still have about magnets

This evaluation highlights areas that interested the students, areas where their knowledge or understanding has been changed and one further idea to work on in future lessons on magnetism. This type of evaluation can show what activities the students enjoyed and produced the best learning outcomes.

Other Activities:

The lesson can be concluded with a simple fishing game. This game consisted of paper "fish" with magnets attached. The students were given a "fishing rod" with a magnet attached and had to catch a fish. Students can design and make their own fishing game. Instructions are described below. This could be carried out with younger students and it is designed to meet the needs of the "design and make" section of the curriculum.

Possible Misunderstandings:

If a teacher has found that students have the misunderstandings described below it is important that they challenge the student to find out the true idea. The activities described above force the students to think about their results. In the activity where students sort out magnetic items and non-magnetic items they may find that they thought all metals were attracted to a magnet and this is not the case. Whenever possible attempt to get the student to construct the truth around a misunderstanding instead of explicitly stating their mistake.

- Not all metals are magnetic. During the investigation students may find that drink cans (Aluminium cans of Coke, Fanta etc) may not be attracted by the magnet. This may also be found with some cutlery which may be a non-magnetic metal coated with a magnetic one, therefore making them only weakly magnetic.
- Some students may believe that larger magnets are stronger than smaller ones. This may be true in the case where the magnets are made of the same material, however it is incorrect, as different magnetic materials have different strengths. This means that a small magnet, made from a stronger magnetic material will have a stronger magnetic field than a larger one made from a less magnetic material.
- A common misunderstanding arises when talking about the Earth's magnetic field. This misunderstanding may arise in higher classes as younger classes may not have covered enough about magnets to draw these conclusions. Students who have studied magnets should understand that unlike poles attract (ie. A north pole attracts a South Pole). When a student uses a compass the north end of a magnet points north. Teachers who mention the Earth's magnetic field should be aware that geographic north is actually a magnetic south. This is why the north pole of a compass points to geographic north.

Appendix F: The sinking of the Titanic

Strand Unit: Energy and Forces

Class: 3rd, 4th, 5th

Duration: Approx 40 mins

Rationale: This lesson will combine science within history by looking at flotation and then carrying out an experiment on the sinking of the Titanic. The lesson starts with the narrative of the titanic and then moves from history to science by testing and discussing floating and sinking. The discussions in the elaborate phase push beyond the sinking of the titanic and ask for some higher level thinking from the students with regard to floating. This activity could be carried out with a higher level class. Inherent in this experiment is the need for a fair test to be carried out.

Equipment needed: Weights (Marbles can be used), several 2ltr bottles. Some of these should have a section cut out of them that will enable students to put both the weights and compartments into them. Bottle ends can be used for the compartments. Diagram of how the bottles should be cut:



Subject links: History: The titanic

Engage Phase:

Class: 4th /5th

Duration: 5 - 10 mins. A prior class may be needed to cover the Titanic.

Rationale: By using the story of the Titanic as an introduction point to floating and sinking a real world event is helping to build the knowledge of the students. This will help the students to recall the subject in the future. In this engage phase questioning, discussions and narrative all set up an investigation into sinking.

Discussion and Questions:

A lesson can be started by asking the students what they know about floating and sinking. A simple investigation can challenge any misunderstandings that they have here. Give the students a large sheet of tinfoil and ask them does it float or sink. If the students place the large open sheet of tinfoil into a basin of water it will float. Once they have done this you could ask is there any other way the tinfoil could be shaped? If you crumple the same sheet of tinfoil tightly it will sink to the bottom of the basin. This can be used to promote discussion about how it is not weight affects floating but in fact something else (Density). From here the idea of boats and ships can be introduced by asking leading questions such as:

- What are ships made of?
- Is this a light material?
- Is it weight that affects floating?
- What about oil tankers, would they be heavy?
- Do oil tankers tend to be small ships? or What shape are oil tankers?

