OLLSCOIL NA hÉIREANN MÁ NUAD

THE NATIONAL UNIVERSITY OF IRELAND
MAYNOOTH

Froebel Department of Primary and Early Childhood Education
M.Ed. (Research in Practice)
(2020 – 2021)

Can my use of Guided Inquiry Based Science Education enhance my pupils learning of and attitude towards Science?

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A Research Dissertation submitted to the Froebel Department of Primary and Early Childhood Education, Maynooth University, in fulfillment of the requirements for the degree of Master of Education (Research in Practice)

Date: 21st September 2021

Supervised by: Dr. Bernadette Wrynn

Cover Sheet

Ainm / *Name*: Niamh Smith

Bliain / *Year group*: Master of Education 2020-2021

Uimhir mhic léinn / *Student number*: 20251327

Ábhar / *Subject*: M.Ed Thesis

Léachtóir / Teagascóir: *Lecturer / Tutor*: Dr. Bernadette Wrynn

Sprioclá / *Due date:* 24th September 2021

Teideal an tionscadail / *Assignment title*: Can my use of Guided Inquiry Based Science Education enhance my pupils learning of and attitude towards Science?

Líon na bhfocal / *Word Count:* 21 366

Líon leathanach / *Number of pages*: 91 (excluding appendices)

Aon ábhar eile sa tionscadal / *Any other material in the assignment*:

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Abstract

The main purpose of this self-study research was to enhance my practice in the area of Science Education, enabling me to live closer to my educational values of inclusion and autonomy. I aimed to improve the children's learning of scientific concepts while fostering positive attitudes towards Science using a child-centred inquiry approach to teaching and learning.

Applying a self-study action research paradigm allowed me to gain a deeper insight into my practice by reflecting critically through multiple lenses (Brookfield, 1995). My reflective journal, children's questionnaires, children's interviews, worksheets (to assess learning) and conversations with critical friends provided data sources from a variety of perspectives. These were analysed and reflected on to offer rigour and validity to the research.

I carried out two cycles of research. Examining my own practice in Cycle 1 (reconnaissance) and introducing an Inquiry Based Science Education (IBSE) approach in Cycle 2. This inquiry approach was hands-on and minds-on, encouraging the children to think critically, work collaboratively and develop their scientific skills.

I have shown that children's interest in and enjoyment of Science increased when engaging with an inquiry approach to teaching and learning, their academic attainment in Science increased with many becoming more articulate in expressing their ideas. Furthermore, IBSE allowed me to embed my values into my practice and re-embrace a constructivist mind-set.

Acknowledgements

I would firstly like to thank my school and all of the 3rd class children for their engagement, enthusiasm and feedback. Without them this research would not have been possible. I would also like to thank my principal and Board of Management for their support of and interest in my research. Also, to my critical friends for their invaluable advice and insight, and their ability to see the positive elements when I could not.

I wish to thank my supervisor, Dr. Bernadette Wrynn, for the generous time and consideration she provided me with. I have greatly admired her attention to detail, positive outlook and genuine passion for learning, she continued to motivate and guide me throughout the process.

I wish to thank my parents, for instilling a desire to continue my own education by demonstrating the importance of life-long learning through their own further studies. And to all of my family and friends for their continued encouragement and interest over the past year.

Finally, thank you to my dad, for all of the walks and inspiring conversations to keep me working towards my goal. Without his encouragement and belief in me I would not have pursued this master's degree in the first place.

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List of Abbreviations

DES	Department of Education and Skills
DEIS	Delivering Equality of Opportunity in Schools
ERC	Educational Research Centre
IBSE	Inquiry Based Science Education
ICSTI	Irish Council for Science Technology and Innovation
INTO	Irish National Teachers Organisation
NCCA	National Council for Curriculum and Assessment
OECD	Organisation for Economic Cooperation and Development
PISA	Programme for International Student Assessment
PSC	Primary Science Curriculum
SET	Special Educational Teacher
SNA	Special Needs Assistant
STEM	Science Technology Engineering and Mathematic

Chapter 1 Introduction

1.1 Introduction

This is an action research self-study exploring how I can improve my practice as a teacher in my classroom. The research specifically looks at how my use of Inquiry Based Science Education (IBSE) can enhance children's learning of Science and improve their attitude towards Science. This chapter will outline the focus and aims of my study, provide the reader with the context and background of the research, highlight the potential contribution of this study, and outline the layout of the thesis.

1.2 Focus and aims of the study

My main focus was to teach Science using a child-centred inquiry-based approach to encourage children to become more engaged in their science lessons. The general aims of this study were to:

- live closer to my educational values
- improve my practice to teach Science effectively
- enhance children's attitudes towards learning school Science.

My educational values of inclusion and autonomy are deeply rooted in this research. In school there are many different types of learners, I believe inclusion gives a voice to all these learners ensuring they are respected. I value autonomy as I feel in a democratic classroom children should be encouraged to have the confidence to take responsibility for their own learning. When I started this self-study in September 2020 I had to reflect on these values and explore whether I was living them in my classroom practice. I soon realised that I was simply a 'living contradiction' (Whitehead, 1989) regarding my values. Through critical reflection I started to question my teaching practices and came to the realisation that I was using a didactic approach which was not conducive to my values.

I chose to focus on an inquiry approach to teaching as it is steeped in constructivism (Harlen, 2010) and appeals to many different types of learners. I hoped that by choosing this pedagogy my practice would be more reflective of my values. Inquiry is a transferable teaching methodology that can be applied to all curricular areas; I chose to use it within Science Education. Science has always been a specialist subject for me during my teacher education years. The 1999 Primary Science Curriculum (PSC) is grounded in constructivism with a child-centred approach to learning (National Council for Curriculum and Assessment, 1999). Although the curriculum does not explicitly mention Inquiry Based Science Education (IBSE) it consolidates many of the principles of the PSC.

Literacy and numeracy have always been at the centre of primary education; however, it is argued that Science supports these subject areas and offers an additional unique yet vital dimension (Millar and Osborne, 1998). Science invites children to discover the world around them and explore new ways of thinking. Scientific literacy is not just essential to understand and explain our world, but it prepares children to be actively engaged and responsible citizens (Hazelkorn, Ryan, Beernaert, Constantinou, Deca, Grangeat, and Welzel-Breuer, 2015), scientific literacy describes an ability to engage with science-related issues as a reflective citizen (Organisation for Economic Cooperation and Development (OECD), 2017). The learning of science in primary school is essential to the fostering of a scientifically literate society (Harlen and Qualter, 2007). Children should be engaged and interested in Science, learning to gain understanding rather than to memorise information (Pollen, 2009), thus it is imperative that the children develop positive attitudes to Science from a young age. This not only influences children's attainment in Science but can also influence their subject choices in post-primary education and their future career path (Osborne, Simon and Collins, 2003). Research demonstrates that moving from a deductive teaching method to an inquiry approach increases children's interest in Science (Rocard, Csermely, Jorde, Lenzen, Walberg-Henriksson, and Hemmo, 2007).

1.3 Research background and context

I am a primary school teacher and I have worked the five years of my career in a suburban disadvantaged (DEIS) school. My school has a very diverse student population, with a variety of cultural and socio-economic backgrounds; this promotes a healthy and inclusive school and classroom environment. Over my years teaching in the school I became concerned with behaviour management, resulting in a more didactic approach to my teaching. This was not a pedagogical perspective I believed in, nor was it part of my teacher education.

Consequently I wanted to foster a culture of curiosity, creativity and critical thinking in my classroom. My constructivist approach diminished when curriculum demands, time constraints and behavioural issues began dictating classroom life for me. I was not the first teacher to experience this internal conflict of values and practice. Research (Varley, Murphy, and Veale, 2008; Murphy, Smith, Varley and Razi 2015; Department of Education and Skills (DES) 2016) shows that teachers in Ireland are still implementing more traditional teacher-directed approaches to teaching Science. According to Murphy et al. (2015) children in Irish primary schools are engaging in hands-on Science however, the frequency and nature of engagement is of concern, it tends to involve them carrying out very prescriptive experiments, following step-by-step instructions from the teacher.

International researchers (e.g. Rocard et al. 2007; Harlen and Allende, 2009) claim that children's interest in science decreases as they move through primary school, and this is concerning for the learning of Science. Over the past 20 years or so a plethora of research has highlighted the importance of Inquiry Based Science Education (IBSE) pedagogies in reversing this decline (Rocard et al. 2007; Harlen and Allende, 2009; Artique, Harlen, Lena, Baptist, Dillon, and Jasmin 2012). IBSE is a very child-centred approach to teaching, children learn through asking questions, reasoning and doing, carrying out their own investigations, and assessing the evidence. Harlen and Allende (2009:11) claim that IBSE offers "experiences that enable students to develop an understanding about the scientific aspects of the world around them through the development and use of inquiry skills".

Most importantly from my perspective, the use of IBSE has been shown to have a positive impact on the attainment of children from disadvantaged backgrounds, and those with lower levels of self-confidence (Rocard et al. 2007). This is particularly significant as according to the Educational Research Centre (2020), PISA results of Irish children in non-DEIS schools significantly out-perform children in DEIS schools in Science Literacy. Narrowing this gap in achievement is critical to offer equal opportunities to all primary school children and foster informed citizens.

1.4 Potential contribution of the study

In embarking on this research I claim to have generated knowledge about how to teach the children in my class Science more effectively using an IBSE approach. By sharing the positive findings of my research with other teachers in my school, I could encourage them to teach Science using an IBSE approach. This could also involve me carrying out professional development courses in IBSE with my colleagues. As teachers are key to engaging children in IBSE (Capps, Crawford, and Constas, 2012) it is essential that they are given opportunities to experience, understand and value inquiry-based learning. I also hope to disseminate the findings of my self-study to educational journals and science education networks.

1.5 Overview of study

This Master of Education thesis tells the story of my learning journey across five chapters.

Chapter One identifies the focus and aims for the research, reviewing my research question and the relevance for me personally and professionally. It provides the reader with an insight to my values and the development of these values in my practice across the course of my research.

Chapter Two reviews and critiques the relevant national and international literature in Primary Science Education. The chapter focuses on constructivism, the Irish Primary Science Curriculum, Inquiry Based Science Education and children's misconceptions in Science.

Chapter Three outlines the methodological framework I applied to this research. It examines the action research paradigm, the ethics process, the data collection methods and the analysis of the data.

Chapter Four details and interprets the data collected in Cycle 1 and Cycle 2 of the intervention. A variety of data sources are analysed, compared, and reflected on to triangulate findings and draw reliable conclusions. A critical reflection on each cycle is also included in this chapter.

Chapter Five identifies the limitations and implications of my research. Here I also describe my learning, both personally and professionally, while reflecting on my values and how they have evolved and changed within my practice over the course of this research.

Chapter 2 Literature Review

2.1 Introduction

This chapter explores and investigates the literature around four distinctly relevant areas. Firstly, the review examines some of the changes that have occurred in educational psychology over the last century and what is deemed to be the most effective pedagogy for use in the classroom. Secondly, this chapter explores the Irish Primary Science Curriculum and the influence of constructivism as a theoretical basis since implementation from 1999. This chapter also discusses the effectiveness of using Inquiry Based Science Education (IBSE) in the classroom, and the importance of progressing from hands-on activities to hands-on, minds-on investigations. Finally, children's misconceptions of Science concepts, their impact on the learning of Science and how they should be identified and addressed in Science lessons will be discussed.

2.2 A move towards constructivist pedagogies

Science education has seen some radical changes over the last century, especially around teaching pedagogies. Behaviourist theories of education dominated the first half of the 20thcentury, up until the late 1970's there was a belief that children were passive empty vessels waiting to be filled with knowledge. This behaviourist approach to teaching was influenced namely by the psychologists; Edward Thorndike, B.F Skinner and John Watson, where the focus of the learning was on content, and the responsibility of learning was with the teacher. "[The teacher] had the responsibility for selecting, pacing, instructing, and evaluating lessons, was the authority on explanations and led question and answer sessions." (Murphy, Varley and Veale, 2012:2).

Over the past 50 years or so there has been a paradigm shift in educational psychology towards a more active and child-centred pedagogy, constructivism. Constructivism is a philosophy where the child's prior knowledge is not only acknowledged but elicited to inform teaching and learning (Phillips, 1995). Constructivist theory seeks to develop the child's existing knowledge and understanding through authentic experiences which has evolved over years, beginning with John Dewey's (1859 – 1952) educational philosophy, espousing that children learn by doing. Dewey rejected the behaviourist approach to teaching, that knowledge is passively transmitted from teacher to child. Dewey believed that children come to the classroom with pre-existing ideas that are drawn upon to make sense of new knowledge and experiences (Smith, 2012). Both Jean Piaget (1896 – 1980) and Jerome Bruner (1915 – 2016) later added to the constructivist philosophy. Piaget reinforced the concept that children shape their own ideas of reality through interaction with their environment, while Bruner added that learning is an active process drawing on the learners' past knowledge (Smith, 2012). A constructivist sees learning in terms of the learner constructing meaning through relevant practical experience that reconstructs thinking (Howard, 2018), the learner makes sense of their experiences by drawing on their pre-existing knowledge (Driver and Bell, 1986). Constructivism is a major influence on the teaching and learning of Science education. However, acceptance of constructivism does not mean it has gone unchallenged by educators (Matthews, 1997). This is discussed in the next section.

2.2.1 Challenges to constructivism

Several educators such as Matthews (1997) and Burbules (2000) have challenged the acceptance of constructivism in education as they argue that the term "constructivism" is overused and too vague. Matthews (1997:492) suggested that constructivism is a spectrum of views:

> Constructivism as a theory of cognition, of learning, of teaching, of education, of personal beliefs, of scientific knowledge, of ethics and politics, and finally constructivism as a worldview.

Burbules (2000) stressed that advocates of constructivism believe that it should be employed by teachers in every aspect of their lives; personal and professional, there should be a belief that reality is just a social structure. Burbules (2000:12) makes the case that teachers don't have to take on all features of constructivism and should be solely concerned with the pedagogical perspective of the theory,

> Constructivist approaches to pedagogy would be generally better off if their advocates stayed out of the epistemological and metaphysical speculations that they seem unable to resist ...these broader pronouncements are neither necessary for constructivist pedagogy, nor particularly helpful to it.

Despite the additional complex theoretical, philosophical, and epistemological focuses intertwining the umbrella term of constructivism, when considered from a purely pedagogical perspective constructivism supports what we currently know about how children learn and their cognitive development (Piaget 1950; Vygotsky 1978; Howard 2011). This explains, in part, the huge emphasis placed on constructivism by the primary school curricula in western societies. Countries, for example, Australia, New Zealand, Canada, the UK and the US, have all structured their curricula around constructivist pedagogies.

2.2.2 Constructivism in the Irish Primary Curriculum

Similarly, to these listed countries above, Ireland's 1971 Primary School Curriculum embraced constructivism and adopted a child-centred philosophy. Influenced by Piagetian constructivism, the 1971 curriculum emphasised the centrality of the child to the learning process and endorsed the ideas of discovery learning (Waldron, Pike, Greenwood, and Murphy, 2009)

The revised Primary School Curriculum (National Council for Curriculum and Assessment (NCCA), 1999a) recognised that children learn in different ways and advocated the use of a variety of teaching methodologies to increase children's enjoyment of learning and desire to learn. The revised curriculum is structured around the current principles of child development and how children learn, including those of Piaget, Bruner and Vygotsky describing them as the most "innovative and effective pedagogical practice" (NCCA, 1999a:2).

Constructivism has an explicit role in the teaching and learning of the Primary Science Curriculum (PSC). Fensham (1992:801) claims "the most conspicuous psychological influence on curriculum thinking in science since 1980 has been the constructivist view of learning". As previously discussed, it is essential for teachers to acknowledge that children come to school with their own ideas about the world, based on their previous experiences. Similarly, in Science education effective teachers must identify and use the children's preconceptions as the starting point for teaching and learning in order to create authentic learning experiences to reconstruct the child's thinking (Piaget, 1950; Vygotsky, 1978; Howard, 2018). In short, prior knowledge should be used as the building blocks for future learning (Howard, 2018).

Many, such as Harlen and Allende (2009), Murphy et al. (2012) and Howard (2018), argue that there is a place for both deductive and inductive approaches to Science education. Howard (2018) claims that behaviourism still has a place in the classroom today, giving the example of teaching a child the parts of a flower or how to use a piece of equipment, such approaches can be "beneficial and indeed essential to learning" (Murphy et al. 2012:16). A combination of these teaching methodologies is recommended to cater for the variety of scientific topics (Rocard et al. 2007) and provide effective teaching and learning of Science in primary schools, as "it is highly likely that adhering to strictly one model of learning may not fit every occasion or child." (Howard, 2018:7). It would be concerning if didactic learning was to dominate over the children's hands-on experiences (Murphy et al., 2012).

2.2.3 Irish Primary Science Curriculum

In the 1971 curriculum Science became compulsory as the 'Nature Studies' strand of the Social and Environmental studies programme for primary schools (DoE 1971). A report by the Department of Education (1983:14) revealed that:

- Teachers did not use the discovery methods when teaching Science.
- Teaching strategies were primarily didactic and prescriptive.
- Majority of teachers of middle and senior classes considered Science the most difficult aspect of the Social and Environmental studies programme;
- Majority of teachers of middle and senior classes did not include Science as an aspect of their respective curricula.

In a survey by the Irish National Teachers Organisation (INTO) in 1987 only 30% of the teachers who were interviewed carried out simple scientific experiments, while 87% had 'nature tables' in their classrooms.

The Irish Government recognised the gap in the primary curriculum for Science when they included it as its own curricular subject in 1999. Science is one of the three compulsory subjects of Social, Environmental and Scientific Education, including Geography and History. As with the other eleven subjects in the revised curriculum, Science teaching is constructivist in nature, not only due to the required pedagogical approach outlined in the Teacher Guidelines, but also due to the equal emphasis on both content knowledge and skills development in the curriculum, "pupils' understanding and application of the scientific process enable them to construct and refine their own framework of fundamental ideas and concepts in science" (NCCA, 1999c:7).

The aim of the present curriculum (NCCA, 1999b) is to improve the level of achievement in Science among primary school children (Murphy et al. 2012). The Science curriculum is steeped in constructivist methodologies, using the child's knowledge as a starting point and reconstructing this knowledge with practical hands-on activities.

> Children begin from their ideas about how things are, and they change and develop these ideas by testing them in practical investigations.... This view of learning involves children developing and constructing more scientific understanding through their own ideas and experience. (NCCA, 1999c:3).

This emphasis on child centred, hands-on learning provides the child with ample opportunity to develop their scientific skills (Harlen, 1997). The importance of skills development is also reflected in the curriculum, with an equal focus on both conceptual and procedural understanding. The curriculum is a spiral curriculum (Bruner, 1960) progressing in depth of knowledge and development of skills (see table 2.1). The 1999 Science curriculum gives the children an opportunity to bring together and apply their new learning and skills in the 'designing and making' feature of this curriculum as well as developing the additional skills of: exploring, planning, making, and evaluating. Design and make encourages the children to explore the creative and imaginative aspects of the scientific process through open-ended problem-solving tasks (NCCA, 1999b:2). These aspects of the Science curriculum were endorsed by the Irish Council of Science Technology and Innovation (ICSTI, 1998) who agreed that Science should not be just about learning laws and theories, but should "aim to develop pupils' curiosity, their capacity for observation, and their analytic and problem-solving skills".

Table 2.1 Primary Science Curriculum - Strands and Strand Units

	Infant – 2nd Classes	**3rd- 6thClass**
Living things	Myself Plants & Animals	Human life Plants & Animals
Energy & Forces	Light Sound Heat Forces Electricity & Magnetism	Light Sound Heat Forces Electricity & Magnetism
Materials	Properties & characteristics of materials Materials & change	Properties & characteristics of materials Materials & change
Environmental awareness & care	Caring for myself and my locality	Environmental awareness Science & the environment Caring for the environment

2.2.4 Science Curriculum (1999) Implementation

The curriculum took four years to be implemented after its publication in 1999, and within that time several initiatives were taken to up skill teachers in preparation. Prior to its implementation the Irish Government were somewhat forewarned about the difficulties of implementing a new curriculum by both the Irish National Teachers Organisation (INTO, 1992) and Matthews (1993). The INTO (1992:46) stated “how in-service is to be delivered will be of critical importance in determining how Science Education is to be taught effectively” while Matthews (1993:45) warned “appropriate, long term, in-service education will be a critical factor in determining the success, or failure, of developing science in National Schools. Especially, National School teachers will not develop their expertise by attending short one day in-service days".

The Primary Curriculum Support Service was set up in 1999 to provide 3 days of in-service to teachers. A report carried out by researchers in Trinity College Dublin (Murchan, Loxley, Johnson, Quinn and Fitzgerald, 2005) found that although teachers were acquiring new knowledge, they were not putting this into practice in their classroom, with their teaching methodologies remaining static. Murchan et al. (2005) and Varley, Murphy and Veale (2008) claimed that teachers were not taking ownership of the revised curriculum.