Once the topic of floating and buoyancy has been discussed the idea of sinking can be introduced. This can be done by asking leading questions such as:

- What causes a boat to sink?
- What could you do to slow down a boat sinking?
- Link: [How Stuff Works: How to survive a sinking ship](#)

Narrative:

In this lesson the narrative of the titanic can be used to inform the class about the subject of the Titanic. The teacher can describe the story or watch a film on the Titanic. If watching a film the teacher must ensure that the way the Titanic sank is shown (i.e. the aft of the ship rising out of the water). This is important as it will be investigated as part of this lesson.

Explore and Explain Phase:

Class: 3rd / 4th / 5th

Duration: 10 -15 mins

Rationale: In this phase the students are still asked questions however, these questions are of a higher order and the students need to understand the subject and history of the titanic. This then introduces the topic of using airtight compartments on boats and ships to stop it sinking. Once this subject has been introduced the students then get a chance to investigate the difference compartments have on sinking.

Questions and Discussion:

Once the subject has been introduced, the following questions can be used to start a discussion on the sinking of the Titanic.

- Why was the titanic thought to be unsinkable?
- What are the compartments?
- What do the compartments do?
- How did they affect the way the ship sank?

Investigation:

Give the students one pre cut bottle, several weights for passengers, and compartment walls (see equipment above). Each group should have a basin of water too. Students must investigate how the compartments affect sinking. The students must figure out that, for a fair test, they must use the same weights each time. Also they must realize that they have to time the ship sinking. In order to see how the compartments affect the sinking the students should firstly sink the bottle and weights with no compartments. Then sink it using one compartment wall and two etc. giving equal size to each compartment. Once they have completed this a discussion can be had on what way the compartments affected the sinking of the bottle i.e. the differences in times, what effect had introducing more compartments or the visual the way the bottle sank etc.

Elaborate Phase

Class: 4th / 5th

Duration: 5- 10 mins

Rationale: This elaborate phase builds on the ideas of airtight compartments and weights in boats to develop an idea of how a modern approach can aid lifeboats.

This video could enhance a discussion on floating and sinking. The video shows a new type of lifeboat that can be fully capsized in water. A teacher may ask questions as to why the students' don't think the boat sinks even when it goes upside down.

The distribution of balast, as well as air tight compartments, stop the ship from staying capsized. This could be demonstrated with a weight attached to the inside of a sealed bottle or container. When you place the bottle in the water with the weight above the water level, the weight will cause the bottle to rotate until it is at the lowest point it could be. This demonstration should only be shown after the discussion has taken place.

Evaluate Phase:

Duration: 5-10 Mins

Write up of investigation:

Ask the students to write up what they found in the investigation, i.e. how the bottle sank with the compartments and if the sinking times increased or decreased. They could create a table comparing weight used to the time it took to sink. Another table that could be used is the number/ size of compartments to the time it took to sink.

Later classes could be asked to create a graph showing weight and time as an evaluate exercise. If a teacher wants to introduce the idea of graphing in science they could use one student's results to create a graph on the board to show the students how to create a graph.

Misunderstandings:

One common misunderstanding that students have in terms of flotation is that they associate weight with floating. This can be challenged by the investigation shown above whereby the same weight of tinfoil is used, whereby in one distribution it sinks and in another it floats. It is density, not weight that affects whether an object floats or sinks.

Appendix G: Casein Extraction

Strand Unit: Living things

Class: 5th/ 6th

Duration: Approx 50 mins

Equipment needed: 1ltr of full fat cows milk, 1 ltr of low fat cows milk, 1 ltr of goats milk, 1 ltr of soya milk, Graduated cylinders (1 ltr), Vinegar, Spoons, Sieves.

Rationale: This experiment is designed for later class groups and stands as an introduction to various experimental ideas and concepts. Firstly the experiment is related to a common household item, milk, which students can identify with and may have some knowledge about. The introduction of the experiment asks students to describe their previous knowledge of milk and its constituents. From here the content of Casein is introduced. Information on Casein can be found [here](#). The experiment also highlights concepts such as fair tests and comparisons.

Engage Phase:

Class: 5th /6th

Duration: 5- 10 Mins

Rationale: In the explore phase the students prior knowledge is identified. This can be done through questioning or carrying out research into milk and its constituents.

Discussion and Questions:

The teacher can begin this lesson by having a discussion about the various types of milk that they will be testing as part of the investigation. Comparisons can be made about the types of milk, their origins and their colours. A teacher may introduce proteins and where they are found and what the protein casein is used for. A teacher may also use this time to reinforce the concept of a fair test and how these are carried out

Research:

Depending on the class group a teacher may not wish for the students to have to research a topic by themselves however it has been proven, when carried out correctly, to be beneficial to student learning. Research must be supervised by the teacher however to ensure that all resources are appropriate to the level of the students. The resources may include methods to extract casein from milk sources as well as sources of information on casein detailing its description, its uses and where it is found.

Explore Phase:

Class: 5th /6th

Duration: 15- 20 Mins

Investigation:

In this investigation the students will be asked to investigate which type of milk has more casein in it. Firstly, depending on the sources of information supplied to the students, they may predict which type of milk will have more casein and why. From here the students may be divided into groups with each group sampling a different type of milk. The students should heat the 1ltr of milk to 60 degrees Celsius, then add 25mls of vinegar to the milk and stir. After a minute or two the students must sieve the mixture and this is the casein. The students should measure the amount of casein they got using a graduated cylinder.

Explain Phase:

Class: 5th /6th

Duration: 5-10 Mins

Rationale: An integral part of IBSE is the students developing their own knowledge from the results of their experiments. In this example a teacher may give the students the milk cartons to identify various pieces of information about the milk sources and the amount of casein in them.

Discussion:

Once the investigation is completed students can compare their results to their predictions and may be able to draw links between the types of milk and the amount of casein in it.

Evaluate Phase:

Class: 5th /6th

Duration: 5-10 Mins

Write up:

The students can write up their experiment in order to evaluate their learning. This exercise should include the students writing their predictions and results and explaining the differences in the types of milk and the casein samples.

Appendix H: The Senses

Strand Unit: Living Things

Class: 3rd/ 4th

Duration: Approx 40 mins

Equipment Needed: Blindfold, Various food stuffs, objects, cardboard box with one side cut out of it, ear muffs.

Rationale: In this lesson students will be introduced to their senses and how senses can be used for distinguishing and identifying objects. The lesson starts by identifying the students' previous knowledge on their senses and builds this into an investigation using several senses. Each activity is divided into its 5E category to help in the planning of a lesson. It is recommended that a teacher select at least one activity from each 5E state to create a complete lesson on the senses. If time allows more than one item per section can be used however; a teacher should select ideas which show different concepts. If students appear not to understand an activity then an alternate activity may make the concept clearer.

At the conclusion of this lesson students should have covered:

- The 5 senses
- The effects of the senses
- Using the senses to identify objects
- Using the senses to distinguish objects

Engage Phase:

Class: 3rd/ 4th

Duration: 5 Mins

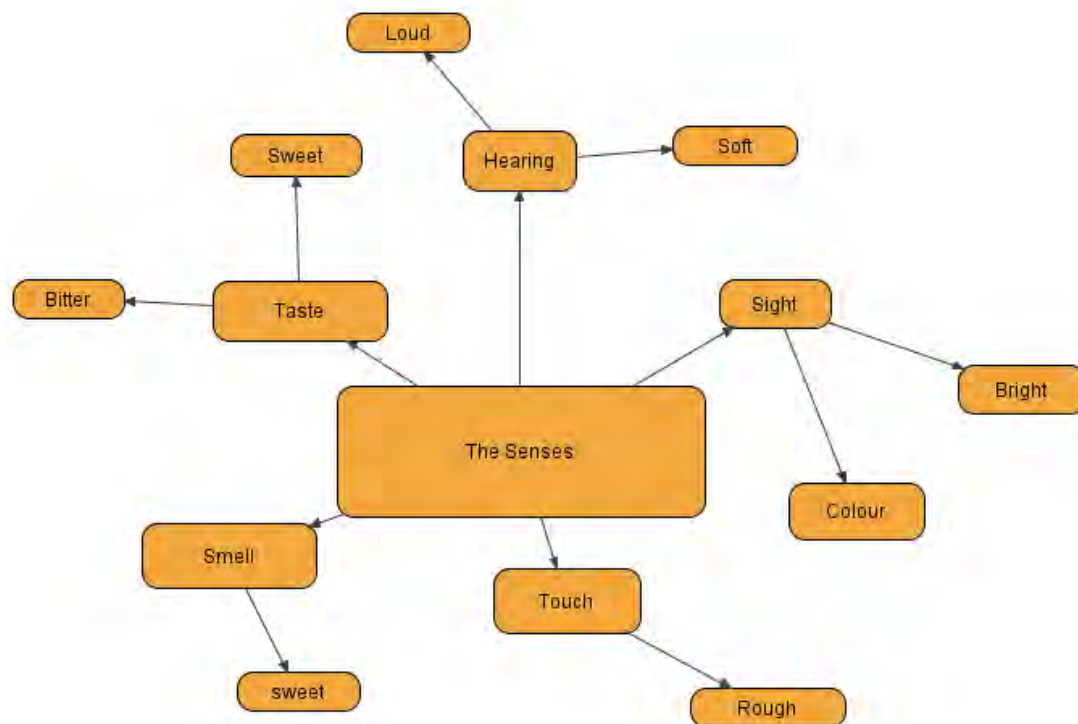
Rationale: The engage phase is used to introduce the topic of the senses to the students. As the students may be aware of the senses and what they do they are first asked to write down a few words that they associate with the senses. This will highlight areas that the students already understand and any possible misunderstandings. Older students may be able to connect the words they describe into a mind map. Once these words have been written a teacher may ask leading questions following on from the words in order to better introduce the topic and give the basis needed for the next activity.

Introduction to the Senses

Ask the students to write down 5 words that they associate with the senses. These words can be the names of the senses, the organs involved or what they associate a sense with. Once this has been completed ask the students to call out their answers and write them on the board. Then discuss why the students associate the particular words with the senses.

Mind Map on the senses

The previous activity could be expanded to include the creation of a mind map on what the students know about the senses. This mind map could divide the words into various groups and highlight connections between the different ideas. A sample mind map is shown below:



Discussion and Questions:

In order to introduce the topic of the senses a teacher can start a discussion with the students using the following questions as guides:

- Do you know what the senses are?
- What senses do you have?
- Describe the senses?
- What do you use for each sense?

The students should be able to at least describe some of the senses they have. Without giving the answers a teacher should be able to give hints and clues to any sense that the students don't describe.

Describing the organs associated with the senses:

Another method to introduce the senses is to place pictures of the organs involved on the blackboard and ask students to describe the sense that is related to that organ. This activity can help dispel some misunderstandings. The video below shows a teacher introducing the senses through this method:

Explore and Explain Phase:

Class: 3rd/ 4th

Duration: 20 Mins

Rationale: In this section the student will actively explore their senses to identify objects and foods as well as carry out an investigation into distinguishing similar substances. By using the senses this way it is hoped that the students will develop ideas of their senses and how they are used. Another important element in this lesson is the involvement of the students in an activity that can be light and fun but still meets educational goals and requirements.

Investigation:

This investigation involves students trying to figure out objects/ foods without the use of one or more of their senses. This investigation can be done a number of ways described below. The video highlights two students trying to identify the foodstuff they have been given and the process that is involved.

Using the sense of touch/ taste/ smell:

Please be aware there are health and safety concerns in this investigation. Firstly ensure that the student is not allergic to any food that you may use. Secondly ensure the student is seated and secure before blindfolding them. Once the student has been blindfolded they are given an object to identify. The object may be anything but foodstuffs ensure that the students can use their sense of taste. The students must then identify the object/ food through touch, smell and taste.

An addition to this investigation would be to block the students' nose and their sense of smell to see if this affects their sense of taste. The outcome of this investigation should help students identify their senses and how they use them. In order to reduce health and safety concerns it is recommended that only one student is blindfolded at a time.

The sense of touch:

In this investigation the students place their hands inside a box which has had one side removed. Ensure that the students cannot see what is inside the box. They must use only their sense of touch to identify the object.