2.3 Inquiry Based Science Education

Over the last twenty years or so, Inquiry Based Science Education (IBSE) has been regarded to be an effective pedagogy for the teaching and learning of Science in the classroom, not only in supporting the development of the child's content knowledge and skills but also in motivating children and improving their attitudes towards Science (Rocard et al. 2007; Harlen, 2010; Artigue et al. 2012). Inquiry supports the constructivist pedagogies as it can be described generally as "an act of building and testing knowledge" (Murphy et al. 2015:3). Linn, Davis and Bell (2004:16) are more descriptive in their definition of inquiry as "the intentional process of diagnosing problems, critiquing experiments and distinguishing alternatives, planning investigation, research conjectures, searching for information, constructing models, debating with peers and forming coherent arguments".

IBSE is often grouped with pedagogies that over-simplify the integrity of inquiry, such as hands-on learning, learning by doing or discovery learning (Capps et al. 2012; Harlen, 2014). These pedagogies only reflect certain elements of the inquiry process. IBSE is far more complex than simply carrying out hands-on activities, as

Gomez-Swiep (2008:451) pointed out “hands-on activities are not enough for students to have meaningful learning experiences”. Science education should not only be hands-on but *minds-on,* hands-on activities should be seen as facilitating experience and thought, which are furthered through communication and discussion (Harlen, 2014). Harlen (2010:3) reflects this complexity of inquiry when she states:

> Inquiry, well executed, leads to understanding and makes provision for regular reflection on what has been learned, so that new ideas are seen to be developed from earlier ones. It also involves the pupils working in a way similar to that of scientists, developing their understanding by collecting and using evidence to test ways of explaining the phenomena they are studying.

Although the aim of IBSE is the understanding of key ideas in Science, IBSE does not solely seek to impart scientific conceptual knowledge to the children, but rather it strongly emphasises the development of the child’s scientific skills (Rocard et al. 2007). Harlen (2012) developed a framework for teaching Science through inquiry and identified several skills to be developed including: questioning, observing, measuring, hypothesising, predicting, planning controlled investigations, interpreting data, drawing conclusions, reporting findings, reflecting self-critically on procedures. These skills directly reflect the skills outlined in the 1999 Primary Science Curriculum (PSC).

IBSE requires teachers and children to engage in different roles than those usually associated with traditional ways of teaching and learning. Children become more autonomous, taking ownership of their learning while teachers facilitate this learning, engaging in probing and progressive questioning but allowing the child to acquire the knowledge and skills themselves.

2.3.1 IBSE and the Primary Science Curriculum

Inquiry Based Education is not a new pedagogy, nor is it unique to Science education (Harlen, 2014). IBSE is reflective of what we already know about learning (Bransford, Brown, and Cocking 1999; Gopnik, Meltzo, and Kuhl 1999). It is grounded in constructivist theory, the work of theorists such as Piaget (1929), Dewey (1933) and Vygotsky (1978), emphasised the role of curiosity, interaction, and imagination in learning (Harlen, 2014). Two key aspects of inquiry and constructivism in Science, are that; (1) the children are actively answering scientific questions that are relevant to their lives (Dewey, 1938; Schwab, 1976; Brown, Collins, and Duguid, 1989) and (2) a focus is placed on eliciting and using children's prior knowledge (Piaget, 1929), “it is important to acknowledge, and to start from, the ideas the students already have” (Harlen, 2010a:3).

The 1999 Irish PSC is centred on constructivist theory and child-centred learning and while the curriculum does not specifically outline IBSE methodologies, IBSE consolidates many of the PSC aims. Both the PSC and IBSE approach aim to develop children’s conceptual understanding and skill acquisition, whilst adopting a scientific approach to problem-solving, emphasising understanding and constructive thinking.

The EU commissioned Rocard report found that moving from deductive to inquiry-based pedagogies increases the interest of children in Science and their teachers’ willingness to teach it (Rocard et al. 2007). The report also proposed that IBSE techniques were effective for children for whom traditional deductive methods were ineffective. From an Irish perspective, Varley et al. (2008) recommended; (1) the introduction of inquiry-based approaches in schools should be actively promoted and supported, and (2) professional development for teachers to enhance their pedagogical knowledge and confidence to implement “innovative inquiry-based approaches” (2008:19).

2.3.2 Barriers to inquiry

As with any pedagogical approach there are several barriers to inquiry teaching (Welch, Klopfer, Aikenhead and Robinson, 1981). According to Harlen and Allende (2009: 15) teacher’s themselves have identified several barriers; these include:

- Teachers’ confidence in their grasp of the subject-matter
- External tests that require only factual knowledge
- Inadequate space and resources
- Shortage of time
- An over-crowded curriculum
- Large classes
- Lack of teaching assistants.

These obstacles are considered to be external to the teacher; however, Anderson (2002) argues that many of the barriers to inquiry are internal to the teacher, relating to their beliefs and values, so instead he adopts the term ‘dilemmas’. Anderson (1996) classifies these dilemmas into three dimensions; technical, political and cultural. There is overlap between the technical and cultural dimensions, often the beliefs and values of teachers influences aspects of the technical dimension, such as assessment and use of textbooks, (Anderson, 2002). The cultural dimension of dilemmas is considered to be the most important, as it encompasses the beliefs and values within the culture of the school community. A key method of overcoming these obstacles is professional development for teachers (Rocard, 2008; Varley et al., 2008; Harlen and Artique, 2009;

Smith, 2012) as research identifies the teacher as being the single most influential factor on children's attainment (Hattie, 2003).

2.3.3 Levels of Inquiry

Within IBSE there can be different degrees of inquiry ranging from full to partial inquiry (Smolleck, Zembal-Saul and Yoder, 2006) these variations affect the role of both teachers and children. Banchi and Bell (2008) defined four IBSE levels (see Table 2.2) corresponding to the extent of teacher's guidance: (1) Confirmation inquiry, the teacher aims to develop observational, experimental and analytical skills of the children. They follow the teacher's step-by-step instruction when carrying out an experiment to verify known principles; (2) Structured inquiry, teachers assist the children by asking questions and provide guidance. Teachers control the lesson procedures which should be followed, questions to be asked and the making of the decision. The children are looking for solutions using their inquiry and explain the answer based on the evidence obtained; (3) Guided inquiry, the role of teacher changes significantly, they cooperate with children to define research questions and give opinions on procedures to be implemented by the children themselves. This increases their level of confidence helping them to work independently, (4) Open inquiry – is the highest level of inquiry, children devise their own questions, carry out independent investigations, analyse data and make conclusions from evidence. Minner Levy and Century (2010) claim that of the four levels of inquiry, Guided Inquiry is the most compatible with constructivist learning.

Table 2.2: Four levels of IBSE

IBSE levels	Questions (defined by teacher)	Procedure (defined by teacher)	Solution (defined by teacher)
(1) Confirmation	Yes	Yes	Yes
(2) Structured	Yes	Yes	No
(3) Guided	Yes	No	No
(4) Open	No	No	No

2.3.4 IBSE and children's attitudes to Science

Despite the growing influence of Science in our daily lives, internationally there is concern regarding the lack of children's interest in Science, and the decline in the number of them opting to study Science beyond post-compulsory education (Murphy and Beggs, 2003; Osborne et al. 2003; OECD, 2007). Children's attitudes towards Science can have a big influence on their learning outcomes, their choice of Science subjects at secondary school, and their career path (Pell and Jarvis, 2001; Osborne et al. 2003). Children form attitudes to Science at a young age, these tend to peak at age 11 (Osborne et al. 2003) and develop from their school experience, especially during their primary years (Murphy and Beggs, 2003).

Researchers (Woolnough, 1994; Osborne and Collins, 2001) have identified several features which were important in children forming attitudes to school Science. These include gender, home life of the child, the teacher, and the learning environment; the most important feature is the type of Science teaching the children experience (Den Brok, Fisher and Scott, 2005). Children develop positive attitudes to Science when their teachers use diverse ways of teaching and actively involve the children in their learning (Osborne and Collins, 2001).

Over the past two decades or so, IBSE has been promoted as having the potential to enhance children's attitudes, interest, and engagement in Science at primary level (Osborne and Dillon 2008; Harlen, 2010; Artigue et al. 2012). In recent years, two European Commission reports Rocard (2007); and Hazelkorn et al. (2015) have recommended IBSE as a suitable methodology to implement in primary classrooms across Europe to engage children in Science. The Rocard report (2007) found that countries did not need to revise their curriculum but rather teachers needed to alter their pedagogies with the support of professional training. In the UK, De Boo and Randall (2001) found that children had few opportunities to investigate or explore their own questions or solve their own scientific problems. Evidence of positive results from professional development can be seen in Australia where the 'Primary Connection: Linking Science to Literacy' programme was implemented to improve teacher confidence and competence in teaching primary Science by developing their pedagogical content knowledge (Peers, 2006). A review of the programme found that teachers were more confident and competent when teaching Science, and they allowed more opportunities to teach Science lessons, the programme resulted in positive effects on the children's scientific knowledge and skills as well as improved attitudes towards the subject (Hackling, Peers, and Prain. 2007).

2.3.5 IBSE in Irish primary schools

There are worries concerning the levels and frequency of engagement with IBSE methodologies in Irish primary schools. Studies (Varley et al. 2008; DES, 2012; Smith, 2012) have found that while Irish primary teachers are providing their pupils opportunities to engage in hands-on Science, it is more commonplace for these activities to be more teacher-directed than child-led.

In 2008, Varley et al. conducted a national study on primary school children's attitudes towards Science five years after the new science curriculum had been implemented in schools. 1,149 child questionnaires from 70 different schools around Ireland were completed with observations in 15 classrooms and 11 child focus groups (Varley et al. 2008). The findings of this report were mixed, generally Irish primary children had a positive attitude towards Science, and they really enjoyed engaging with hands-on Science investigations. However, the emphasis of the curriculum on constructivism and child-centred learning was not evident in the realities of the classroom. There was significant evidence of the teacher carrying out entire experiments as demonstrations while the children simply observed and recorded the results. The study showed that children's skill development were not developing progressively through their time in primary school (Murphy et al. 2012), for example, 'predicting', was simply making a guess with little or no recourse to the child's experience or prior knowledge.

Varley et al. (2008) were concerned with the frequency of hands-on activities in Science, with no evidence of practical experiences in some cases. Where practical activities were happening there was still a concern regarding the type of hand-on investigations the children were participating in. Many tasks were prescribed and teacher-led, affording the children few opportunities to engage with the explorative and creative element of Science. Murphy et al. (2012:13) added, "the application of different scientific skills would appear to be uneven in comparison with the ideals suggested in the curriculum". Positively, regardless of the type of hands-on Science the children were engaging in, there was still “evidence that some were acquiring scientific conceptual knowledge as a result”.

2.4 Children’s misconceptions in Science education

As we have previously established, children come to school with prior knowledge gained through a multitude of observations and experiences of the world around them. This knowledge has helped children make sense of different scientific phenomena; however, it is not always scientifically accurate and may interfere with the child’s future learning. Harlen’s (2001) assessment of results from two influential reports, the Learning in Science Project (LISP) in New Zealand (Osborne and Freyberg, 1995) and Science Processes and Concept Exploration (SPACE) in the UK (Osborne, Wadsworth, Black and Meadows, 1994) have shown that children come to school with their own ideas about Science, many of which are unscientific, and use these ideas when approaching Science topics in class. Many different terms are used to describe these prior ideas such as ‘misconceptions’, ‘alternative conceptions’ and ‘children’s ideas’ (Osborne and Freyberg, 1995). Hamza and Wickman (2008:1) describe “Misconception” as the most widely used term in the research and so for this reason it will be employed in this research. Schmidt’s (1997:12) definition of a misconception states, “children’s ideas that differ from definitions and explanations accepted by scientists” and is applied for the purposes of explanation in this self-study

2.4.1 The complexity of misconceptions in Science

Misconceptions are not just misunderstandings, they are integrated with other concepts that children use to make sense of their experiences and the world around them (Southerland, Abrams, Cummins, and Anzelmo, 2001) and therefore they are deep-rooted, difficult to overcome and can impede future learning, with teaching even influencing these misconceptions in unintended ways (Osborne and Cosgrove, 1983).

Often children are unaware that their ideas are not scientifically correct as they have been developed through first-hand experiences and interactions (Driver, Newton and Osborne, 2000), misconceptions are unlikely to change if the child does not see the relevance for altering their own explanation (Posner, Strike, Hewson and Gertzog 1982; Tao and Gunstone, 1999). Misconceptions can also be detrimental to learning, posing a barrier to understanding (Clement, Brown and Zietsman, 1989) and often remaining even after instruction (Eryilmaz, 2002). Some research has revealed that teachers can facilitate learning for children to reconstruct ideas into more scientifically acceptable ones (Osborne et al. 1994). Research by Pine, Messer, and John (2001:93) with primary school children in the UK showed that misconceptions are significant and should not be ignored in the learning process as they are; "foundations upon which knowledge is built". Meyer (2004) echoed this, he examined expert teachers and found that they too included their pupil's misconceptions and used them to inform their instruction. Before misconceptions can be corrected, they need to be identified; teachers can identify their pupils' misconceptions by asking probing questions and encouraging the children to engage in peer discussions around the topic in question (Robelen, 2013). It is not enough to simply acknowledge the child's misconception, teacher's must also establish its origin to unravel it, Russell and Watt (1992) encouraged teachers to ascertain the reasons the children have for holding their ideas.

2.4.2 Addressing misconceptions

Science teaching should involve a process of change (Asoko, 2002). This should be achieved through a constructivist approach to learning, creating practical and memorable experiences for the children (Varley et al. 2008). Constructivism, as previously stated, implies building on the child's knowledge, but we must go a step further to reconstruct that knowledge as is recognised and endorsed in the Irish Primary

Science Curriculum, "meaningful learning occurs when pupils construct their understanding by modifying their existing ideas in the light of new insights gained from scientific investigations" (NCCA, 1999c:7).

The most successful methods of addressing misconceptions include some form of cognitive conflict (Gomez-Zwiep, 2008), whereby the child's expectation due to their misconception is called into question by their observations. This idea of cognitive conflict is integrated into the conceptual change process (Posner et al. 1982) this involves "not only making the individual aware of his or her misconception, but also involves causing the individual to become dissatisfied with his or her previous notion through experiences and teacher guidance specifically designed to cause conflict between the misconception and their observations" (Gomez-Zwiep, 2008).

Educational theorists such as Piaget (1950), Vygotsky (1978) and Howard (2018) stress the importance of only addressing misconceptions relevant to the stage children are at in their cognitive development, specifically their age and readiness to learn, "trying to teach the correct science at an inappropriate stage of development is likely to be unfruitful" (Howard, 2018:13), some concepts should be left until later in the child's education (Howard, 2018).

2.5 Summary of salient issues

The main purpose of my examination and critique of the research literature was to create a theoretical framework for my research. I began by looking at the influence of constructivism on teaching and learning especially, in primary Science in Ireland (NCCA, 1999b). I then explored the influence of IBSE as an effective pedagogy for the teaching and learning of Science in primary schools. I examined how IBSE supports constructivist pedagogy and how it has been promoted as having the potential to enhance primary school children's attitudes and interest in Science (Rocard et al. 2007).

I then considered some of the barriers of implementing IBSE and the different levels of IBSE. Most importantly having read through the literature I established that because of the young age of the children in my class and their lack of experience engaging in IBSE, I had to scaffold their learning and pick the most appropriate level of IBSE, namely Guided Inquiry, this will be outlined in detail in Chapter 3. Finally, from reading through the literature, I believe it is very important to consider children's prior knowledge in Science especially their misconceptions and to scaffold their learning around this. Identifying, addressing, and overcoming misconceptions helped me to monitor the learning that occurred in my classroom.

My main aim in undertaking this study is to enhance the teaching and learning of Science in my class. From my experience in college, school and reading through the relevant literature for this study, I believe that teaching Science through IBSE could potentially enhance children's engagement in and attitudes towards primary Science.

Chapter 3 Methodologies

3.1 Introduction

This chapter outlines the methodologies adopted for this self-study and the rationale behind these choices. The chapter discusses research paradigms, describing why action research was the most suitable choice for this study, and how it encompasses my values. The chapter then outlines my action plan and the two cycles of research conducted and the ethical considerations involved. Finally, the chapter discusses data analysis and how a variety of data collection instruments were utilised to provide credible and reliable findings.

3.2 Research Paradigms

The concept of the research paradigm is defined by Willis (2007:8) as "a comprehensive belief system, worldview or framework that guides research and practice in a field". To determine the research approach that best reflects my personal philosophy I considered the positive, interpretivist and critical theory paradigms.

Positivism is seen as a philosophical ideology that adheres to the 'factual' knowledge acquired through measurements and observation (Cohen et al. 2007). Proponents of positivism suggest if something cannot be observed and thus measured it is of little importance, the positivist paradigm is a rigid scientific method (Kivunja and Kuyini, 2017), inappropriate for a fluctuating environment such as a classroom. On the other hand, an interpretivist paradigm is concerned with perceptions or meanings, beliefs and attitudes, feelings and emotions and answers the 'how and why' parts of the research, creating more detailed findings (Creswell, 2011). It involves the researcher observing their subjects (Kivunja and Kuyini, 2017) but not actually participating in the research (McDonagh, Roche, Sullivan, and Glenn, 2020). Critical theory developed as a critique of positivist and interpretivist methods of research, on the assumption that research is never neutral, but used by the researcher for a specific purpose (McNiff and Whitehead, 2006:41).

The critical theory paradigm involves the researcher and participants working together to bring about a beneficial change (Scotland, 2012). The critical paradigm is also known as the action research paradigm (Sullivan, Glenn, Roche, and McDonagh 2016; McDonagh et al. 2020) and it seeks to improve a particular situation. I felt that the critical paradigm best matched my ontological and epistemological values as it sees the children as being co-investigators in the research process (Merriam and Tisdell, 2016), reflecting my values of the children being of equal significance to the teacher in a learning community. I will explore the action research paradigm in more detail in section 3.7.

3.3 Nature of my research

I used mostly qualitative and some quantitative methods to collect data and generate evidence. Denscombe (2007) describes quantitative data as that which takes the form of numbers. This data gives the researcher a snapshot of whether there is a problem, however, it does not provide the researcher with a full picture, for example where the problem has originated (Mc Donagh et al. 2020). I decided to use closed questions in my surveys and questionnaires with the children, this allowed me to identify any discernible issues on the surface of my practice before exploring them in more detail. They also worked well as a ‘first-glance’ assessment tool before analysing all the data I had collected.

Qualitative data is data that is formed by words (written or spoken) and visual images (observed or creatively produced), such as interviews, observations, and open-ended questions in surveys or questionnaires (Denscombe, 2007). When collecting qualitative data, the researcher must listen to the views of the participants and must ask broad and general questions to make the appropriate changes to improve the situation they are researching (Creswell, 2005). As a teacher who values the voice of the child and their autonomy it was important for me to listen to the views of the children and allow their ideas and opinions to inform my teaching, planning, and research. I therefore incorporated open-ended questions into all questionnaires and interviews carried out with the class and provided the children with opportunities to draw on their thoughts and opinions. Crucially, the answers to these open-ended questions provided me with an insight into the child's thinking, and therefore any changes in their thinking over the course of the research. I also sought honest and constructive feedback from my critical friends through informal conversations.

I believe using such an approach complemented the action research process and my study, enhancing the credibility and validity of my findings through triangulation.

3.4 My Values

Values refer to what we value and what we hold as good (McNiff, 2013). Beginning with your values is vital in action research, "the researcher is informed by their own values, beliefs and assumptions" (Sullivan et al. 2016:25). Interrogating and critically reflecting upon my values was an essential element of my journey of learning. I found that, although my practice and methodologies may have altered and adapted throughout the process, my core values did not. These values were what motivated me and encouraged me as a teacher.

My values are inclusion and autonomy. I believe that all children have the right to learn, regardless of academic ability or socio-economic background, this is a value that I believe should be especially ingrained in teachers working in DEIS schools. Inclusion ensures that the voice of every child is equally respected and valued, it also recognises children's individual strengths and their role in the class is not only acknowledged but appreciated. Inquiry based Science lessons are multifaceted, drawing on a range of different skill sets making them accessible to all types of learners (Capps et al. 2012), a feature that has always appealed to me.

I also believe that children are as valuable to the learning community as the teacher, and that their autonomy in demonstrating this value should be supported and encouraged by teachers. Child centred learning (Piaget, 1929; Dewey, 1938) encourages children to take responsibility for their learning and have the confidence in their own abilities and strength. I am excited by a respectful and democratic classroom in which children can support and learn from one another, acknowledging the strengths of their peers and themselves.

When I started this self-study, I thought about how I was teaching Science in my school over the past few years, I concluded that I was a "living contradiction" (Whitehead, 1989) the reason being I was not carrying out my values in my classroom practice. Through critical reflection I realised that my Science lessons were prescriptive and teacher led, rather than child centred and constructivist.

> *Although the children were engaging in hands-on activities they were all carrying out exactly the same activity and hoping to get the 'correct' result. There was little creativity or ownership to their work, they were simply completing a task (Reflective Journal, 17th February 2021)*

Identifying that my values of inclusivity and autonomy were being denied in my practice was a crucial step in my learning journey. It was an acknowledgment I needed to make to improve my practice and support the children I teach in reaching their potential. I endeavour to create a positive, open and creative learning environment where all the children feel safe, secure and valued, this allows for the best possible learning to take place

3.5 Research design

The research design section outlines a description of the research site, the research participants and the intervention model used.

3.5.1. Research Site

The research took place with children of 3rd class in a suburban Dublin co-educational primary school with a DEIS status. School community has a diverse socio-economic and multi-ethnic community. Table 3.1 shows the various personnel in the school.

Table 3.1: Personnel in the school

Research Site	
	Number
Principal	1
Home School Community Liaison (HSCL)	1
Mainstream Teachers	8
Special Education Teachers (incl. Deputy Principal)	5.5
Special Class Teachers	4
Special Needs Assistants (SNA)	11
Caretaker	1
Secretary	1
Children	210

3.5.2 Research Participants

The participants who took part in my study are shown in table 3.2 below

Table 3.2: Research participants

Participants	Participant Details
22 children from 3rd class (age 9/10)	12 boys and 10 girls
Critical friend - inside school	Mainstream teacher in same school
Critical Friend - outside school	Second level Science teacher

First, ethical approval was granted by the University and school Board of Management, then, all of the children in the class provided their informed assent to take part in the research and all of their parents/guardians provided their informed consent for their child to take part in the research.

3.5.3 Intervention Model

Major topics arising from the relevant literature provided guidance for the intervention programme used in this self-study. As stated previously I believe that the 4th level of IBSE i.e. 'Open Inquiry' is closest to my values of inclusion and autonomy. However, having read through the literature and engaged in reflective conversations with my critical friends I realised that because of the young age of the children and their inexperience of carrying out IBSE it was more pragmatic to engage in the 3rd level of IBSE i.e. Guided Inquiry (see Chapter 2 section 2.3.3).

The content of the programme was drawn from the PSC (NCCA 1999a). The model of learning through inquiry used in this research was based on Harlen's (2012) Framework for Inquiry (Figure 3.1). This framework starts with the children's existing ideas regarding a specific scientific concept, and explanations for having those ideas.

Children are given opportunities to plan and carry out a range of investigations to test their ideas and draw tentative conclusions about their initial ideas to share with peers.

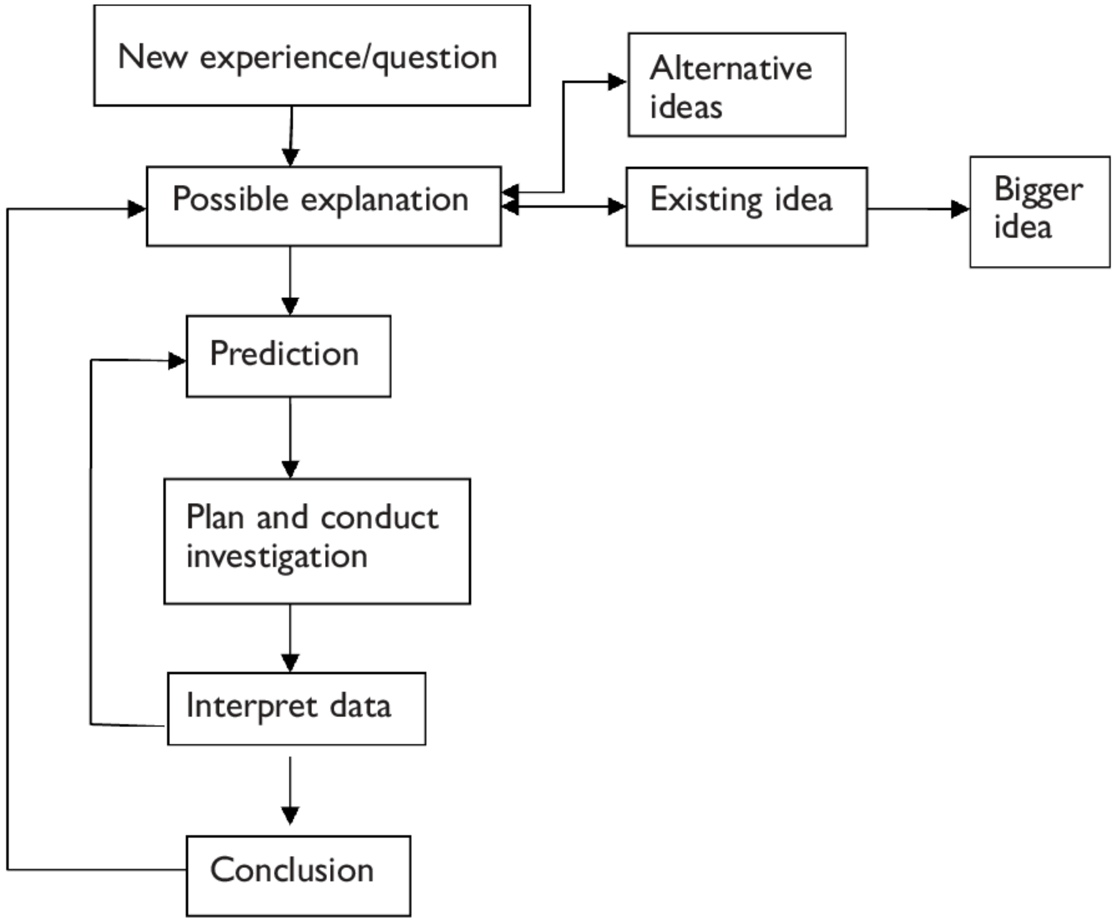


Figure 3.1: Harlen (2012) Framework for teaching science through Inquiry

3.6 Ethical considerations

As my research was concerned with the teaching and learning of the compulsory primary Science curriculum, it was reasonably low risk by nature (Felzmann, 2009). However, the area of vulnerability still had to be considered as the research involved children. Throughout this research I was cognisant of my duty of care to the children and that my role as their teacher superseded my role as a researcher. I always endeavoured to reflect the Teaching Council (2016) values of Respect, Care, Integrity and Trust in my practice. I was also aware of the power dynamics between myself, as the teacher and adult, and the children, as the learners. I took several steps to ensure that my research protected the children, respected their autonomy and that it met the appropriate safeguards, these are outlined below.

3.6.1 Informed Consent and Assent

Once I was granted ethical approval from the Ethical Committee of Maynooth University Froebel Department of Primary and Early Childhood Education, I provided the Board of Management and school principal with a detailed description of my intended research, the forms of data collection I intended to use and assured them of the anonymity of the children and the school in the research (appendix F). I was granted oral and written permission to proceed with my research. I discussed my research with my critical friends, I received their permission orally to reflect on any discussions we might have around the lessons, the progress of the teaching and learning or the direction of my research.

Before sending information to parents I discussed my research with the children for them to be fully informed in an accessible manner, as recommended by Sullivan et al. (2016). I described my research to the class and what I was hoping to achieve, I reassured the children that I was the subject of the study, not them, and that they would be my co-researchers. I explained to them that their identity would not be known to anyone else except me and that they could choose to stop participating at any stage. The children then filled out a form (see appendix G) establishing whether they would be comfortable participating in the research, before signing a form with their parents or guardians after further discussion at home.

Finally, I sought the written permission from the parents and guardians of the children in 3rd class. Again, I provided the parents with a detailed description of my intended research and the role of their child in the research in the first language at home. I assured parents of the anonymity of their child and the school and reminded them of their right to withdraw their child from the research at any stage (appendix H). Additionally, I asked the parents to further discuss the research with their children at home before providing their written consent and their child's written assent. I did not begin collecting data until I had the necessary permissions; all of the children and parents/guardians provided their assent and consent.

3.6.2 Data protection and storage

As per Maynooth University Research Integrity Policy all data collected over the course of this research is being stored securely for the next ten years. This data is only available to me, the researcher, and University officials, upon their request. Physical data is being stored in a locked filing cabinet, while digital data is password protected. As outlined in the terms of consent to my research, the Board of Management requested that all signed consent forms were to be kept on school premises until the children taking part are 18 years old, these are stored in a secured filing room in the school. I also retained a copy of these consent forms for my records.

The Maynooth University; Research Ethics Policy (2019) and Child protection Procedure (2017) were adhered to throughout the research (see appendix I for researcher declaration form).

3.7 Action Research

Elliott (1991:69) defines action research as, "the study of a social situation with a view to improving the quality of action within it" and argues that engaging in action research can improve quality of life in a social situation (such as a classroom). Action research always seeks to improve a situation, a practice or an understanding of practice (Carr and Kemmis, 2004), "the action aspect of action research is about improving practice. The research aspect is about creating new knowledge about practice. The knowledge created is your knowledge of your practice" (McNiff and Whitehead, 2005:5). This newly created knowledge informs your current and future practice; therefore, action research is continuous, it requires constant engagement in reflection, collaboration, generation of knowledge and practice transformation (Reason and Bradbury, 2001; Bell, 2005; McNiff, 2016).

In contrast to empirical research, where the researcher carries out the study *on* other people, in action research the researcher carries out research on *themselves* (McNiff, 2002). Furthermore, the research is carried out *with* the participants, such as the children, making them co-researchers rather than subjects (Merriam and Tisdell, 2016). Action research tries to bridge the divide between theory and practice (Somekh, 1995). Unlike empirical research, with action research, the researcher is key in all facets of the study. Most importantly they decide on what topic or issue should be investigated. Self-study action research gives a sense of ownership to the practitioner engaging them in their own practice and gives them the opportunity to solve problems. Ziegler (2001:1) claims "action research reaches into the uncertain world of practise and engages the practitioner on a personal and practical level and promises the opportunity to solve persistent problems".

Action research is ideal for teachers to learn about themselves and their children as they try to improve their classroom practice (Ferrance, 2000), it is flexible and allows for unexpected occurrences (Cohen, Manion, and Morrison, 2007) an advantage in the ever-changing classroom environment. Self-study action research embraces change and invites the researcher to reflect on any changes or decisions, as reflection is thought to be a crucial component in the development of practice (Dewey, 1933). 'Reflective Practice' (Schön, 1983, 1987) is an essential element of the action research process; McNiff (2002) refers to action research as a form of self-reflective practice. Reflective practice also allows us to go a step further in the action research process to assess whether we are living to our values (McNiff, 2002), therefore ascertaining whether we are a “living contradiction” (Whitehead, 1989) in order to generate our own “living theory” (Whitehead and McNiff, 2006).

These features of action research noted above make it useful in bringing about improvement of practice and the ideal research approach for my self-study, as I attempt to enhance my classroom practice, by promoting an inquiry approach to the teaching of Science education.

3.7.1 Action Research Cycles

There are many models of action research, such as Elliott 1991; Zuber-Skerritt 1996; Kemmis and Mc Taggart, 2000; McNiff, 2002. They all share four fundamental stages which were first described by Lewin (1946) namely: strategic planning, taking action, observing and critically reflecting. Zuber-Skerritt model of action research (see figure 3.2 below) was chosen for use in this self-study. The model (outlined in Cohen et al. 2007) consists of four cyclical steps (a) strategic planning, (b) implementing the plan (action), (c) observation, evaluation, and self-evaluation, (d) critical and self-critical reflection on the results of (a) – (c) and making decisions for the next cycle of research. Due to time constraints, only two cycles of this model were completed in this study.

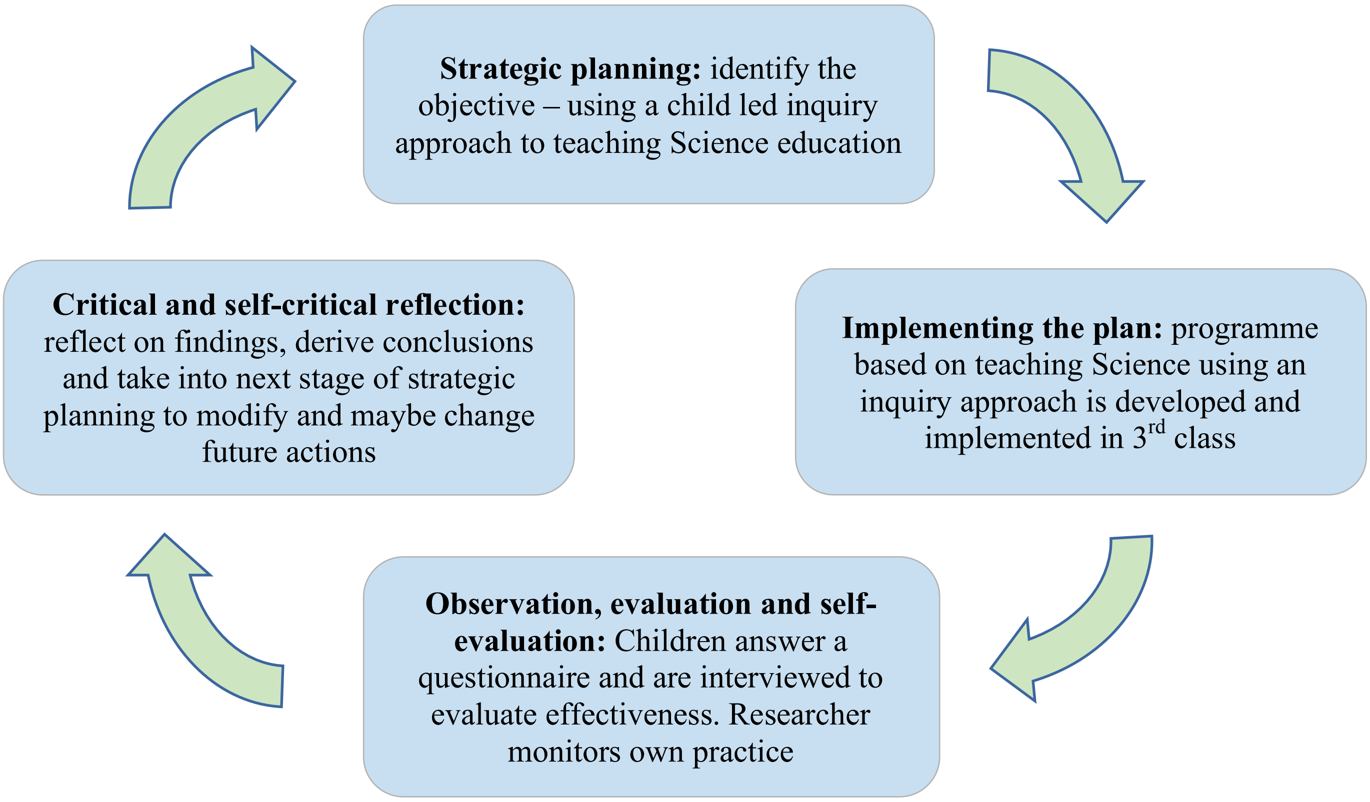


Figure 3.2: Model of Action Research used in study (adapted from Zuber-Skerritt, 1996)

3.7.2 Action Research Cycle 1

When I began teaching Science to 3rd class (ages 9-10) in September 2020 I noticed the misconceptions some children had regarding several important Science concepts and how strongly these were held. I began to wonder whether my teaching approach could, or was contributing to the development of these misconceptions, therefore a lack of inclusive learning. I considered if I could change the way I was teaching to help children address and overcome such misconceptions and enable participation. I decided this was an area I wanted to explore and research.

Cycle 1 of my research self-study acted as a “reconnaissance” (Elliott, 1991) phase of my research. It occurred once all ethical approval had been gathered and consent was obtained from the relevant "gatekeepers" (Cohen et al. 2007). I began to analyse my current practice through honest reflection, conversations with critical friends and data collected from the children, these will be discussed in more detail in Chapter 4. I continued to teach Science to the class applying the same pedagogies I had for the previous four years, which, upon reflection, were more teacher-led than I had assumed.

In Cycle 1 I taught two areas of the curriculum, using my own 'regular' teaching style. The children's misconceptions were assessed before and after the teaching of each topic. At the end of Cycle 1 I administered a questionnaire to the whole class (appendix A) and interviewed a group of 4 children (interview questions see appendix B) regarding their experiences of and attitudes towards primary Science. I then collated this data to inform the changes I would implement in Cycle 2 of my self-study.

3.7.3 Action Research Cycle 2

In Cycle 2 of my self-study, I implemented pedagogical changes to my practice, incorporating a teacher Guided Inquiry approach to Science education. I documented my practice, observations and any changes that occurred from Cycle 1, both in myself, as teacher-researcher, my teaching and in the children. I recorded, analysed and reflected on these in my reflective journal, and I discussed them in detail with my critical friends.

As in Cycle 1, I taught two areas of the Primary Science Curriculum using an inquiry-based approach (Pollen, 2009; Capps et al. 2012). Again, I assessed the children's misconceptions on each of the topics before and after the teaching of those areas. At the end of Cycle 2 I administered the same survey to the whole class, as used in the first cycle, and interviewed the same group of 4 children using the same interview questions as I had done in Cycle 1.

The collected data was then analysed, each cycle was compared, these findings are discussed in Chapter 4.

3.7.4 Action Research Timeline

The NCCA suggests a weekly time allocation per subject per week, the time allocated for SESE (History, Geography and Science) is three hours per week, which is usually divided into one hour per subject. Due to the hands-on nature of my Science lessons I chose to combine the one hour of Science per week into a two-hour lesson per fortnight to allow the children ample time to participate in and benefit from the lesson. These lessons generally took place on a Thursday afternoon straight after lunch until the end of the school day (12:45pm - 2:20pm). There was also time allocated to the completion of misconception worksheets in the days before a new concept was being taught and again in the days after a concept was taught. Figure 3.3 below outlines the overall schedule of research. For a detailed schedule of research see appendix C.

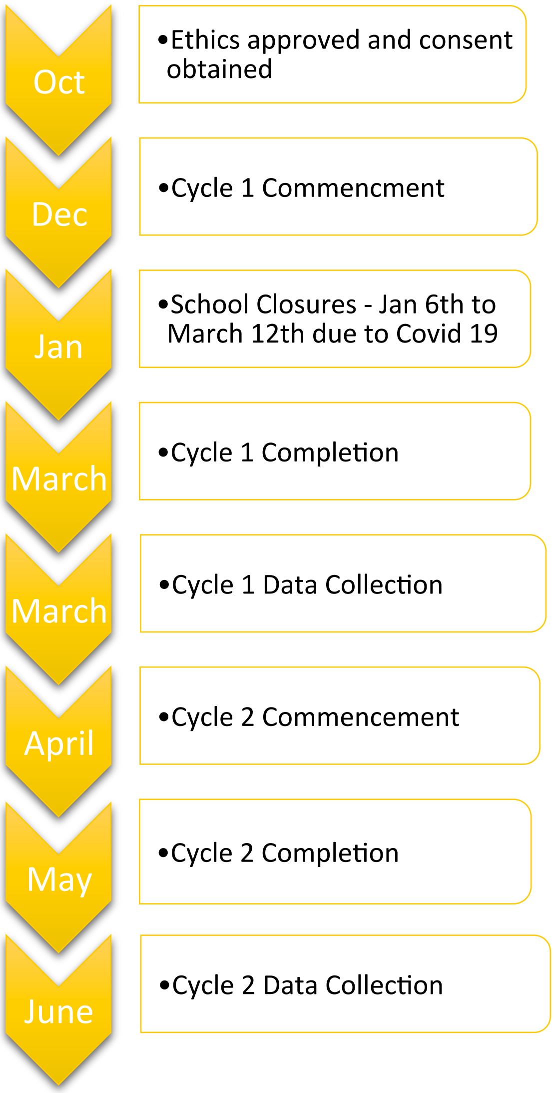


Figure 3.3: Schedule of research

3.8 Data Collection Methods

I adopted Brookfield's (1995) four lenses to examine my practice and to achieve a more accurate perspective on what was going on. Brookfield (1995) identifies four lenses through which we can analyse ourselves, and our practice, including our self, our students, our colleagues and the theory. As part of my data collection, I kept a reflective diary, surveyed, tested, and interviewed the children, had discussions with my critical friends and researched the literature around IBSE - providing triangulation of data for validation purposes (Sullivan et al. 2016).

Data was gathered using qualitative and quantitative instruments. Data were gathered before and after the children experienced the intervention programme. The data collected used five instruments.

1. Teacher reflective journal.
2. Pre- and post-intervention child questionnaires.
3. Pre- and post-intervention child interview.
4. Critical friend conversations.
5. Misconception worksheet.

3.8.1 Reflective Journal

Reflection is a fundamental component of self-study action research (McNiff, 2013) and keeping a reflective journal is endorsed by many researchers (Schön, 1991; Moon, 2006; Brookfield, 2009; Sullivan et al. 2016). Reflective journals document the learning process and provide insights into our thinking, practice and decision making (Sullivan et al. 2016). My reflective journal provided me with the space to be honest and to think critically about my practice with the goal of improving it, reflection *on* action (Schön, 1983). I found Bortons' (1970) framework to be an effective form of reflection, particularly for day-to-day guidance on where to take my research next, asking myself "What? So what? Now what?"

I recorded my own internal conversations about my lessons, scrutinising what went right or wrong, the challenges I faced and the changes I would make. These reflections often echoed real conversations with my critical friends. It was also important to me to analyse the deeper aspects of my practice, such as my values - whether or not I was living to them, my biases - their influence on my practice and my teacher identity and any issues of hegemony that were arising in my classroom (Brookfield, 2017).

3.8.2 Child questionnaire

The questionnaire (appendix A) was adapted from Varley et al. (2008) in their research into children's attitudes to Science. This allowed the findings of my research to be compared to their findings.

The pre-intervention questionnaire was administered in March 2021 (end of traditional teaching). This data was analysed to inform the direction of my intervention. An identical post-intervention questionnaire was carried out at the beginning of June 2021 (end of inquiry teaching). The results of both were compared to establish any changes in the children's attitudes to Science.