The sense of hearing:

In this investigation a student must identify where another student is in the room through their sense of hearing. One student must be blindfolded for this experiment (please take precautions with this). Once this student has been blindfolded another student can make a noise in the room (either by using an object or talking). The blindfolded student must identify what direction the noise is coming from and possibly the object that is being used to make the noise.

The sense of sight:

Cover the students' ears using ear muffs. Ask another student to say a sentence to the student. The student with the ear muffs must then try to identify what the student said by trying to lip read the previous student. You must ensure that the ear muffs are noise cancelling and that the student that is using them can't hear anything. There is a health and safety risk here as the student would not be able to hear alarms. Ensure that the student is not left alone while wearing ear muffs.

Identifying substances properties using the senses:

Give the students samples of salt, sugar and flour. All three of these substances have similar looks but are drastically different. Using their sense of touch, smell, and sight students must compare and contrast the

three substances. Using sight the students may identify the colour, shape, and feel of the substances. They may use touch to try and ground the substances to see which ones are harder to break or if they can break the substance. They can smell the substances to see if there are any differences here.

Evaluate Phase:

Class: 3rd/ 4th

Duration: 15 Mins

Rationale: In the evaluation phase the students are asked to write up the activities and investigations that they carried out in the lesson. This helps to identify gaps in knowledge or misunderstandings that have been developed. It also helps to solidify the activities as a learning experience instead of just a fun class activity.

Write up Investigation:

Ask the students to record the experiment that they carried out taking note of the senses, their organs, and what they observed when a sense was removed.

Record of substance comparison:

The following table can be drawn on the board and filled in once the students have completed their investigation. A discussion can be had about the results.

	Touch	Taste	Smell
Salt			
Sugar			
Flour			

Possible Misunderstandings:

A lot of students associate the hands with their sense of touch. A teacher must ensure that the students understand their skin is the organ used for the sense of touch. Students can be guided to this answer through guiding questions such as can you feel with your arm/ toes?

Appendix I: Introduction to Electricity

Strand Unit: Energy and Forces

Class: 1st / 2nd

Duration: Approx 1 hour

Equipment Needed: Candle, devices that have plugs, devices that use batteries, pictures of electrical devices, balloons.

Engage Phase:

Questions and Discussion:

In order to engage the students and find out their prior knowledge and misunderstandings, leading questions may be asked such as the ones below. Visual cues may be included such as the use of a candles /oil lamps for old sources of light etc.

- What do you know about electricity?
- What uses electricity?
- What electrical devices do you use in everyday life? or What electrical devices are in your Kitchen/ Bedroom etc?
- What did people use before electricity? (ie. how did people light their rooms, wash their clothes)

Some answers that would be expected:

Students may have various levels of knowledge about electricity. Some of this may include health and safety knowledge like not touching switches with wet hands or putting metal objects into plug sockets. Students should be able to name several devices that use electricity from devices at home (Dishwasher, lights, lamps, washing machine, dryer etc), at school (the lights, data projectors, computers) to personal devices (mobile phones, mp3 players) etc.

Students may be able to describe how candles were used for lights but may not have heard of oil lamps (to introduce these pictures or examples would help). Students may not know how clothes were washed before washing machines such as using rivers and washboards.

Engage and Explore Phase:

Sorting out activity:

Once the students have been introduced to electricity and some electrical devices the teacher can introduce images that they have brought in of specific devices. The teacher can then ask the students to place these devices into one of three groups: essential devices, useful devices and unimportant devices on the board. A reason for placing a device in a category must be given.

Drawing Activity:

Ask the students to draw 2 or 3 things that use electricity in the school. You can then discuss what they drew. This activity can be repeated with things that use electricity at home.

Experiments: Static Electricity

In these experiments students will investigate the effects of static electricity. For each of these experiments the students can investigate what materials charge the balloon/ comb more.

Students can attempt to use electricity to attach a charged balloon to a wall. For this the students can be given an inflated balloon. They must then rub the balloon on their sleeves (this will work better if the students' jumpers are wool). From here they may attempt to see if the balloon sticks to the wall of the classroom.