The questionnaire used a three-point Likert scale "smiley" face to help the children to show the strength of agreement with a statement. The questionnaire in the present study was made up of five parts:

- Children's attitudes to school.
- Children's' attitudes to school Science.
- Children's' attitudes to Science experiments in school.
- Children's' attitudes to learning in Science.

In the final part, children were asked three open-ended questions concerning their favourite Science lesson and least favourite lesson. They were also asked to "draw a picture of oneself and your class doing Science at school".

3.8.3 Child interviews

I chose to interview children in a group as this approach could enable children to help each other to extend their thinking (Brooker, 2001) and give me more insights into their experiences of school Science. Within the class, 4 children were selected for interview. Children's names were put in a box and I randomly picked four names from the box. The same four children participated in the pre and post intervention interviews.

In both interviews the four children were asked to respond to several broad open-ended questions, aimed at ascertaining their attitudes to being at school, their experiences of learning Science at school and their views of Science in general (appendix B). The post-intervention interviews tried to identify/reveal changes in children's' attitudes and establish some of the elements that might have influenced children's' change of attitude. Each interview lasted between 20 - 25 minutes and was audio recorded.

3.8.4 Critical Friend

Action research relies on dialogue and conversations developed with critical friends. Kember, Ha, Lam, Lee, NG, Yan, and Yum (1997:464) claim that, "the role of 'critical friend' in action research is perceived as an agent for teacher development". Costa and Kallick (1993:50) define the role of the critical friend as:

> ...a trusted person who asks provocative questions, providing data to be examined through another lens, and offers critique of a person's work as a friend. A critical friend takes the time to fully understand the context of the work presented and the outcomes that the person or group is working toward. The friend is an advocate for the success of that work.

I ensured this happened in this self-study by forming a 'critical friend' relationship with two people. The first, a teacher colleague in the same school with a proficiency in primary teaching and interest in research. The other colleague is a second level Science teacher, who has experience in teaching primary Science education at third level. I trusted my critical friends to analyse and critique my work, provide feedback, engage in robust discussion and constructive criticism, with the aim of improving my practice.

3.8.5 Misconceptions worksheets

The research discussed in Chapter 2 (section 2.4) revealed that regarding understanding of key Science concepts, many children have misconceptions. Some of their ideas and views conflict with scientific views.

To direct my planning and teaching, I developed a misconception worksheet (see appendix D/E) specific to each Science topic I taught, to identify the children's misconceptions and the origins of these misconceptions. This consisted of a number of closed questions to identify misconceptions they may have regarding one particular concept (e.g. light, sound) and a number of open questions to explain their reasoning. These worksheets were administered several days before the children were taught the specific topic for me to assess their prior knowledge. They were given the same worksheet several days after the final lesson on that topic. This enabled me to assess their learning and the effectiveness of those lessons.

3.9 Researcher Role

Small-scale action research has been critised by traditional researchers because of lack of objectivity and rigour (Campbell, Freedman, Boulter, and Kirkwood, 2003). The personal involvement of the researcher can cause him or her to interpret data in a potentially subjective way (Bogdan and Biklen, 1983). As the intervention programme used was designed by the teacher as researcher, I am therefore conscious of the possibility of bias during the study. My values and beliefs regarding the teaching of Science informed by the research literature, critical friend conversations and classroom practice qualified me to undertake this research and bring a positive unique perspective to the interpretations. However, I made every effort to safeguard objectivity when analysing the data and took a number of measures to ensure validity and rigour of the data.

3.9.1 Validity

The process of validation was an important consideration for the present small-scale action research self-study. Validity refers to the accuracy of research - do the findings really represent what they are supposed to measure. Sullivan et al. (2016) claim that traditional research maintains that validity relates to replication and generalisation. They suggest that action research does not align such assumptions and that authenticity can be used as criteria of validity. According to McNiff and Whitehead (2009:14) "in action research the validity of your claim can be demonstrated when you show that you have moved towards a situation in which you are living your values more fully in your practice." They put forward two forms of validation: personal validation, and social validation. McNiff and Whitehead (2009:15) argue that personal validation is a form of self-validation whereby the researcher asks him or herself "can you show to your own satisfaction that you are trying to live your values more fully in your practice?". Social validation is where others critically consider the validity of your claim to knowledge.

Even though this study was small scaled and aimed at improving teaching and learning of Science with my class, it was still very important to show validity in my findings. The use of triangulation, involving multiple data sources can enhance validity as it reduces the dependency on one position (Denscombe, 2007). I used a variety of data sources during this study, this enabled me to triangulate the data. These included: questionnaires (closed and open-ended responses), semi-structured group interviews, reflective journal and 'critical friend' conversations. As stated previously action research is very subjective, to uphold objectivity I made my research accessible for scrutiny by others (Sullivan et al., 2016) including my critical friends, colleagues and children affording them opportunities to verify or contest the accuracy of my claim i.e., that my classroom practice was in line the values that I held.

3.9.2 Rigour

The aim of rigor in qualitative research is to reduce the chance of bias and maximize the accuracy and credibility of research results. Winter (1989) sets out six criteria which can be used by action researchers to strengthen the rigour of their research (see table 3.3 below). I have tested the rigour of my claims to knowledge by fulfilling all six criteria in this study.

Table 3.3: Winter's six criteria of rigour

Winter's Criteria	**Addressing Winter's Criteria**
Reflexive Critique:	I made modest claims based on reflections from my own practice, surveys and interviews
Dialectics Critique:	The study allowed me to engage with IBSE, which enabled my values to be embodied in practice as I facilitated the implementation of IBSE with my class.
Collaborative Resource:	I sought viewpoints and criticisms of children's, critical friends and supervisor - enabling me to gain insights into my own practice
Risk:	The purpose of this study was to change and improve my classroom practice. It was a challenge to change my classroom practice from teacher centred to a more children centred.
Plural Structure:	A variety of viewpoints were included: children, critical friends and supervisor
Theory, Practice, Transformation:	The study intertwines theory and practice - study allowed me to develop and then to test. A theory in my classroom practice. I engaged with the theory set down by others to bring about improvement in my classroom practice.

3.10 Data Analysis

Data was collected using both quantitative and qualitative methods. The quantitative data (closed questions on questionnaire) were analysed numerically (Cohen at al., 2007). Thematic analysis was used to analyse the qualitative data (open questions on questionnaire, children's drawings, reflective diary and critical friend conversations). Thematic analysis involves "identifying, analysing and reporting patterns (themes) within the data" (Braun and Clarke, 2006:6). According to Denscombe (2007) qualitative research can collect large amounts of data. Creswell (2014:180) argues that qualitative data analysis consists of "preparing and organising the data (transcripts) for analysis, then reducing data into themes …and finally representing the data in figures, tables or discussion". I chose thematic analysis as it enabled me to 'make sense' of a large amount of data and convey themes in a clear, constructive and meaningful way. Thematic analysis encounters criticism with scientists suggesting that it has "no particular kudos as an analytical method" (Braun and Clarke, 2006:97). While I acknowledge the subjective nature of qualitative research, I enhanced the validity of using thematic analysis by pursuing a six-phase process (Braun and Clarke, 2006) shown in table 3.4.

Table 3.4: Braun & Clarke, six-phases of thematic analysis

	Phase	Description of the process
1	Familiarising yourself with your data:	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2	Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3	Searching for themes:	Collating codes into potential themes, gathering all data relevant to each potential theme.
4	Reviewing themes:	Checking if the themes work in relation to the coded extract (Level 1) and the entire data set (Level 2), generating a thematic 'map' of the analysis.
5	Defining and naming themes:	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6	Producing the report:	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis of the research questions and literature, producing a scholarly report of the analysis.

3.11 Conclusion

This chapter outlined the research methodologies used in this action research study. The choice of research paradigm was interrogated, the rationale of the nature of the research was reviewed and the ethics process was described. In the next chapter I will discuss the analysis of the collected data and subsequent findings.

Chapter 4 Findings

4.1 Introduction

In this chapter I examine findings relating to the use of inquiry-based learning in my Science lessons to encourage the children to develop positive attitudes towards school Science.

The central focus of this chapter is to reveal how I tried to improve my practice by using an inquiry-based approach in the teaching of Science. The chapter consists of two cycles of research, and these are presented in a chronological manner. The first cycle took place over four lessons, two in December 2020 and two in March 2021 (gap due to school closure because of Covid). I adopted my traditional approach to teaching Science in Cycle 1 (reconnaissance). Cycle 2 (inquiry-based) occurred over 6 lessons in April and May 2021. My engagement in this research enabled me to recognise and better understand my own core values that influence my teaching (McNiff, 2002).

4.2 Rationale

Primary Science can present children with a chance to understand the world around them and help develop their cognitive and scientific skills (Harlen, 2010). To achieve this, primary Science needs to be experienced as an engaging and interesting subject related to the everyday life experiences of the children (Rocard et al. 2007).

When I started out on this self-study, I was concerned that the children in my class were not actively engaging in Science lessons, taking responsibility for their own learning, or very interested in learning Science. I thought that maybe my teaching approaches to Science contradicted my educational values. I was not providing children with the opportunities to carry out their own inquiries, inhibiting them from becoming self-directed learners.

My review of the literature has informed my belief that implementing an inquiry-based approach to teaching Science could enable the children to appreciate and develop an interest in Science.

4.3 Cycle 1 - Misconception findings

Prior to introducing a new Science topic, teachers should elicit children's prior knowledge (Gomez-Zwiep, 2008). Before I taught a new Science topic, I asked the children several questions around each topic to elicit their knowledge and misconceptions (and reason why) regarding this topic (see appendix D). I repeated this after teaching the concept and compared the results. I chose two Science concepts to teach in Cycle 1, *Heat* and *Materials* (see appendix J for Cycle 1 lesson plans).

Children's answers on misconception worksheets (pre-reconnaissance) showed they had many misconceptions about *Heat*. For example, as shown in Table 4.1 only 40% of children thought that heat and temperature were not the same thing, and significantly none of those children had an accurate explanation for their answer.

Initially I was pleased with a large increase in children having the correct answer for all five questions post-reconnaissance. For example, 67% of children thought that heat and temperature were not the same thing (Q1) and an increase of 52% who thought that heat could travel through solids (Q5). However, children's explanations in their open answers showed that many of the children still had not acquired the accurate scientific explanation, and therefore had not overcome their misconceptions. Only 8% provided an accurate explanation for Q1 and 23% for Q5.

Table 4.1: Misconception findings for the topic of Heat

Misconception	Pre-reconnaissance (n=20)		Post- reconnaissance (n=18)	
Topic: Heat	**Correct answer**	**Correct ans with correct reason**	**Correct answer**	**Correct ans with correct reason**
1. Is heat and temperature the same thing?	40%	0%	67%	8%
2. Which desk is warmer, teachers or SNAs?	5%	100%	56%	20%
3. Does heat travel from hot to cold, cold to hot or in both directions?	15%	0%	39%	29%
4. Does hot water have more/ less/the same amount of energy as cold water?	25%	20%	56%	30%
5. Can heat travel through a solid material? Like metal or wood	20%	25%	72%	23%

The results for the topic *Materials and Change* were quite varied (see table 4.2 below). Answers for Q2 pre- and post- reconnaissance were very similar, leading me to believe that most children's ideas about the concept did not change after two lessons. However, the answers post-reconnaissance were far more positive for Q1 and Q3. There was an increase of 24% of children selecting the correct answer for Q1. For Q3, there was an increase of 41% of children selecting the correct answer, with 70% of them having an accurate reason that a dissolved substance has not disappeared.

Table 4.2: Misconception findings for the topic of Materials and Change

Misconception	Pre –reconnaissance (n=19)		Post – reconnaissance (n=15)	
Topic: Materials and Change	**Correct ans**	**Correct ans with correct reason**	**Correct ans**	**Correct answer with correct reason**
1. What happens when you put a spoonful of sugar into water?	63%	100%	87%	100%
2. Will a glass of water with sugar in it weigh the same as a glass of water without sugar in it?	58%	55%	60%	56%
3. When you dissolve something do you make it disappear?	26%	40%	67%	70%

Upon reflection (throughout Cycle 1) I felt that some of the misconceptions I was attempting to teach were too abstract for the children and unsuitable for their age group, particularly regarding the area of *Heat*.

Reflecting on my own practice in Cycle 1, I found that perhaps I did not allow enough time for discussion around *why* the different phenomena did or did not occur. I did not relate the activity back to the scientific concept explicitly, and I think many of the children found it difficult to make those connections on their own.

> *Others [concepts] I fear are too abstract in general and perhaps beyond the ability of 3rd class children. I also wonder if some of the activities were too abstract, maybe the investigations were too far removed from a direct line of thinking and the children could not grasp the full concept (Reflective Journal, 10th December 2020).*

Particularly for some of the activities in the lessons on *Heat*, a conclusion was implied rather than proved, which might have led to the children maintaining their misconceptions. Where there was a clear connection between the activity and misconception there were positive results from the post- reconnaissance answers.

4.4. Children's attitudes to school and school Science

As discussed in Chapter 2, research suggests that children's attitudes to Science form during their experience of Science in school (Murphy and Beggs, 2003), these attitudes influence the child's learning outcomes and uptake of Science in secondary school (Pell and Jarvis, 2001; Osborne et al. 2003). After teaching Science in my own traditional way (Cycle 1), I administered a questionnaire (March 2021) to the class to ascertain their attitudes to school, Science, and the teaching of Science (appendix A). I also interviewed four children (see appendix K for interview transcript – post Cycle 1).

4.4.1 Children's attitudes to being in school

The first section of the questionnaire was concerned with the children's attitude to being in school. This allowed me to compare their attitudes of school Science to that of their school experience. Findings are shown in table 4.3 below.

The children were positive about being in school. For example, 83% enjoyed working with their friends and 66% were happy at school. Interestingly, 83% of the children claimed that they work very hard at school however, only 33% thought school was interesting and only 22% enjoyed doing schoolwork.

The next section contrasts these findings with children's attitudes towards school Science.

Table 4.3: Children's attitudes to school

Statement	Pre-intervention (n = 18)		
What I think about being in school:	**Yes**	**Not sure**	**No**
1. I like school	66%	11%	22%
2. I'm happy at school	66%	6%	28%
3. I work as hard as I can at school	83%	11%	6%
4. I find school interesting	33%	39%	28%
5. I enjoy doing schoolwork	22%	33%	44%
6. I enjoy working with my friends at school	83%	6%	11%
7. I enjoy working on my own	39%	11%	50%

4.4.2 Children's attitudes to school Science

Table 4.4 shows the children had a positive inclination towards school Science. For example, 77% of the children found school Science interesting, this contrasts with only 33% of the children who found school interesting. An interesting finding is the percentage of children who enjoy Science better than other subjects i.e. 39%. This finding may seem low however, when you consider that there are 12 subjects on the primary curriculum it is quite positive. Curiously only 28% of children found Science easy and just 44% are looking forward to Science in secondary school.

Table 4.4: Children's attitudes to school Science

Statement	**Pre-intervention (n = 18)**		
What I think about school Science:	**Yes**	**Not sure**	**No**
1. School Science is easy	28%	33%	39%
2. School Science is interesting	77%	12%	11%
3. I like school Science better than other subjects	39%	39%	22%
4. I look forward to Science lessons	55%	28%	17%
5. I am looking forward to learning Science in secondary school	44%	33%	22%

4.4.3 Children's attitudes to Science experiments

Section three relates to children's attitudes about Science experiments, see table 4.5. 72% of the children liked working with their friends, whereas only 39% enjoyed doing Science on their own. This was reiterated in the interviews with the children when one child explained that he liked working with friends because they could help each other, while another child said,

> "Sometimes I don't like when we do it in groups because sometimes, we argue about what we should do".

Interestingly, 71% of children enjoyed finding out why the experiment worked, however, only 44% enjoyed planning and doing their own experiment. It is possible that the children were unfamiliar with this way of doing Science, i.e. they were not used to planning and doing their own experiment. This could also be the explanation to why they had such a high response (77%) to the question *I enjoy watching the teacher doing experiments*. Again, data from the interviews correlates results, "I also like when we do the Science experiments separately and then you show us if we got it wrong… that's fun".

Table 4.5: Children's attitudes to Science experiments

Statement	**Pre-intervention (n = 18)**		
I enjoy Science experiments when...	**Yes**	**Not sure**	**No**
1. I do an experiment by myself	44%	12%	44%
2. I do an experiment with my friends	72%	17%	11%
3. I watch my teacher doing an experiment	77%	6%	17%
4. I plan and do my own experiment	44%	28%	28%
5. I find out why the experiment worked	71%	6%	11%
6. I chose my own equipment	50%	33%	17%

4.4.4 Children's attitudes to learning of Science

Table 4.6 shows children had a negative response to too much reading and writing in Science lessons, only 28% enjoyed completing worksheets/workbooks, 33% enjoyed reading their Science textbook and 39% enjoyed writing about what they did during Science lessons. This is reflective of the responses from the children during the interview (discussed in next section). As seen from Q3 and Q6 the children preferred to be actively engaged when learning Science.

Table 4.6: Children's attitudes to how Science is taught

Statement	Pre-intervention (n = 18)		
What I enjoy in science lessons: **I enjoy Science when…..**	**Yes**	**Not sure**	**No**
1. My teacher explains things to the class	66%	22%	11%
2. The teacher tells me what to do	50%	17%	33%
3. When we go outside the classroom	83%	6%	11%
4. I fill in my worksheet/workbook	28%	11%	61%
5. I write about something I did in Science class	39%	22%	39%
6. I design and make my own things	72%	11%	17%
7. I read my Science schoolbook	33%	39%	28%

4.4.5 Children's attitudes to Science lessons

Careful analysis of the children's responses to open-ended questions, drawings of themselves and their class doing Science in school and interviews reveals more detail on their engagement in and attitudes towards Science lessons.

Table 4.7: Reasons children enjoyed Science lessons

Why did you like the Science lesson	**No. of children (n = 18)**
Fun	6 (33%)
Hands-on activity	4 (22%)
Yes (possibly misunderstood question, answered *did* you like it?)	3 (17%)
Enjoyed observing events	2 (11%)
Interesting	2 (11%)
Did it ourselves NB: Regarding filters (a once off lesson for Science Week)	1 (5.5%)
I don't like Science	1 (5.5%)
Other	3 (17%)

Results from table 4.7 reveal a positive attitude towards Science lessons in general, with 6 (33%) of children regarding Science as fun. Results also found that the children enjoyed the active nature of Science lessons, with 4 (22%) children mentioning a hands-on element of lessons and 1 (5.5%) enjoying the autonomous element of a lesson carried out for Science Week. Interview data echoes this in which the children said they preferred doing experiments, when asked whether it is more fun doing experiments themselves or watching the teacher do it, one child answered, "doing it ourselves" and a second child agreed.

It is worth noting that 5 (28%) children had difficulty articulating themselves and answering an open-ended question, with 3 (17%) answering "yes", 1 (5.5%) answering "I like this" and 1 (5.5%) leaving the question blank. Interestingly, only 2 (11%) children mentioned the lessons being interesting, in contrast to the 77% of children who found Science interesting in the closed responses. This could again be related to literacy levels within the class and children finding it more challenging to write a response than tick their preferred box.

The results from table 4.8 below show 7(38%) children found Science lessons boring, again in contrast to the 77% who find Science interesting (based on closed questions). Here the children are referring to a particular lesson they did not like, so it is plausible that although the children found this lesson boring it has not changed their overall opinion of school Science. However, during the interview when asked, "do you like doing Science in school?" one child stated,

"it is boring for me" …. "I don't like doing the worksheets"

It is interesting to note that in the open questions only one child mentioned too much writing as being a negative, while this point was reiterated by all four children in the interview setting, who said they liked "everything except for the worksheets" and asked for "more experiments, less writing!".

The children drew a picture of their class doing science, 67% of these illustrated the children participating in hands-on activities (see appendix L), with many also featuring the teacher, see figure 4.1 below. The drawings were mainly concerned with two topics "bubbles" and "filters", neither of which were taught in Cycle 1. This result coincides with Varley et al. (2008), where 57% drew pictures of themselves engaging in hands-on activities.

Table 4.8: Reasons children did not enjoy Science lessons

Why did you not like the science lessons	No. of children
Boring / not interesting	7 (38%)
Blank	4 (22%)
Did not have desired outcome / didn't work	2 (11%)
Least favourite of all lessons (no actual reason given)	1 (5.5%)
Took too long	1 (5.5%)
Want to know what's next	1 (5.5%)
Looked weird	1 (5.5%)
Didn't like content	1 (5.5%)
Don't like Science	1 (5.5%)
Don't like working with others	1 (5.5%)
Don't like doing experiments	1(5.5%)
Too much writing	1 (5.5%)

Figure 4.1: Child's drawing of Science at school (Cycle 1): children carrying out experiment on dissolving.

4.5 Reflection on Cycle 1

Cycle 1findings have raised several points to consider, particularly in relation to my values and whether they were evident in my practice at the time. At the beginning of the research process, I identified my values as children's autonomy and inclusivity. Throughout the reconnaissance phase I referred to these values, however, I was surprised to find as I reflected that these values were not as central to my practice as I would have wanted.

Many children retained their misconceptions around *Heat* after the teaching and learning had occurred. However, the results were more positive around the concept of *Materials and Change.* Conversations with my critical friend revealed that my learning objectives and misconceptions should be reflective of each other.

> *I think you need to consider what you are trying to achieve in carrying out these lessons, the lesson content and misconceptions you are addressing might need to be more explicitly connected so that the children have a clear understanding of what is being expected of them. (Conversation with critical friend, 15th December 2020)*

Upon reflection, it is probable that I did not spend enough time on each topic to generate cognitive conflict and support the children to reconstruct their thinking (Gomez-Zwiep, 2008). Also, the content of the misconception worksheets might be too advanced for the class level. I concur with Howard (2018) who claims some concepts are too complex for most primary school children and are better left until secondary school.

> *It is often the open ended, higher order questions, that cause difficulty for the children, dividing the class. The children seem to struggle with rationalising their own ideas and explanations, or maybe lack confidence in themselves as this is a new expectation or request. (Reflective Journal, 14th December 2020)*

The children really struggled with the amount of writing within the lessons, as many of the children did not have the literacy skills to articulate their thinking accurately, providing me with an inaccurate assessment of their learning. This had implications for how I wanted to approach Cycle 2.

> *I found that the children had real difficulty in verbalizing their ideas and thoughts about different science concepts. Many of the children when asked to explain their ideas about a topic simply gave a yes/no answer… I noticed this amongst many of the children of all different academic abilities. However, it was more prevalent amongst the children who had a lower literacy level or language level. (Reflective Journal, 10th December 2020)*

The lessons that I was teaching involved the children being active and hands-on with their learning. However, this did not mean that they were working autonomously, upon deeper reflection I realised that this was not reflective of my values.

> *Just because the children are doing things themselves, does not mean it is a creative and meaningful learning experience. They are just following a procedure without any thought process behind it and possibly without even knowing why they are doing it. I know this makes things easier for classroom management and ticking off learning objectives but it does not actually reflect my values. I would prefer if the children did not necessarily get the desired result but actually developed their skills and learnt something from the process, this learning could be different for every child. (Reflective Journal, 10th February 2021)*

The children were carrying out prescriptive activities with a predetermined result. They had no choice in the lesson, if an experiment did not give the desired result I demonstrated it for the class rather than allowing the children the chance to try it again themselves to problem-solve.

> *I: Which part is more fun, doing it yourself or watching me do it?*
> *B: I think doing it ourselves*
> *L: Yeah*

I: And do you think you'd like to see me doing it to do it right or would you like to try it again yourself to get it right?
B: I think try it again
I: Try it again yourself?
B: Yeah *(Interview A, 24th March 2021)*

My critical friend reminded me that children being active in their learning is not just being physically active, but also "minds on". It is important that they decide elements of the procedure, so they understand why they are carrying out certain steps and are invested in the lesson and the learning.

When I critiqued my practice during Cycle 1, I found that I was not living as closely to my values as I had allowed myself to believe. The children were not learning autonomously but rather they were following a procedure without any self-direction. This also meant that there was no creativity to the lessons, the children could not further explore an aspect of the lesson that they were interested in. I had always considered Science to be one of the more inclusive academic subjects, as it draws on a range of skill sets not dependent on academic ability. However, I found that I over-emphasised writing and question sheets which led to children with a lower academic or literacy ability being unable to participate to their full potential. This was a significant learning moment for me, I had to consider what changes I could make to really embed my values in my practice for Cycle 2.

4.6 Implications for Cycle 2

I took the time after Cycle 1 to reflect on what I had written in my journal, discussed with my critical friend and what the children had told me in questionnaires and interviews to decide on the changes I was going to implement in Cycle 2. I knew that I wanted the children in the class to have more ownership over their work, while also developing their scientific skills.

I decided that using a Guided Inquiry approach would be best to achieve this, encouraging the children to work as scientists and problem solve issues relevant to them (Capps et al. 2012). This meant that I would act as a facilitator of learning while the children designed their own procedure and solution. Using IBSE meant that the children were developing their skills, an area of the curriculum that I had not emphasised previously.

> *I have always included skills when planning lessons, however, they were just a consequence of the activity, they were never something I actually focused on or sought to develop and tease out (Reflective Journal, 25th January 2021)*

To improve classroom management and listen to the requests of the children in the interview, I decided to allow the children to choose their own groups and work with friends. Additionally, the positive response the children gave to working outdoors prompted me to incorporate this into my lesson planning. I decided to move away from tedious, long-winded worksheets and use simple post-its and drawings to assess the children's learning and provide them with the opportunity to express themselves and learn without language causing a barrier.

> *Worksheets seemed to be causing a major issue for some children. They either take too long, meaning they miss out on the active part of the lesson or they are not able to do it at all and their self-confidence takes a hit. If I value inclusivity it is important that every child gets to engage with every part of the lesson. It is also likely that those who find writing difficult might have talents in other aspects of the lesson, so they need the opportunity to excel and reach their potential (Reflective Journal, 27th March 2021)*

I chose to focus on misconceptions that were more relevant to the children and their life experiences; I also planned the activities and learning objectives in relation to these misconceptions to support the children's learning. Finally, I allowed more time to cover each topic so that I could conference with every child/group of children and allow them to engage fully with the activity.

4.7 Cycle 2 - Misconception findings

For Cycle 2, I chose two Science concepts to teach, *Falling Objects* and *Floating and Sinking* (for lesson plans for Cycle 2 see appendix M). It can be seen from table 4.9 that pre-intervention the children had good prior knowledge of the concept of *Falling Objects* with 95% of the children answering Q1 correctly with a plausible answer, and 24% of those answers mentioning the term *gravity*. Although 75% of the children had the correct answer for Q2, only 27% of those correct answers were in line with scientific thinking.

Post-intervention the results improved significantly. All the children achieved the correct answer for Q1 and Q2. The number of children who mentioned gravity as a factor in their Q1 answer more than doubled. Significantly, 76% of the children had a plausible reason for their correct answer for Q2. For Q3, 60% of the children had a correct reason for their answer, mentioning either the shape or gravity being the same.

Table 4.9: Misconception findings for the topic of Falling Objects

Misconception	Pre-intervention (n = 20)		Post-intervention (n = 17)	
Topic: Forces - Falling objects	**Correct ans**	**Correct ans with correct reason**	**Correct ans**	**Correct ans with correct reason**
1. If I hold up a golf ball and let it go, what will happen and why?	95%	100% correct reason. 24% mentioned gravity	100%	100% correct reason. 53% mentioned gravity
2. If I drop a scrunched A4 page and a flat A4 page at the same time, from the same height, will they hit the ground at the same time?	75%	27%	100%	76%
3. If a drop a golf ball and a Ping-Pong ball at the same time, from the same height, will they hit the ground at the same time?	25%	20%	59%	60%

Upon reflection, there are several factors that may have contributed to these positive results: (1) the concept was relatable to the children, they could connect it to their prior experiences; (2) the misconceptions were phrased appropriately for the children; and (3) the content and learning objectives of the lessons were explicitly linked with the three misconceptions.

Table 4.10 shows that the pre-intervention results concerning *Floating and Sinking* were very positive with more than half of the children having the correct answers for many of the questions, and approximately half of those children having the correct reasons for their answers.

Table 4.10: Misconception findings for the topic of Floating and Sinking

Misconception	Pre-intervention (n = 18)		Post-intervention (n = 17)	
Topic: Forces - Floating and sinking	**Correct ans**	**Correct ans with correct reason**	**Correct ans**	**Correct ans with correct reason**
1. Do all heavy objects sink in water?	56%	50%	88%	67%
2. Do all light objects float in water?	61%	55%	71%	75%
3. Does the shape of an object affect whether it floats or sinks?	72%	62%	41%	57%
4. Do all big objects sink in water?	83%	47%	76%	62%
5. Do all small objects float in water?	83%	67%	76%	69%

The post-intervention results were very varied. While the results for Q1 and Q2 improved, the results for Q3, Q4 and Q5 deteriorated. There was a 32% increase in the number of children answering Q1 correctly, with 67% of those children having a correct reason. Half of the children who had a correct reason referred to whether the object was hollow or solid, "Depends on what's inside, if it's hollow it might float", this was significant as these terms had not been used by any child on the pre-teaching worksheets. The result that was most disappointing was Q3, there was a decrease of 31% of children getting the correct answer, with only 57% having the correct reason post-intervention in comparison to 62% pre-intervention. The answers the children gave illustrate the complex nature of the concept of *Floating and Sinking*.

The poor results from Q3, Q4 and Q5 surprised me, however the concept of *Floating and Sinking* is multifaceted, with several interconnecting elements. When I reflected on why this happened, I concluded that the concept may have been beyond the expectations of the 3rd class Science curriculum. An understanding of *density* is critical to truly understanding floating and sinking, however, density is not included on the Primary Science Curriculum, for any class level. Additionally, Q3 had the highest number of blank answers, with 22% of children leaving the answers blank pre-intervention and 35% of children leaving the answer blank post-intervention. Perhaps the lessons did not support the children in overcoming their misconceptions of this concept.

4.8 Cycle 2 - Children's attitudes to school and school Science

4.8.1 Cycle 2 - Children's attitudes to being in school

Table 4.11 shows that many of the children's attitudes to school became more negative post-intervention. There was a slight decrease in the number of children who answered positively for almost all questions. It is interesting to note the discrepancy between a decrease of 16% of children who like school (from 66% to 50%), while the number of children who found school interesting increased from 33% to 56%.

Table 4.11: Children's attitudes to school (pre and post-intervention)

Statement	Pre-intervention (n = 18)			Post-intervention (n = 18)		
A: What I think about being in school:	**Yes**	**Not Sure**	**No**	**Yes**	**Not Sure**	**No**
1. I like school	66%	11%	22%	50%	17%	33%
2. I'm happy at school	66%	6%	28%	56%	22%	22%
3. I work as hard as I can in school	83%	11%	6%	78%	11%	11%
4. I find school interesting	33%	39%	28%	56%	22%	22%
5. I enjoy doing schoolwork	22%	33%	44%	17%	22%	61%
6. I enjoy working with my friends at school	83%	6%	11%	89%	11%	0%
7. I enjoy working on my own	39%	11%	50%	33%	22%	44%

4.8.2 Cycle 2 - Children's attitudes to school Science

As discussed in section 4.4.2 the children were positively disposed to school Science pre-intervention. These positive attitudes further improved post-intervention. It can be seen from table 4.12 that there was an increase of 28% of children who said they liked Science better than other subjects. There was a 34% increase in children looking forward to Science lessons and this was reinforced by the number of children looking forward to doing Science in secondary school almost doubling from 44% to 83%.

These are very significant results as they concur with research that found that inquiry-based approaches to Science can improve children's motivation in and attitudes towards school Science (Rocard et al 2007; Harlen 2010).

Table 4.12: Children's attitudes to school Science (pre and post-intervention)

Statement	Pre-intervention (n = 18)			Post-intervention (n = 18)		
C: What I think about school science:	**Yes**	**Not Sure**	**No**	**Yes**	**Not Sure**	**No**
1. School science is easy	28%	33%	39%	33%	39%	28%
2. School science is interesting	77%	11%	11%	78%	6%	17%
3. I like science better than other subjects	39%	39%	22%	67%	17%	17%
4. I look forward to science lessons	55%	28%	17%	89%	0%	11%
5. I am looking forward to learning science in secondary school	44%	33%	22%	83%	11%	6%

4.8.3 Cycle 2 - Children's attitudes to Science experiments

> *I was really amazed when I calculated the final results from the Attitudes Questionnaires, I knew the children already had a positive attitude to Science anyway, but to see some dramatic increases in results, it really made the whole process worthwhile for me. I couldn't believe how perceptive the children had been to the changes I had made and how assertive they were in recognising how they learn and how they feel about their learning. (Reflective Journal, 10th June 2021)*

IBSE encourages an autonomous exploratory approach to teaching Science. Some of the most significant differences pre- and post-intervention can be seen in children's attitudes to Science experiments (see table 4.13). For example, an increase 28% of children who enjoyed choosing their own equipment (78% post-intervention) and an increase of 17% of children who enjoy experimenting with their friends (89% post-intervention). In contrast, there was only a 3% increase in the number of children who enjoyed planning and doing their own experiment (47% post-intervention), however, it is possible that the children perceived this question as working alone rather than autonomously, especially considering the low number of children who enjoyed working alone, 17% post-intervention.

Table 4.13: Children's attitudes to carrying out Science experiments

Statement	**Pre-intervention (n = 18)**			**Post-intervention (n = 18)**		
B: What I enjoy in Science experiments: I enjoy science experiments when…	**Yes**	**Not Sure**	**No**	**Yes**	**Not Sure**	**No**
1. I do an experiment by myself	44%	11%	44%	17%	28%	56%
2. I do an experiment with my friends	72%	17%	11%	89%	0%	11%
3. I watch my teacher doing an experiment	77%	6%	17%	72%	11%	17%
4. I plan and do my own experiment	44%	28%	28%	47%	35%	18%
5. Finding out why an experiment worked	71%	18%	12%	72%	17%	11%
6. I choose my own equipment	50%	33%	17%	78%	11%	11%

Figure 4.2: Children working collaboratively to make a boat

The positive findings were strongly echoed in the post-intervention interview (see appendix N for full transcript), the children responded positively to the autonomy they had in their learning and the ownership they felt over their work, with numerous comments such as

> "I like creating, like designing your own stuff" and
> "Usually we create our own stuff".

When one child was asked why he liked his chosen favourite investigations of the Filter, the Parachute and the Boat (all IBSE based investigations) he replied;

> "I think because all of those three we got to design and make our own ones …well my filter didn't work out but my parachute worked and my boat did"

When asked how this made him feel he said, "happy and proud".

4.8.4 Cycle 2 - Children's attitudes to learning Science

As a key focus of my IBSE intervention was to change my practice from a teacher-directed approach to a child centred one, I was pleased that the children were more positive to learning Science post-intervention, see table 4.14 below. I found it interesting that although the children enjoyed working autonomously with friends, they also wanted direction and support from the teacher. There was an increase in the children who answered *yes* to enjoying Science when *the teacher tells them what to do* and when *the teacher explains things to the class* (11% and 17% respectively). This was echoed in my own reflections and observations;

> *I chose the Guided level of IBSE (level 3) to ensure that I was living to my values and providing the children with many opportunities to work as scientists developing their skills and problem-solving abilities, as well as taking ownership over their work. I chose this level rather than level 4 because of the children's age and lack of experience with IBSE previously, however, from my observations perhaps level 2 would have been more appropriate. The children have really struggled to come up with their own procedures themselves and require a lot more scaffolding and support than I anticipated. This has led to me doing extra lessons so that I could demonstrate what needed to be done. As much as I didn't want to do this, it was important for the children's learning and I also needed to remember the lack of experience the children had with this style of teaching and learning. (Reflective Journal, 12th May 2021)*

Table 4.14: Children's attitudes to learning Science

Statement	Pre-intervention (n = 18)			Post-intervention (n = 18)		
B: What I enjoy in Science experiments: I enjoy science experiments when…	**Yes**	**Not Sure**	**No**	**Yes**	**Not Sure**	**No**
1. The teacher tells me what to do	50%	17%	33%	61%	28%	11%
2. My teacher explains things to the class	66%	22%	11%	72%	22%	6%
3. When we go outside the classroom to do Science	83%	6%	11%	94%	6%	0%
4. I fill in my workbook/worksheet	28%	11%	61%	17%	28%	56%
5. I write about something I have done in Science class	39%	22%	39%	56%	17%	28%
6. I design and make my own things	72%	39%	17%	94%	0%	6%
7. I read my Science schoolbook	33%	39%	28%	35%	29%	35%

There was a decrease in the number of children who enjoyed writing in workbooks or on worksheets, this was to be expected given the feedback in the interviews after Cycle 1. However, what was interesting was the increase in the number of children who enjoyed *writing about something they have done in science class,* with half of the children enjoying this element of writing post-intervention. It is possible that the children enjoyed the planning and drawing element of the lessons as it was not prescriptive and gave them autonomy over their work. Drawings are considered to be an effective way of allowing children to express their emotions and attitudes (Barrza, 1999).

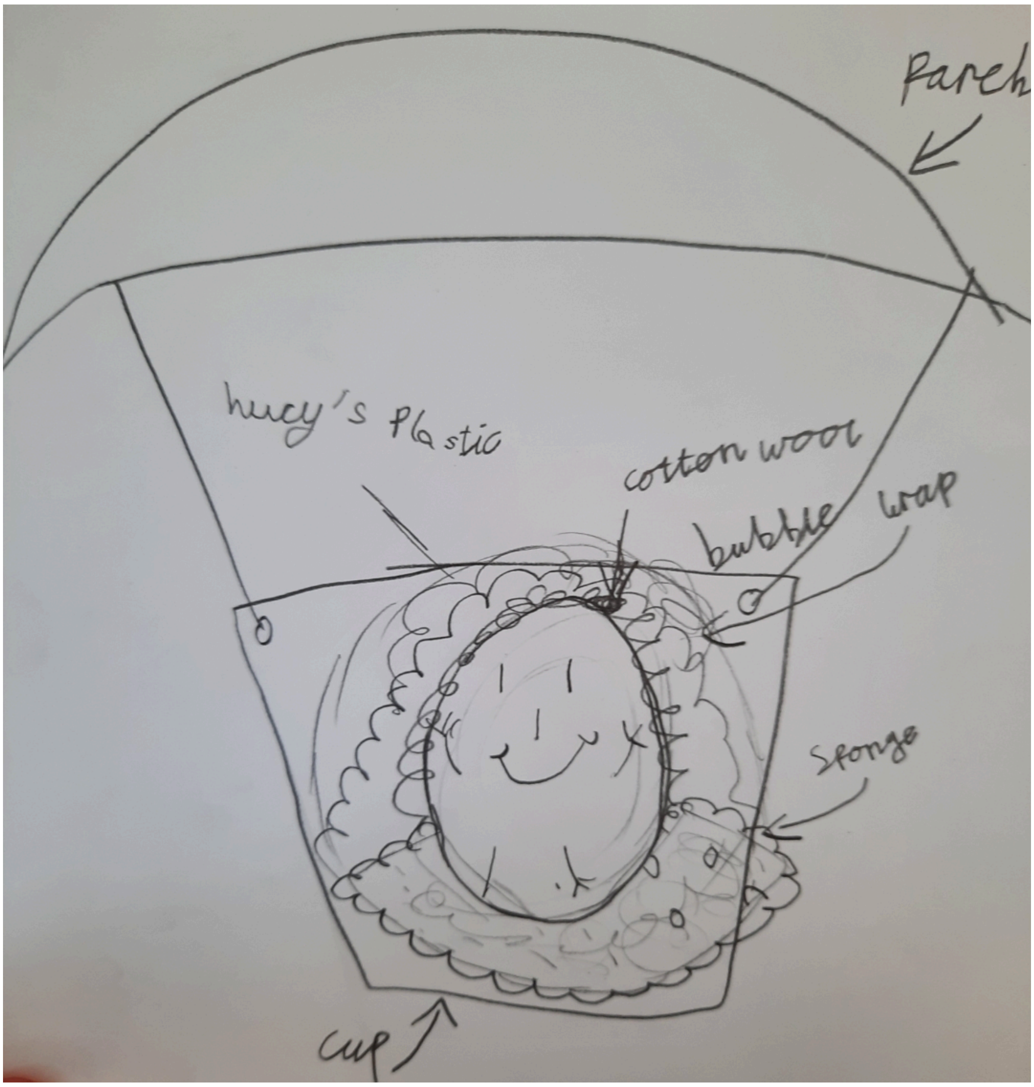


Figure 4.3: Child's plan for egg holder and parachute

4.8.5 Cycle 2 - Children's attitudes to Science lessons

In-depth analysis of the children's attitudes to inquiry lessons was gleaned from their responses to open-ended questions, drawings, and interviews. These provide further evidence of the positive impact of IBSE on children's attitudes to Science lessons. For example, table 4.15 shows that post-prevention 8 children (44%) found Science fun compared to 6 children (33%) pre-intervention. Evidence of "hands-on" Science was further illustrated in the children's drawings of themselves doing Science, 89% of the drawings depicted the children doing "hands-on" Science compared to 67% pre-intervention.