Students can see the effects of static electricity when a charged balloon is placed near a student with long fine hair. Students can investigate what material produces better results for this experiment, such as a woollen jumper, a silk scarf etc.

Students can use what they have learned previously to charge a comb. Ask the students to place the charged comb near a stream of running water from a tap. If the comb has been charged the stream of water should deflect away from the comb.

Discussion:

A discussion can be had about health and safety with electricity. A picture can be shown (From either a textbook or other source) that shows dangerous practices with electricity in the house or school. Students should find out several things from this discussion:

- That putting electrical wires in water is dangerous
- That wires that have lost their protective coating are dangerous
- That putting metal objects into electrical sockets is dangerous
- That overloading sockets with devices is dangerous
- That people can trip over loose wires

Evaluate Phase:

Questions:

A teacher can evaluate the learning that has occurred in the class by asking the students questions about what they have learned during the class about what devices use electricity, what did people do before electricity etc.

Appendix J: Introduction to Electrical Circuits

Topic: Forces: electricity

Class: 5th / 6th

Duration: Approx 1 hr

Equipment needed: Torch, Bulbs, Wires, AA batteries,

Engage Phase

Questioning and Discussion:

Students should recall what they have learned previously on the subject of electricity. Students can be introduced to electrical circuits using a torch to start a discussion. Questions can be asked about the torch to find out about previous knowledge and misunderstandings.

- How does it work?
- What powers it?
- What parts are in it? (Battery, switch, bulb, mirror)

Concept Maps:

Another method to identify students' prior knowledge on electrical circuits is to utilise a concept map. Ensure that the students know how to create a concept map before attempting this exercise. There is a guide to creating concept maps on this page. Some of the terms that can be used are: Electricity Insulator Conductor Bulb Energy Electron Light Break Wire Motor Switch Rotate Direction

Explore and Explain Phase

Investigation:

The following investigations build on one another to create a meaningful learning experience. Students should take note of what they do in each investigation and their results. Students can work individually or in groups for these investigations.

1. Give the students 1 bulb, 1 battery and 1 wire and ask them to get the bulb to light.
2. Give the students 1 bulb, 1 battery and 2 wires and ask them to get the bulb to light.
3. Give the students 1 bulb, 2 batteries and 2 wires and ask them to light the bulb using all of the equipment. If the students perform this task first time ask them to turn around one of the batteries to see what happens.
4. Give the students 2 bulbs, 1 Battery and 4 Wires and ask them to make both bulbs light. Once they do this ask them is there another way that they can connect the circuit to make both bulbs light.

Investigation 1 should not light the bulb. By performing investigation 2 the idea of a complete flowing circuit can be explained to the students. Investigation 3 should show that the orientation of batteries is important to light the bulbs. Investigation 4 should yield 2 results as shown in the pictures below. This shows the various ways that circuits can be made.

Evaluate phase:

Write up of investigations: Ask the students to write up the 4 investigations that they have carried out including diagrams of what they built.

Presentations: After each of the investigation ask one student/ group to draw the circuit that they created on the blackboard while another student describes it and their results.

Appendix K: Teacher A CoRes lesson plan: Rate of Flow

Properties and characteristics of materials, different liquids flow at different rates	Big Idea 1	Big Idea 2
1. What do you intend students to learn about this idea	Working scientifically	Rate of flow of Water Rate of flow washing up liquid
2. Why is it important for students to know this	Variables to show a fair test	To be able to compare rates of flow
3. What else do you know about this idea (that you do not intend students to know yet)	Central to scientific investigation	That children will be asked to make prediction re tomato ketchup
4. Difficulties/ Limitations connected with teaching this idea	Childs patience when eager to get answer	Childs patience when eager to get the answer
5. Knowledge about students' thinking which influences your teaching of this idea	Childs concepts of fair play in short play	Children enjoy planning and working on investigation
6. Other factors that influence your teaching of this idea	Left Blank	Left Blank
7. Teaching procedures (and particular reasons for using these to engage with this idea)	Observation, collection of data, questioning follow procedures	Discussion Concept of fair test Elicit steps –prediction
8. Specific ways of ascertaining students' understanding or confusion around this idea (including likely range of responses)	Care measuring out liquids Repeat measurements Repeat investigation	Checklist – use of scoring guide to determine understanding of concepts