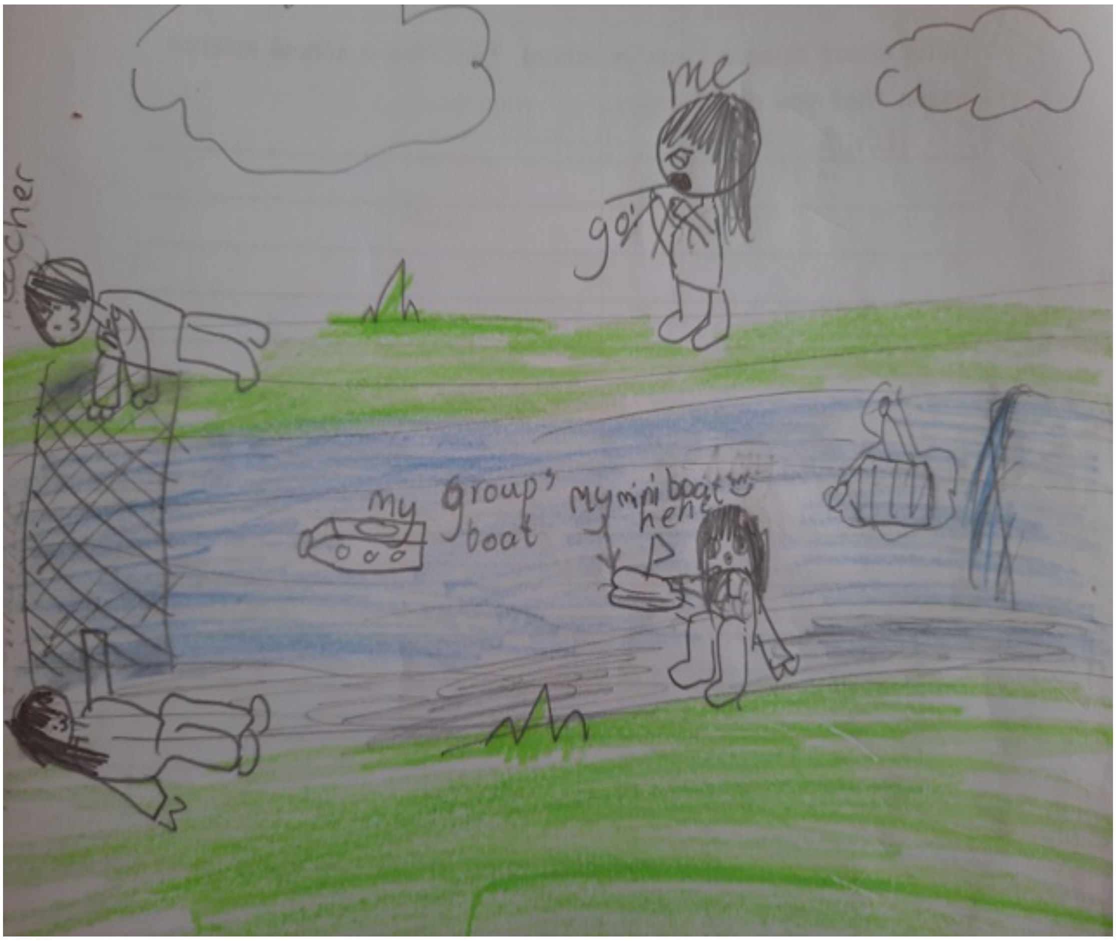


Figure 4.4: Child's drawing of their favourite Science lesson (Cycle 2): Children racing their boats in the river

Table 4.15: Reasons children enjoyed science lessons (pre- and post-intervention)

Why did you like the science lesson	**Pre-Inquiry No of children (n = 18)**	**Post-Inquiry No of children (n =18)**
Fun	6 (33%)	8 (44%)
Hands-on activity	**4 (22%)**	**5 (28%)**
Yes (possibly misunderstood question, answered *did* you like it?)	3 (17%)	-
Enjoyed observing events	2 (11%)	1 (5.5%)
Interesting	2 (11%)	1 (5.5%)
Did it ourselves	1 (5.5%)	2 (11%)
I don't like science	1 (5.5%)	-
Went outside	-	3 (17%)
Collaborative	-	2 (11%)
Designing	-	2 (11%)
Worked out	-	1 (5.5%)
Other	3(17%)	6 (33%)

There were several elements that the children enjoyed after Cycle 2 which had not been mentioned after Cycle 1;

- going outside
- working with friends
- designing their own projects.

These were all elements that I chose to introduce based on findings from Cycle 1, this was reiterated in the interviews when a child said;

> "The last interview we did we said we'd prefer to do some Science lessons outside and you said "yeah", and we did go outside, we did the parachutes and the boats".

This was significant to me as it was evident that I was now living closer to my values in hearing *and* responding to the voice of the child, but also the child recognised that he was being listened to and his voice was valued.

Table 4.16 reveals the reasons the children did not enjoy Science lessons. *Boring / Not interesting* was still a main reason given. It is significant to note that although the questionnaires were answered after Cycle 2, many of the lessons the children liked the least were not taught in Cycle 2. The three least favourite lessons were the body (pre-cycle 1), dissolving and melting ice (Cycle 1). Interestingly, these were listed as the favourite lessons after Cycle 1, however their ranking significantly declined after engaging with the IBSE lessons.

Table 4.16: Reasons children did not enjoy Science lessons (pre- and post-intervention)

Why did you not like the Science lessons	Pre-Inquiry No of children	Post-Inquiry No. of children
Boring / not interesting	**7 (39%)**	**6 (33%)**
Blank	4 (22%)	-
Did not have desired outcome / didn't work	2 (11%)	-
Least favourite of all lessons (no actual reason given)	1 (5.5%)	-
Took too long	1 (5.5%)	1 (5.5%)
Want to know what's next	1 (5.5%)	-
Didn't like content	1 (5.5%)	1 (5.5%)
Don't like Science	1 (5.5%)	-
Don't like working with others	1 (5.5%)	-
Don't like doing experiments	1 (5.5%)	-
Too much writing	1 (5.5%)	-
Not fun	-	1(5.5%)
Not hands-on enough / didn't have enough to do	-	1 (5.5%)
Other	1 (5.5%)	6 (33%)

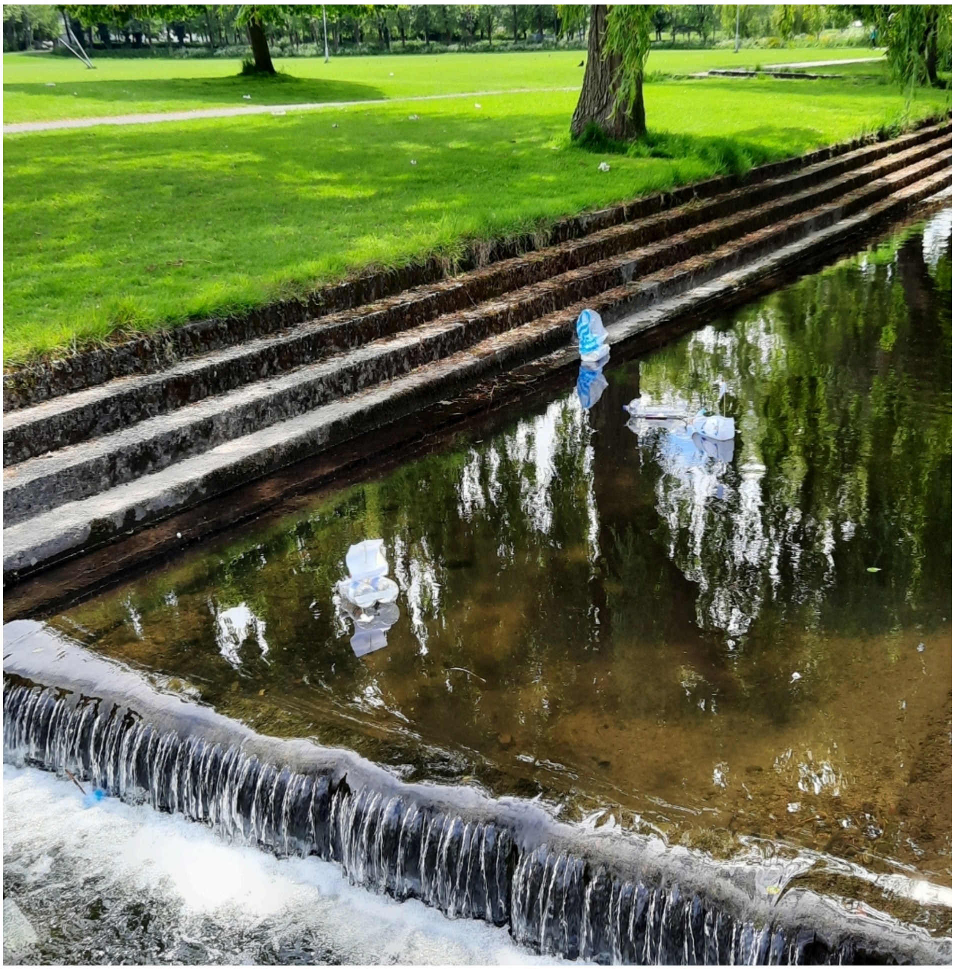
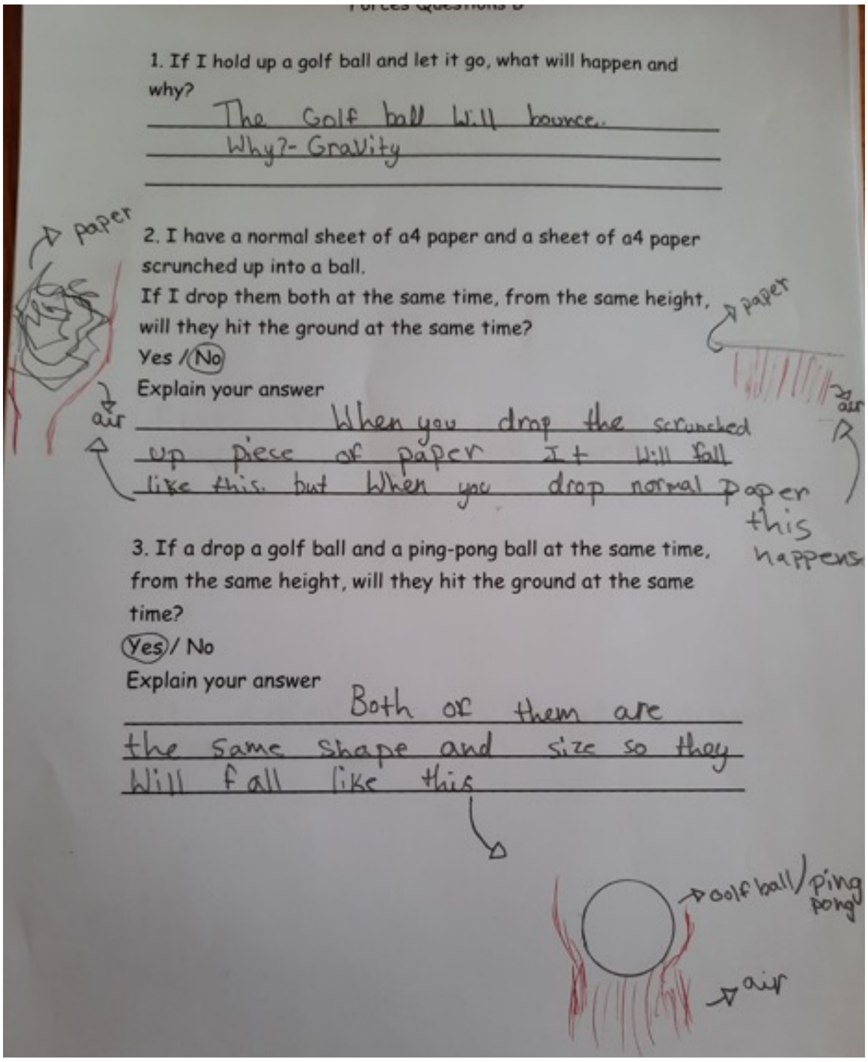


Figure 4.5: Children's boats racing on the river

4.9 Reflection on Cycle 2

Although the results of the misconception questions in Cycle 1 all improved slightly it is my opinion that the learning that took place in Cycle 2 was more valuable. The number of children overcoming their misconceptions in Cycle 1 was significantly low, while in Cycle 2 the percentage of children with correct answers and reasons were higher, particularly in *Falling Objects*. I was concerned with the drop in correct answers for *Floating and Sinking* Q3, however, after a discussion with my critical friend we concluded that the concept was too difficult for the children. Although there was a decrease in correct answers for some questions, overall, the scientific reasoning to support the children's answers was more accurate and considered than it had been in

Cycle 1. One child drew diagrams to explain their thinking, see figure 4.6 below. This gave me the confidence that an IBSE approach was not impeding the children's learning.


1. If I hold up a golf ball and let it go, what will happen and why?

The Golf ball Will bounce.
Why?- Gravity

2. I have a normal sheet of a4 paper and a sheet of a4 paper scrunched up into a ball.
If I drop them both at the same time, from the same height, will they hit the ground at the same time?
Yes / (No)
Explain your answer

When you drop the scrunched up piece of paper It will fall like this. but When you drop normal paper this happens

3. If a drop a golf ball and a ping-pong ball at the same time, from the same height, will they hit the ground at the same time?
(Yes) / No
Explain your answer

Both of them are the same shape and size so they Will fall like this

Figure 4.6: Child using words and diagrams to explain answers to *Falling Object* questions

Teaching Cycle 2 using an IBSE approach was an extremely positive and rewarding experience for me as a teacher, not just throughout the process but particularly when analysing the data and comparing it to Cycle 1.

The children were more engaged and enthusiastic about the Cycle 2 lessons (see appendix O for photographs of the children learning through inquiry), in one reflection I described the atmosphere in the classroom as being *"electric"*. This was carried over into day to day experiences, with more children asking me when we were going to do Science again and then more specifically when are we going to; "make our boats" or "drop the eggs" .This added to my confidence in what I was teaching, and more importantly *how* I was teaching. I found there was a cyclical effect when it came to enjoyment of and engagement in the lessons, the children's motivation and positive attitudes inspired me to be more enthusiastic and creative in my planning and teaching of the IBSE lessons. This cultivated a positive relationship between myself and the whole class.

Classroom Management and Time Management were the two challenges I faced in Cycle 2. Classroom Management was a challenge however, it improved as Cycle 2 progressed. I reflected on a number of reasons for this: (1) children were more engaged with the tasks they were doing so had less need to be disruptive, (2) The children were working with friends so getting along better with peers during group work; (3) the relationship between the class and myself was improving over time.

Time Management was a challenge I identified in Cycle 1, I implemented changes in my practice in an attempt to overcome this challenge, such as fewer activities in each lesson. However, IBSE itself was more time consuming to implement, not only with planning but also when it came to activities. An important aspect of IBSE is that the children are working autonomously but that the teacher conferences with them to get their rationale and extend their thinking and learning.

> *The biggest challenge I felt in this lesson was being pulled in multiple directions by each group. I couldn't get around to conference with each group and have a conversation with each of them. (Reflective Journal, 20th April 2021)*

Another contributing factor to the challenge of Time Management was trying to gauge an appropriate level of support for the children. Initially I wanted to use IBSE Level 3 (Guided), however, I found that the children had far more difficulty with coming up with their own procedure than I had anticipated. The additional support that I had to provide also impacted my Time Management. However, it was important to provide the time for this support as developing the children's skills will contribute to their academic learning of scientific concepts.

> *I had decided to leave the design of the parachutes open-ended to allow the children to be creative and explore options. I was surprised and baffled at how much guidance and scaffolding the children needed to make a functioning parachute…. I was shocked that I needed to help some children with straightforward elements of the parachute making e.g. tying knots. This just reiterated to me the importance of developing these basic skills… I had been hesitant to show the class a pre-made example of a parachute, as I was afraid it would take the creativity and discovery elements out of the learning and it would become too prescribed… In an ideal world I would have been able to sit with each group, discuss their ideas and work with them and ask questions to promote them to make alterations to their work themselves. Unfortunately, time restrictions and classroom management in a busy classroom does not allow for this. (Reflective Journal, 20th April 2021)*

The engagement and positivity the children had within the lessons really excited me. The changes in writing tasks and collaborative nature of the lessons meant that literacy levels were not an obstacle in participating and learning. This allowed me to live more closely to my values and create an inclusive learning environment where different learning styles and abilities were incorporated and respected.

> *I was delighted to see that this lesson really appealed to all types of learners and academic abilities. With Design and Make the children work to the best of their own abilities, they are supported by their peers and scaffolded by the*

teacher to progress their design and probe their way of thinking. (Reflective Journal, 29th April 2021)

Although Time Management was a challenge for me, I do ultimately feel that the Voice of the Child was heard and valued in my classroom. The children's confidence as self-directed learners and their genuine interest in and enjoyment of Science was evident from the questionnaire and interview findings. I had the reassurance I needed from both the children and the data to know that I was making a difference in a positive way.

I felt like everything I had been doing has been worthwhile. There was a great sense of autonomy that emerged [from interviews] that I didn't realise was emerging from the regular classroom interactions. In some ways, I underestimated myself and the children. I didn't give them the credit to see the difference between the lessons, and they managed to do that. (Reflective Journal, 2nd June 2021)

4.10 Conclusion

My main aim in engaging in this study was to improve my classroom practice and the children's learning of Science. Analysis of the findings suggest I successfully introduced inquiry-based learning to my teaching and used it to enhanced the children's enjoyment of Science lessons and develop positive attitudes towards learning Science. By teaching through IBSE I helped the children to become independent learners, taking responsibility for their own learning. Chapter 5 draws further on these findings and discusses the significance and limitations of the study. Recommendations for my future practice and wider study will also be examined.

Chapter 5 Conclusion

5.1 Introduction

In this self-study I wanted to find out if using an inquiry-based approach to teaching Science could enhance the children's attitudes and learning. Data analysis and triangulation found that not only did the children's attitudes improve significantly but their scientific reasoning, thinking, skill development and general learning of the subject was also enhanced. Additionally, my enjoyment of and confidence in teaching Science also improved as my pedagogical practice shifted back from a deductive to inductive approach. This chapter is concerned with the conclusions I have drawn from my experience in conducting this self-study, it includes limitations of the study, my learning, reflecting on my values and recommendations for future research

5.2 Limitations of the study

I found the biggest limitation for my research was time. I began my Cycle 1 - Reconnaissance in December 2020, however, this was interrupted halfway through by school closure (January to March 2021) due to Covid-19. Consequently, I had a shorter period to complete Cycle 1 and carry out Cycle 2, which led to weekly lessons in Cycle 2 rather than the fortnightly lessons which occurred in Cycle 1.

A significant limitation when working in a teacher/researcher role with children is the potential for bias in responses. It is plausible that the children might have altered their responses to please their teacher (me), rather than answering honestly. This is also a potential limitation in the conversations with critical friends, due to their personal and professional relationship with me they may have embellished their responses.

As the children were new to IBSE I should have applied a more structured level of IBSE to scaffold their learning and ideally if time allowed, I would introduce the children to more open Guided Inquiry in Cycle 3. This is something I intend to explore with my class next year.

5.3 My learning and the implications

Since beginning this self-study in July 2020 I can see a significant development in my own learning, both personally and professionally.

Although I had a basis in reflective practice from my undergraduate degree, it is only since beginning this journey that I have really begun to understand and observe the benefits honest reflection can have on my practice. I have learnt that reflection should not just be used when I face a challenge in the classroom, but rather it should be integrated into my day-to-day practice (Brookfield, 2017), with the potential to enhance all aspects of school life, even those with no perceived difficulties. Interrogating assumptions and identifying problems can be just as valuable as solving them (Biesta, Filippakou, Wainwright and Aldridge, 2019).

Another significant implication for my practice was my ‘return’ to a constructivist pedagogy and mind-set (Piaget, 1950; Vygotsky, 1978). I had previously felt my teaching style slipping to a more didactic approach, even though this contradicted my beliefs and values I felt powerless to stop it. Embarking on this research has given me the tools I needed to reset and refocus myself and my practice, solidifying a child-centred mentality that I will continue to bring into future practice.

Using an inquiry based approach was integral to my ability to teach in a constructivist way. I learned how to use inquiry effectively in one subject. Having observed the positive impact on the children’s learning and attitudes I am empowered to integrate it into other subject areas next year. As I have previously stated, inquiry was a new departure for many of the children in my class but by introducing it slowly and gradually moving through the levels (Smolleck et al. 2006) of support across the school year, I hope to inspire a classroom of self-directed, enthusiastic and independent learners

Opening up my classroom to carry out this research has been an extremely rewarding and beneficial experience for me. I had previously found teaching to be an isolating profession, however, liaising with colleagues, peers and critical friends offered me a new perspective on my practice.

> *I have always been critical of myself and my practice, zoning in on what went wrong and beating myself up about it. Breaking things down with my critical friend has really helped me to acknowledge the positive aspects of my teaching and give myself credit for what has gone well. (Reflective Journal, 23rd May 2021)*

Using these different lenses (Brookfield, 1995) gave me confidence in what I was doing, while also giving me an insight into the practice of others, providing me with new ideas and strategies to explore. Honest and constructive dialogue is essential for professional growth and developing a "community of practice" (Wenger, 1998), engaging in reflective practice as a staff would be extremely beneficial to my school environment to promote and encourage change in a positive direction.

5.4 Reflecting on my values

At the beginning of this research, I identified my values as, autonomy and inclusivity. These were values that were instilled in me as a person and therefore as a teacher. However, on reflection I found that these values were no longer as evident in my practice as they had once been.

> *I was amazed to see that the beliefs and values evident in my B.Ed reflections are the same that I identified at the beginning of this research, inclusion and autonomy. The foundations of my professional identify have always remained*

the same but were overshadowed and buried by the practical day-today aspects of school life. (Reflective Journal, 22nd February 2021)

With reflection and scrutiny of my practice throughout the reconnaissance (Cycle 1) phase of my research I was disappointed to find that I was not living closely to my values. Although I was carrying out “hands-on” activities in Science lessons, these tended to be prescriptive and teacher-led (Varley et al. 2008), they did not encourage autonomy or self-directed learning. When I observed the experience each individual child had during a lesson it was clear their engagement and learning was not equal. Literacy and language levels were obstructing the children’s ability to participate fully in lessons, preventing them from learning Science effectively or developing scientific skills. Being an inclusive teacher was particularly important to me after years working in a DEIS school and embracing children of all cultural and socio-economic backgrounds. Acknowledging that inclusivity and autonomy were being denied in my practice was difficult, however, it was the push I needed to make a change in my practice.

Introducing an inquiry based pedagogy to my Science lessons provided me with the opportunity to live closer to my values. I acted as a facilitator of learning which allowed for the children to become self-directed in their learning, explore different ideas and work collaboratively as scientists. The lessons were no longer teacher-led nor did I have all the answers to their circumstantial questions, therefore the children had to work through trial and error, identifying the solutions and conclusions themselves, this was a new way of learning for many of them (Pollen, 2009; Artigue et al. 2012). Not only were the children now more autonomous, their voices and opinions were being listened to and valued by both their peers and me, their teacher. They could see where their feedback was being incorporated into lessons and they were appreciative of this, therefore not only was I aware that I was living more closely to my values, but the children were as well.

The collaborative work and emphasis on skill development rather than writing created a more inclusive environment within the lessons, catering to all academic abilities. The explorative nature of IBSE meant that every child could get involved with varied levels of peer support or scaffolding, and every child had a role and was engaged in learning (Harlen, 2010a).

Through reflection and conversations with critical friends (Costas and Kallick, 1993) I began to recognise a value that I had not previously identified but passionately believed in, creativity. IBSE gave the children the opportunities to be creative; choose their own materials, plan their own designs and make their own product. The children's desire to be creative and do things their own way was evident even from the first lesson.

> *I was really glad that I decided to encourage the children to have the option to look at other things apart from the size. The children got really creative and included things that I had not previously considered, some putting holes into the wings, others extending the wings using the post-its, allowing for a more autonomous investigation. (Reflective Journal, 15th April 2021)*

IBSE truly encapsulated the embedding of my values, by introducing it within my classroom I felt rejuvenated to a way of thinking and teaching that I had forgotten about. Deep reflection has helped to 're-root' me and remind me of the reasons I fell in love with teaching in the first place, bringing back a sense of enthusiasm and gratitude into my practice.

5.5 Significance of the study and recommendations for further research

There are concerns regarding the learning of primary Science in Irish schools, as "child–led, autonomous investigations appear to be used relatively rarely as a hands-on strategy" (Varley et al. 2008:192). International research (Harlen, 2010; Artigue et al.

2012) indicates that IBSE has a positive influence on children's interest in Science and developing their content knowledge and skills. The findings of my study signify that primary teachers can effectively implement IBSE into their practice and setting, to varying degrees.

The main aim of the study was to improve children's attitudes towards learning school Science by teaching using an ISBE approach. The findings indicate it was successful. I believe IBSE is very important to enhancing children's attitudes to Science and that more extensive research should be conducted in this area. This is especially true in the Irish context where there is limited published research regarding the influence of IBSE on children's attitudes to learning Science in primary schools. (Murphy et al. 2015; Murphy et al. 2019). Furthermore, the use of IBSE in DEIS school could be effective in closing the gap of achievement between children in DEIS and non-DEIS schools (ERC, 2020).

Before teaching a Science concept in this self-study I found out what misconceptions children had regarding that concept and tried to overcome them using cognitive conflict. However, the findings of the study revealed a number of the common scientific misconceptions were too complex for the age group, the misconceptions we are trying to overcome should be age appropriate. My second recommendation for future research is to compare the frequency of common scientific misconceptions among children from different age groups.

5.6 Final Thoughts

The children's learning of Science has been transformed in a positive sense. My self-study findings show that the children's interest in and attitudes towards school science improved, as has my motivation in teaching Science.

Carrying out this self-study required me to take an honest and critical look at myself as a teacher. As a reflective practitioner, I now value my inner lens and realise the impact my actions and ideologies have on the experience of the children in my classroom. For me the real success has been the journey I have undertaken rather than the destination. I now have a much deeper understanding of my core values and their instinctive influence on my practice. (Reflective Journal, 17th July 2021)

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Appendices

Appendix A: Questionnaire on Children's Attitudes to Science

Questionnaire on Children's Attitudes to Science

Put your hand up if you need help filling this in

My name is ……………………………………………………………
My class is …………………………………………………………..
Today's date is ………………………………………………………………

When you come to a question, put an X on the smiley face that is closest to your opinion. Try the following examples.

	Yes	Not Sure	No
1. I like watching television	☺	😐	☹
2. I like dancing	☺	😐	☹

You are now ready to start
Please turn over when your teacher tells you

→

Remember to put your hand up if you need help filling this in

A. What I think about being in school:	**Yes** ☺	**Not sure** 😐	***No*** ☹
1. I like school	☺	😐	☹
2. I'm happy at school	☺	😐	☹
3. I work as hard as I can in school	☺	😐	☹
4. I find school interesting	☺	😐	☹
5. I enjoy doing school-work	☺	😐	☹
6. I enjoy working with my friends at school	☺	😐	☹
7. I enjoy working on my own	☺	😐	☹
8. I enjoy using the computer	☺	😐	☹
9. I enjoy doing science experiments	☺	😐	☹

Remember to put an X on the smiley face that is closest to your opinion.

What I enjoy in science experiments: I enjoy science experiments when….	***Yes*** ☺	**Not sure** 😐	**No** ☹
1. I do an experiment by myself	☺	😐	☹
2. I do an experiment with my friends	☺	😐	☹
3. I watch my teacher doing an experiment	☺	😐	☹
4. I plan and do my own experiment	☺	😐	☹
5. The teacher tells me what to do	☺	😐	☹
6. My teacher explains things to the class	☺	😐	☹
7. Finding out why the experiment worked	☺	😐	☹
8. When we go outside the classroom to do science	☺	😐	☹
9. I choose my own equipment	☺	😐	☹

What I enjoy in science lessons: I enjoy science when….	***Yes*** ☺	**Not sure** 😐	**No** ☹
10. I fill in my workbook/worksheet	☺	😐	☹
11. I write about something I have done in science class	☺	😐	☹
12. I design and make my own things	☺	😐	☹
13. I read my science schoolbook	☺	😐	☹

Put an X on the smiley face that is closest to your opinion.

What I think about science:	**Yes** ☺	**Not sure** 😐	**No** ☹
1. School science is easy	☺	😐	☹
2. School science is interesting	☺	😐	☹
3. I like science better than other subjects	☺	😐	☹
4. I look forward to science lessons	☺	😐	☹
5. I am looking forward to learning science in secondary school	☺	😐	☹
6. When scientists give an explanation about something it is always true	☺	😐	☹
7. You have to be clever to do science	☺	😐	☹
8. Science is just too difficult	☺	😐	☹
9. TV, telephones and radio all need science	☺	😐	☹

Rank your favourite subjects from 1-8
1 is your favourite subject and 8 is your least favourite subject

English	
Irish	
Maths	
Science	
Geography	
History	
Music	
Art	

Think about your science class in school. What was your favourite science lesson.

____

Write down what you did in your favourite science lesson

____

Why did you enjoy it?

Think about science class in school. Describe a school science lesson that you didn't enjoy.

Why didn't you enjoy it?

Think about how your class does science in school. Draw a picture of yourself and your class doing science at school.

Great work well done and thank you very much!

Appendix B: Interview Questions for Children (pre/post intervention)

1. Do you like doing science in school?

Probe - Why /Why not?
- What things do you like about science in school?
- What kinds of things do you not like about science in school?

2. I am an alien from another planet, I am meeting you all for the first time and I know nothing about science. Could you tell me what you do in your science lesson?

Probe - What would you be doing?
- What would the teacher be doing?
- Does your teacher read out of a book?
- Does your teacher demonstrate experiments?
- Do you do experiments?

3. Can you tell me what you did in your last science lesson?

Probe - What did you do during this lesson?
- Did you like this lesson?
- Did you carry out an experiment during this lesson?
- What did you like/not like about this lesson?
- What was your favourite part of the lesson?
- What did you learn in this lesson?

4. When was the last time you did an experiment in a science lesson?

Probe - What did you do?
- Did you like doing it?
- Do you do experiments yourself or does the teacher show you?
- Would you like to do more experiments?

5. Do you ever work in groups in science lessons?

Probe - What do you like about working in groups (if yes)?
- Would you like to work in groups (if no)?
- What kinds of things have you done in groups?
- Do you have special jobs to do when you are in groups?
- Do you work in groups in any other lessons?

6. Do you have a textbook for science in school?

Probe - do you like your textbook?
- What do you like/dislike about it?
- Have you done any of the experiments in your science textbook?
- Does your teacher read from the textbook in class?
- Do you read from the textbook in class?
- Do you like reading from the book?

7. Do you do much writing during science lessons?

Probe - Do you like writing?
- Does the teacher put writing on the board during science lessons?

8. If I was going to be your teacher next year, what kind of things would you like me to do in science?

Probe - What things would you like to do more of?
- What things would you like to do less of?

Appendix C: Detailed Research Timetable

Date	Action
October 2020	• Ethical approval granted by Maynooth University • Consent obtained from principal, board of management, parents, and guardians • Assent obtained from children
Cycle 1 - Traditional teaching	
26th November - 16th December 2020	**Science topic: Heat** • Heat misconception worksheet administered prior to teaching • 2 lessons based on Heat • Heat misconception worksheet administered after teaching
School closures due to Covid-19 from January 6th to March 12th	
15th – 23rd h March 2021	**Science topic: Materials** • Materials misconception worksheet administered prior to teaching • 2 lessons based on Materials • Materials misconception worksheet administered after teaching
23rd – 26th March 2021	**Data collection** • Questionnaire carried out with whole class • Interviews carried out with small group • Data analysed and reflected upon to inform second cycle
Cycle 2 - Inquiry teaching approach	
12th – 29th April 2021	**Science topic: Forces – Falling objects** • Falling objects misconception worksheet administered prior to teaching • 3 lessons on falling objects Falling objects misconception worksheet administered after teaching
10th – 28th May 2021	**Science topic: Forces – Floating and sinking** • Floating and sinking misconception worksheet administered prior to teaching • 3 lessons on floating and sinking • Floating and sinking misconception worksheet administered after teaching

2^{nd} – 4^{th} June 2021	**Data collection** • Survey carried out with whole class • Interviews carried out with small group • Data compared with data from cycle 1 to analyse findings

Appendix D: Misconception Worksheets - Cycle 1

Heat Questions

1. Is heat and temperature the same thing? Yes / No

Explain your answer

____

____

2. Which area do you think is warmer, teacher's desk or SNA's desk? ___________________________

Explain your answer

____

____

3. Does heat travel from hot to cold, cold to hot or in both directions? _______________________________________

Explain your answer

____

____

____

4. Does hot water have more/less/the same amount of energy as cold water? More / Less / the same / neither have energy

Explain your answer

____

____

____

5. Can heat travel through a solid material? Like metal or wood. Yes / No

Explain your answer

____

____

____

Materials and Change Questions

1. What happens when you put a spoonful of sugar into water?

____

____

2. Will a glass of water *with sugar* in it weigh the same as a glass of water *without sugar* in it?

   They will both weigh the same / The one with sugar will weigh MORE / the one with sugar will weigh LESS / I don't know

   (Both have the same amount of water and the glass weighs the same, the only difference is the sugar)

   Explain your answer:

____

____

____

3. When you dissolve something do you make it disappear? Yes / No / I don't know

   Explain your answer:

____

____

____

Appendix E: Misconception Worksheets – Cycle 2

Forces Questions

1. If I hold up a golf ball and let it go, what will happen and why?

____
____
____
____

2. I have a normal sheet of a4 paper and a sheet of a4 paper scrunched up into a ball.
If I drop them both at the same time, from the same height, will they hit the ground at the same time?
Yes / No
Explain your answer

____
____
____
____

3. If a drop a golf ball and a ping-pong ball at the same time, from the same height, will they hit the ground at the same time?
Yes / No
Explain your answer

____
____
____
____

Floating and Sinking

1. Do all heavy objects sink in water? Yes / No / Some / I don't know

Explain you answer: ____
____

2. Do all light objects float in water? Yes / No / Some / I don't know

Explain you answer: ____
____

3. Does the shape of an object effect whether it floats or sinks?
   Yes / No / I don't know

Explain you answer: ____
____

4. Do all big objects sink in water? Yes / No / Some / I don't know

Explain you answer: ____
____

5. Do all small objects float in water? Yes / No / Some / I don't know

Explain you answer: ____
____

Appendix F: Letter to Board of Management

Maynooth University Froebel Department of Primary and Early Childhood Education

Roinn Froebel Don Bhun- agus Luath- Oideachas Ollscoil Mhá Nuad.

16th October 2020

Dear Chairperson and Principal,

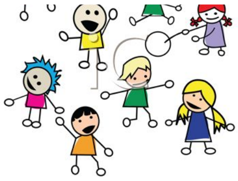
As you may already know, I am a student on the Masters of Education programme at Maynooth University. As part of my degree I am doing a research project. The focus of my research is based on Science Education. I am looking at my own methods of teaching science and hoping to improve them. In order to do this I will be teaching the science curriculum to 3rd class for the duration of the year.

With parental permission I hope to collect data for my research by interviewing the children in the class, taking audio recordings of group conversations, taking samples of the childrens work and conducting questionnaires. I also hope to use some of the children's work since the beginning of the year. All of this information will be completely confidential, neither the child nor the school will be named in the thesis that I will write at the end of the research. Involvement in this research is voluntary and the children will be allowed to withdraw from the project at any stage, this will not impact on their participation with science lessons.

All information will be destroyed in a stated timeframe in accordance with the University guidelines. The correct guidelines will be complied with when carrying out this research. The research will not be carried out until approval is granted by the Froebel Department of Primary and Early Childhood Education.
Please find a copy of the parental information sheet attached, which along with consent forms I hope to distribute to 3rd class parents at your discretion.
If you have any queries on any aspect of this research project feel free to contact me by email at niamh.smith.2021@mumail.ie
Yours faithfully,
Niamh Smith

Appendix G: Children's assent forms

Maynooth University
National University of Ireland Maynooth



Child's name …………………….

I am trying to find out how best to teach science in primary school. I would like to find out more about this. I would like to watch you and listen to you when you are in school and to write down some notes about you.

Would you be ok with that? Pick a box

Yes **No**

I have asked your Mum or Dad or Guardian to talk to you about this. If you have any questions I would be happy to answer them. If you are happy with that could you sign the form that I have sent home?

If you change your mind after we start, that's ok too.

Maynooth University Froebel Department of
Primary and Early Childhood
Education

Roinn Froebel Don Bhun- agus
Luath- Oideachas
Ollscoil Mhá Nuad.

Child's assent to participate

My parent/guardian has read the information sheet with me and I agree to take part in this research.

Name of child (in block capitals):

____

Signature: _______________________

Date: _______________________

Appendix H: Information and consent form for parents and guardians

Maynooth University Froebel Department of Primary and Early Childhood Education

Roinn Froebel Don Bhun- agus Luath- Oideachas Ollscoil Mhá Nuad.

Dear Parent(s)/Guardian(s),

You all know me as Ms Smith a teacher in the school for the past four years. This year I am studying on Masters of Education programme at Maynooth University. As part of my degree I am doing a research project. The focus of my research is based on Science Education. I am looking at my own methods of teaching science and hoping to improve them. In order to do this I will be teaching the science curriculum to 3rd class for the duration of the year.

With your permission I hope to collect data for my research by interviewing the children in the class, taking audio recordings of group conversations and interviews, taking samples of the childrens work and conducting questionnaires. I also hope to use some of the children's work since the beginning of the year. All of this information will be completely confidential, neither your child nor the school will be named in the thesis that I will write at the end of my research. Involvement in this research is voluntary and your child will be allowed to withdraw from the project at any stage, this will not impact on their participation with science lessons.

All information will be destroyed in a stated timeframe in accordance with the University guidelines. The correct guidelines will be complied with when carrying out this research. The research will not be carried out until approval is granted by the Froebel Department of Primary and Early Childhood Education.
I would delighted for your child to be involved in my research and would like to invite you and your child to give permission for him/her to take part in this project.
If you have any queries on any part of this research project feel free to contact me by email at niamh.smith.2021@mumail.ie
Yours faithfully,
Niamh Smith

Maynooth University Froebel Department of
Primary and Early Childhood
Education

Roinn Froebel Don Bhun- agus
Luath- Oideachas
Ollscoil Mhá Nuad

PARENTAL CONSENT FORM

I have read the information provided in the attached letter and all of my questions have been answered. I voluntarily agree to the participation of my child in this study. I am aware that I will receive a copy of this consent form for my information.

Parent / Guardian Name ______________________

Parent / Guardian Signature______________________

Date: _____________________

Name of Child _______________________________

Child's signature: ____________________________________

Date: _____________________

Maynooth University Froebel Department of Primary and Early Childhood Education

Roinn Froebel Don Bhun- agus Luath-Oideachas
Ollscoil Mhá Nuad.

Information Sheet

Parents and Guardians

Who is this information sheet for?

This information sheet is for parents and guardians.

What is this Action Research Project about?

Teachers undergoing the Master of Education in the Froebel Department of Primary and Early Childhood Education are required to conduct an action research project. This means that I will be examining an area of my own practice as a teacher and hoping to improve it to benefit the children's learning. Data will be generated using observation, reflective notes, questionnaires, audio recordings of interviews with the children and group conversations. I, as the teacher, am then required to produce a thesis documenting this action research project.

What are the research questions?

- How can I improve my teaching strategies to identify, confront and overcome children's misconceptions regarding science concepts?

What sorts of methods will be used?

- Observations, questionnaires, audio recordings of interviews with the children and group conversations, teacher reflective journal.

Who else will be involved?

The study will be carried out by me Niamh Smith as part of the Master of Education course in the Froebel Department of Primary and Early Childhood Education. The thesis will be submitted for assessment to the module leader Dr Bernadette Wrynn and will be examined by the Department staff. The external examiners will also access the final thesis.

What are you being asked to do?

You are being asked for your consent to permit me to undertake this study with 3rd class. In all cases the data that is collected will be treated with the utmost confidentiality and the analysis will be reported anonymously. The data captured will only be used for the purpose of the research as part of the Master of Education in the Froebel Department, Maynooth University and will be destroyed in accordance with University guidelines.

Contact details: Student: Niamh Smith **E:** niamh.smith.2021@mumail.ie

Appendix I: Declaration by researcher

Maynooth University Froebel Department of Primary and Early Childhood Education

Roinn Froebel Don Bhun- agus Luath- Oideachas Ollscoil Mhá Nuad.

Declaration by Researcher

This declaration must be signed by the applicant(s)

I acknowledge(s) and agree that:

a) It is my sole responsibility and obligation to comply with all Irish and EU legislation relevant to this project.

b) I will comply with Irish and EU legislation relevant to this project.

c) That the research will be conducted in accordance with the Maynooth University Research Ethics Policy.

d) That the research will be conducted in accordance with the Maynooth University Research Integrity Policy.

e) That the research will not commence until ethical approval has been granted by the Research and Ethics committee in the Froebel Department of Primary and Early Childhood Education.

Signature of Student:

Date:

Appendix J: Lesson Plans from Cycle 1

<table>
<tr><td>Cycle: 1</td><td colspan="2">Lesson: 1</td></tr>
<tr><td colspan="2">Strand: Energy and Forces</td><td>Strand Unit: Heat</td></tr>
<tr><td colspan="3">Learning objectives:
• Learn that heat can be transferred
• Recognise that temperature is a measurement of how hot something is</td></tr>
<tr><td colspan="3">Skills developed:
• Observing
• Predicting
• Investigating and experimenting
• Recording</td></tr>
<tr><td colspan="3">Learning Activities:
• Misconceptions worksheet carried out in advance of lesson to identify the misconceptions the children hold about heat and why.
• Discussion to introduce the topic around heat and whether or not it can travel through a solid.
• Teacher explanation of the investigation, variety of children asked for their predictions of what will happen and an explanation.
• Investigation: placing a blob of butter on the top of three spoons each made from different materials, metal, wood and plastic, bottom of the spoons then placed in hot water.
• Children work in groups of 3 or 4, resources distributed among the groups, teacher responsible for hot water.
• Children observe the spoons over time.
• Children record their predictions and methods on worksheet.
• Class observe and discuss their results, teacher demonstration of investigation that worked well. Question and hypothesis why some investigations worked better than other.
• Record results and conclusions on worksheet.</td></tr>
</table>

Cycle: 1	**Lesson:** 2

Strand: Energy and Forces	**Strand Unit:** Heat

Learning objectives:

- Measure changes in temperature using a thermometer
- Measure and compare temperatures in different places in the classroom, school and environment and explore reasons for variations
- Recognise that heat is a form of energy

Skills developed:

- Observing
- Predicting
- Investigating and experimenting
- Measuring
- Analysing
- Recording

Learning Activities:

- Discussion around previous weeks lesson, demonstration of previous weeks lesson set up at the top of the class due to a lack of results.
- Two thermometers left in two different areas of the classroom, to return to later.
- Class discussion around what happens to ice when in water. Teacher explanation of the investigation, variety of children asked for their predictions of what will happen and an explanation.
- Investigation: observing whether an ice cube will melt faster in hot water or tepid water. Observing the change in temperature of the water when ice cubes are added.
- Before beginning the investigation, children record the investigation aim, equipment needed and their prediction. Procedure is written on the board to record.
- In groups of 4 or 5 the children place a thermometer in two cups of water; one containing room temperature tap water, the other half tap water half hot water from the kettle.