Appendix L: Teacher B CoRes lesson plan: Magnetism

	Idea 1	Idea 2	Idea 3
1. What do you intend students to learn about this idea	Introduction to magnets	What is magnetism	Materials attracted by magnets
2. Why is it important for students to know this	Magnets are in the environment	It is part of the curriculum	They can seek out further examples at home
3. What else do you know about this idea (that you do not intend students to know yet)	Will be used to create games at a later stage: e.g. fishing game	North pole/ south pole	Like poles can repel
4. Difficulties/ Limitations connected with teaching this idea	None	None	None
5. Knowledge about students' thinking which influences your teaching of this idea	Have to keep vocabulary and information at level of children's ability	Children are naturally inquisitive, good teaching will motivate them more	Hands on approach best- safety important
6. Other factors that influence your teaching of this idea	Have to keep it simple	Make them more aware	Children should enjoy it and want to learn more about it
7. Teaching procedures (and particular reasons for using these to engage with this idea)	Children learn by discovery, Will give them a selection of objects to test	Children will discover that magnetism is an invisible force	Discovery and discussion
8. Specific ways of ascertaining students' understanding or confusion around this idea (including likely range of responses)	Lots of discussion and worksheets	Discussion: proper definition	How knowledge can be applied in other situations

Appendix M: Teacher B CoRes lesson plan: Electricity

	Idea 1	Idea 2	Idea 3
1. What do you intend students to learn about this idea	Things worked by electricity in home	Static electricity	Introduction to circuit
2. Why is it important for students to know this	How dependent we are on electricity	Electricity in everyday environment	Dangers of electricity
3. What else do you know about this idea (that you do not intend students to know yet)	How electricity travels How it works	Causes lightning	Things (materials) that conduct electricity
4. Difficulties/ Limitations connected with teaching this idea	Limited to discussion and pictures	None	A little too advanced for children
5. Knowledge about students' thinking which influences your teaching of this idea	Do not wish to give more information they can cope with	They will have fun and they will remember it	Conserving energy by switching off
6. Other factors that influence your teaching of this idea	Do not know much about it myself	Will arouse interest in learning more	Do not know much about it
7. Teaching procedures (and particular reasons for using these to engage with this idea)	Will go back in time to when there was no electricity	Balloons	Made up circuit or game with batteries
8. Specific ways of ascertaining students' understanding or confusion around this idea (including likely range of responses)	Basic knowledge of how gadget has to be connected to plug to work Electrical survey: Essential, useful, not important	They will try to think of other instances of static electricity in the environment	

Appendix N: Teacher C CoRes lesson plan: Magnetism

	Idea 1	Idea 2	Idea 3
1. What do you intend students to learn about this idea	Why the Titanic was thought to be unsinkable	How watertight compartments help to maintain a ships buoyancy	How the Titanic sank
2. Why is it important for students to know this	As part of what we are studying in history	Design features and safety features of a ship	As part of what we are studying in history
3. What else do you know about this idea (that you do not intend students to know yet)	Displacement in ships	No Answer Supplied	Multiple slits in the ship's hull sank the boat
4. Difficulties/ Limitations connected with teaching this idea	No Answer Supplied	Understanding of buoyancy	As part of a course of study on the titanic
5. Knowledge about students' thinking which influences your teaching of this idea	As part of course of study on the titanic	I want them to understand why the ship was designed that way	Integration with history
6. Other factors that influence your teaching of this idea	Interesting Idea	Helps kids out with the scientific process	Active learning, guided discovery, pair work
7. Teaching procedures (and particular reasons for using these to engage with this idea)	Talk and discussion, pictures, questioning	Talk and discussion, active learning, pictures guided discovery	Active learning
8. Specific ways of ascertaining students' understanding or confusion around this idea (including likely range of responses)	Questioning, recording of experiment	Questioning	No Answer Supplied