- The children record the temperature at beginning and then every 30 seconds once a single ice cube is dropped into each cup (at the same time).
- Children observe in which cup the ice melts faster and record the changes in temperature.
- Class discussion about the results and the conclusion of the investigation – hot water melts the ice faster as it has more energy.
- Children record their results and conclusion.
- Return to butter investigation at the front of class to observe and discuss the results.
- Children read the temperature of the thermometers in two different classroom locations and discuss the results.

Cycle: 1	Lesson: 3
Strand: Materials	**Strand Unit: Materials and Change**

Learning objectives:

- Investigate how materials may be changed by mixing
- Predict and identify which materials will dissolve in water
- Observe how more sugar can be dissolved into hot water
- Define the terms; dissolve, solute, solvent and solution
- Observe how evaporation can be used to separate a mixture (sugar in Coca Cola)

Skills developed:

- Observing
- Predicting
- Investigating and experimenting
- Recording

Learning Activities:

- Misconceptions worksheet carried out in advance of lesson to identify the misconceptions the children hold about dissolving and separating solutions and why.
- Class discussion about what happens to sugar when you put it in water and mix the two. Elicit the term dissolve and ask the children to explain it.
- Teacher explanation of the investigation, variety of children asked for their predictions of what will happen and an explanation.
- Investigation worksheet filled out for Title, Equipment and Prediction.
- Materials distributed. Children carry out the investigation. With 4 cups of equal quantities of water (solvent) labeled; A, B, C and D. And small amount of sugar, salt, pepper and flour (solutes), also labeled A, B, C and D. Each child is given a different cup and solute to be responsible for. The children add the same amount of each solute to the corresponding cup of solvent. They stir the solution for 30 stirs and observe the results.
- The children discuss their results as a class and hypothesize the explanation.
- The children then record their method, results and conclusion on their

worksheets, they can also draw a labeled diagram of the experiment time allowing.

- Teacher demonstration: dissolving cups of sugar in a bowl of hot water until the solution is saturated. Children taste the solution to identify that there is sugar dissolved even though we cannot see it. Solution poured into shallow plate and left on the windowsill for next lesson.
- Video from YouTube showing the results when Coca-Cola Zero is evaporated from a pan Vs when regular Coca-Cola is evaporated from a pan (sugar syrup residue)

Cycle: 1	Lesson: 4
Strand: Materials	Strand Unit: Materials and Change

Learning objectives:

- Investigate how materials may be changed by mixing
- Explore some simple ways in which materials may be separated
- Answer questions based on the previous weeks investigation (Science Quest 3)
- Predict and identify what happens to the weight of a cup of water when sugar is added and dissolved
- Observe what happened to the sugar solution left on the windowsill the previous week and hypothesis the results

Skills developed:

- Observing
- Predicting
- Investigating and experimenting
- Recording

Learning Activities:

- Class discussion revising the investigation from the previous science lesson.
- Class answer questions based on the previous investigation from the Science Quest book.
- The children discuss their results as a class and hypothesize the explanation.
- The children observe the results of the sugar solution on the windowsill. Elicit the term evaporation. Class discussion around the results and rationale, touch and observe the crystals formed.
- Teacher demonstration: take two cups of water, same type of cup, same amount of water, same weight. Add sugar to one cup and stir until dissolved. Children predict what will happen to the weight. Place each cup back on to the scales separately. Discuss the results as a class and identify a conclusion.
- Teacher read aloud: from the interactive whiteboard (IWB) reading about different types of methods to separate mixtures.
- Teacher demonstration: Using coffee filter paper to show the effects of chromatography and how is separates the different coloured ink in certain markers.

Appendix K: Interview Transcript – Pre Intervention

I – Interviewer (me)
C – Conor*
L – Lara*
B – Beth*
A- Alex*
*pseudonyms to provide anonymity to participants

I: So it is the 24th of March and I have my lovely 3rd class with me and we're going to talk through some questions. So, do you like doing science in school?

L, C, B: Yes

I: Alex, do you not like doing science in school?

A: No

I: Why not?

A: its just kind of boring for me

I: What do you find boring about it?

A: Like, the times when we have to do the worksheets

L: Yeah same, I don't like the worksheets but I like like doing

B: Like science experiments and I also like when we, um, um, when we do the science experiments separately and then you show us if we got it wrong

I: Oh okay, so you guys do your own science experiments and then I show you the right way to do it?

B: Yeah that's fun

I: Which part is more fun, doing it yourself or watching me do it?

B: I think doing it ourself

L: Yeah

I: And do you think you'd like to see me doing it to do it right or would you like to try it again yourself to get it right?

B: I think try it again

I: Try it again yourself?

B: Yeah

I: Okay. What do you think Conor about science in school?

C: I think it's really fun and interesting

I: Okay and what do you like about it?

C: Everything

L: Same

I: Everything?

C: Except for the worksheets

I: Except for the worksheets, everything except for the worksheets

L: Yeah I think that too

I: Okay. And if I'm an alien coming in from another planet, and I'm meeting you all for the first time and I know nothing about science, could you tell me what you do in your science lessons

L: Well it's kinda hard, if we like know, like, yeah… Like we have to think about what we want to show you first but if we knew like what to show you then it would be easy

B: What we do in our science experiments is like you tell us a bit about it and what you have to do and then we do it by ourselves and then you usually do it like again

I: okay, so the way it usually goes is, I tell you what to do, you do it and then I show you the way it should go at the end?

B: Yeah

I: Would you all agree with that?

B: Like the butter thing, we did it separately by ourselves and then you showed us.

I: The next week cause it didn't work that well, sure it didn't?

B: Yeah

I: Okay. Well what do you think? How would you explain science to a –

A: So, I think like, say you're telling us that were doing a science experiment about bubbles, so you need washing up liquid and water, when you squirt them together and mix them some kind of reaction comes, but you don't tell us that thing. So, we do it and at the end when we saw the bubbles, we tell our like, what we thought, why the reaction happened like that and you tell us what really the reaction was

I: Okay, okay good.

L: She's an alien, so like she doesn't know anything about science

I: So can you explain to me how a science lesson works basically? Conor, what about you?

C: Probably the same as Beth

I: Well what would, so if we were doing a science experiment, would I read out from a book? Would I be reading from a book?

C: Well yeah, you could be reading from a book, but if there was no book then we'd have to tell you how to do science.

I: Okay, and would you guys use books often?

Over each other

A: No, we don't really

L: Yeah, I have loads of fact books

I: You use science books at home?

L: Yeah

A: Science is basically you just *inaudible* so you don't even have to take things from a book you can like say put sanitizer and flour in and see what happens, that's science, just seeing what things happen when you mix them together, that's what I do all the time

B: Yeah we don't usually use books, you just say

I: Okay so in school you don't usually use books I'm telling you

B: Yeah

I: So Alex and Lara, what you guys were saying there is what you do at home, but would you use your book much in school for science?

Mix of 'yes', 'no' responses

L: Kind of

B: Only like, we would usually use the books with Ms Byrne* to see about the bubbles and only yesterday we used the books

I: Okay perfect, okay so, does your teacher demonstrate, so would I demonstrate for you?

L and B: Mmmmm

I: We've already kind of said that haven't we, at the end?

B: At the end yeah, and then you guys do it. And are there other time when I just do the demonstration totally and then you guys watch?

B: Yeah and then we write about it I think

I: Okay so I do the demonstration and then you guys watch and then write about it

A, L and B: Yeah

I: Okay. Conor do you agree with all that? Yeah?

C nods

I: Yeah? Good man. Okay, so Conor you tell me then, what did you do in your last science lesson?

C: we did the dissolving where we put flour, sugar, salt and pepper into water and we mixed them around for –

A: 30 seconds

C: 30 seconds and –

L: No we mixed them for 30 stirs

C: And the flour and pepper didn't really dissolve, but the salt and the sugar did

I: Okay good, and then what did you do?

A: So then you just put lots of sugar into a bowl and started mixing it with hot water and we couldn't see it but we knew that it was dissolved

L: Because we tasted it

A: Yeah and we tasted it

B: And then a few weeks or a week later the sugar was like left there –

L: It was crispy, it was like crisps

A: And the water had like dissolved cause the sun burned it out

L: It evaporated

B: Yeah

I: Okay so the water evaporated and left the sugar. And in yesterdays science lesson what did we do?

L: Wait, what did we do yesterday?

A: I can't remember

B: Ummm

L: We did… We did… oh yeah we checked on the sugar, and we touched it

I: Yeah you were able to look at the sugar crystals that were left behind

L: Yeah I made it at home

I: Oh did you?

L: Yeah

I: Did it work well?

L: Well it's still evaporating

I: Evaporating yeah, sometimes its good to add food colouring as well, you can make colourful crystals. And so tell me guys, yesterdays science lesson, we were doing our worksheets and answering some?

ALL: Questions

I: Questions, okay, so the questions were based on the science from last week weren't they?

Mixed answers, one says "were they?" two others say "yeah yeah"

I: Yeah we did some about the jars, the different jars, your A, B, C, D jars. And then we were also reading something at the end, what were we reading?

L: Emm our science book

I: Our science book and what else did we read? On the internet, do you remember?

Speaking over each other

B: Emm about… coca cola?

C: Just some facts

A: The sugar test

L: Solute, salute and salvation?

I: Solute, solvent, solution good

B: I don't really mind doing worksheets, but if they were less long and didn't have to put so much detail and just say "no I don't think it will dissolve" and not put why it will not dissolve

I: Okay and why don't you like putting in the detail

B: Because it's kinda hard to think sometimes

L: And also my hand gets tired

I: Fair enough

L: Kind of waste of my time too, but like my hand gets tired

I: Okay, so what was the last science experiment you did?

C: The dissolving

I: The dissolving yeah, did you like doing it Alex?

A: Emm yes, kind of, I dunno

I: Why don't you know?

A: Ugh I don't know

L: So kind of?

A: Kind of yeah

B: So yeah I really liked it, it was really fun

L: I like all the science experiments, except the body parts

I: Why didn't you like the body parts Lara?

L: We had to put the thingy into the plastic thingy

I: Oh the plastic body?

L: Yeah

B: I really liked that one actually, because –

C: I liked when we had to draw a skeleton

B: I liked that too

A: I didn't really like the body one

I: Why did you like the body one?

B: Because I liked the body and all the parts, and its cool. And then umm, we didn't have to do any worksheet but we lay down, someone lay down on a piece of paper and we had to draw their bones

I: So you liked that one because you didn't have a worksheet? Is that another reason why you liked it?

A: I didn't like that one –

L: Wait no I was out for that day

I: You were out that day?

A: I didn't like that one because like nobody was helping me to draw the bones

I: So your group wasn't working very well together?

A: No, I was the only one working there, and I accidently hit Sam in the shoulder when I was getting out of my chair and he said I'm mean so he didn't even help me and the same with John

I: So do you like doing group work then Alex?

A: Emm kind of

B: I would like if we mixed the groups up instead of the same groups all the time

I: In what way? Mix them how?

B: Like emm, maybe different pods together, like for example, Conor, Lara, me

I: Yeah cause you guys are in separate pods. Okay, so then… Everyone's opinion about working in groups, do you like working in groups?

Inaudible talking together in agreement

L: I like working with my friends

I: Okay, so tell me more about what you do like about working in groups? So working with your friends for one, anything else?

C: Getting help from each other

I: Getting help from each other, good one Conor

L: I like doing the experiment too

I: You doing the experiment?

B: Emm sometimes I don't like when we do in groups because sometimes we argue about what we should do

A: Yeah, the same with me. Because once when it was the filters with you *speaking to Lara* I said that we were gonna cut that filter out and put it in and you said no lets put it on the top

L: Yeah you were emm like…

I: So different ideas? So sometimes others people have different ideas

A: And you don't like accept each one

I: Yeah exactly

L: Like, I like doing it alone too, but then you feel like lonely cause its only me in the experiment, cause the experiment is mine…

I: Any other challenges about working in a group guys?

L: I like doing hard stuff cause it's a challenge, the easy stuff is just like too easy

B: It's kinda boring cause you have it done in a second, I didn't really like the butter one cause it didn't really work and it was kinda boring

I:What was boring about it?

B: It was just umm, the butter didn't work and we didn't really learn anything about why the butter didn't work or learn anything about how the butter could have worked

I: Okay, do you think maybe there was a bit of waiting as well? You were just watching and watching and watching? Was that boring

B: Yeah, instead of just... We could have done another experiment

I: Okay, Conor were you going to say something about that?

C: Yeah cause we put four spoons in, the metal one kinda –

L: No we put three

C: Fine, the metal one kinda worked, the wooden one didn't work?

L: The wooden one *inaudible speaking over each other*

C: The wooden one didn't really work and the…

B: The plastic one didn't work

C: The plastic one

A and C: kinda worked

A: because the heat that was going up the steam it was kind of –

C: I think the plastic spoon should have kinda melted if it was boiling water

L: Oh yeah ehh my sister put boiling water in a plastic bottle and then it like shrinked

A: I tried it before and I had like a plastic bottle, I put it in the sink in this really hot water and then it started like shrinking

I: And when you are doing science in groups, do you have any special jobs when you're in the group?

Mixed responses yes and no

I: Do you think jobs would help to stop arguments?

All: Yeah

B: I would think that maybe in every group there should be umm, you pick who's going to be the… the kind of leader who kinda makes the main decisions and then who's going to bring the equipment up and then the other person… there's usually three in a group…

A: I don't really think the jobs would help the arguments stop, cause say somebody was like "Hey I wanted to do that job" and then you're saying "No I'm doing it right now" and then like "I don't want to bring the spoon, I want to bring the butter" or something like that

B: Yeah, that's what the persons job is, bringing the equipment

I: Yeah but Alex is saying that sometimes even giving a job might cause an argument cause you might not get the job you want

L: Because like one person will be the leader, one person will bring the equipment and what about the last person?

I: Okay, and do you have a text book for science in school?

L: Textbook? What's a textbook?

I: Like a workbook, a schoolbook, you don't write into it but you read from it

All: Yeah

A: Science Quest

L: Like the Geography book

B: I like it, I like the pictures

I: Does everyone else like it?

C: Yep

L: It's okay. But I've got better books at home

A: Same with me

I: What do you not like about it?

L: Cause it has like, fill in the spaces, and like you can't read it cause you have to fill in the spaces

B: I think if we still did the worksheets but we didn't really write about it, we'd talk about it in class, and maybe some people would think yes and some people would think no

L: Listen, maybe in the future there will be paper that you press and it records so you don't have to write it yano? Its like a card

A: Ohhh it's like a printer like you say "Hello my name is Alex" and its like "Hello my name is Alex" zip zip zip, woo I'm done

I: And Conor what do you like about the book?

C: I dunno I just find it a bit interesting and the pictures look cool

I: Yeah it's nice to have pictures to back things up

B: Yeah instead of just boring

I: Instead of having to imagine things for yourself

L: I got two fact books for my birthday, I keep reading it but I've finished it, one has like 5000 facts but I read all of it, and one is about science but I have read all of it so when I get home I'm gonna read it

I: Have you don't any experiments in your science book this year?

Mixed answers of No and Yes from all

A: Well I don't really know

B: No we haven't actually… wait this year, yeah we did the bubbles yeah and that was from the… that was with Ms Byrne* and we did bubbles

L: I did the rainbow one at home

I: You did a rainbow one at home? Did you read that with Ms Byrne* was it? And then you were able to do it at home? That's cool. Okay and next question, does your teacher ever read from the text book in science class?

All: Yes

I: Okay, and do you like to read from the book?

Mixed responses yes and no

L: Yes but if it did have the words, not like the fill in the spaces

I: Okay, and who else said yes? That you do like to read from the book? Conor, why?

C: I dunno I just like reading

I: You like reading? Good. And what about no, who said no?

A: I like reading cause it just like gives up the time, it's like you spend your time so say there's 15 minutes, 1 hour left and you start reading one page and it took you like lets say 1 hour and you didn't even feel like 1 hour. It was like me when I was in the hospital with my arm they put me asleep for 3 hours but it felt like 5 seconds cause I went to sleep, then woke up 5 seconds later but really it was 3 hours we went through.

I: So you like reading cause the time goes by really quickly?

A: Yes the same way we spend the problem, the same with problems and when your sleeping.

I: Okay so the last few problems, do you do too much writing during science?

A, B, L: Yes

C: Not really

B: Like emm, we once just wrote about what we did, we didn’t do any science experiment, we just wrote about what we did last

I: And do I, or does your teacher, put much writing on the board?

L: Yes

B: Writing?

I: So do I write much stuff onto the whiteboard?

A: Yes, yes, yes

B: Kind of

A: Kind of, not really, like a quarter of it

L: Half I would say

A: Yeah

B: you usually do what the method is, and again I think we should talk about it not write

I: Talk about it not write it. Okay so after Easter what kinds of things would you like me to do in science?

A: I would like to do ubleq

All in agreement: Ubleq!

L: And also I would like to do a food experiment so we can eat it, cause I love eating food

B: And then like write down what, or talk about what it tasted like, or did some people like it and some people didn’t… like if we had lemons

L: We could do a data chart thingy

A: After Easter for science, I would like to have like a tasting where you could put a blindfold on, we wouldn’t watch the food you would cover it with a towel, you would put a blindfold on us we would pinch our nose and we could only like eat through our nose guess what the thing is we have to like taste it but not smell the food. And like you can buy things like skittles or mentos or something that we don't know

L: Like put coke, or mentos into coke and then puuhhh (explosion noise)

C: You put mentos into coke and throw it and when it hits the ground it shoots up like a rocket

I: And is there anything that you would like me to do more of? Anything we're already doing that you want to do more of?

L: Experiments!

A: More experiments, less writing

L: Yes!

B: I think that's the big thing

L: And more tasting

I: Okay so more experiments, less writing and a bit of food science

L: Yes and eating it

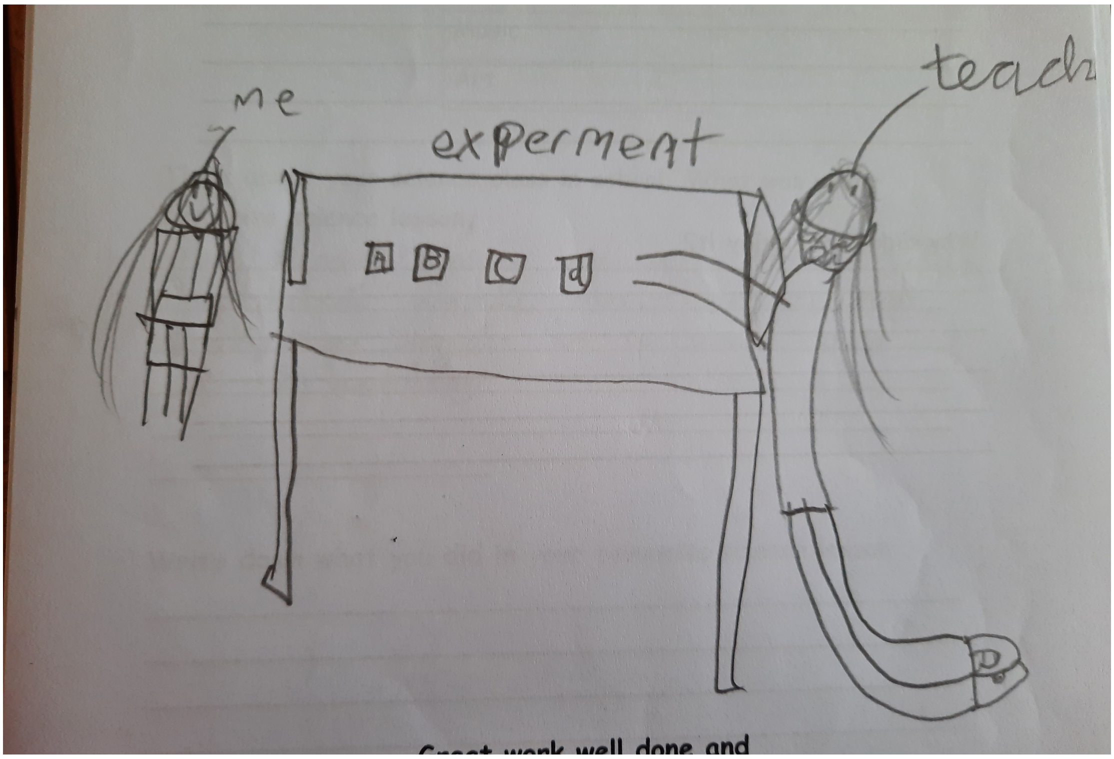
I: Okay and anything else you want to add for the interview before we go?

A: I love going home and in two days it's going to be Friday and I can play Roblox

L: I love science, and I love food. So we have to do a food experiment.

Appendix L: Photographs of children's drawings pre intervention

Drawing of child's favourite lesson pre-intervention



Drawing of child's favourite lesson pre-intervention

Appendix M: Lesson Plans for Cycle 2

Cycle: 2	**Lesson: 1**
Strand: Energy and Forces	**Strand Unit: Forces**

Learning objectives:

- Investigate falling objects
- Investigate how the size of an object can impact the speed at which it falls
- Investigate the effect of air resistance on a falling object

Skills developed:

Investigating; experimenting; observing; analysing; measuring/timing; recording and communicating

Learning Activities:

- Show the children a video of a sycamore seed falling in slow motion. Discuss why there are blades attached? Are there any benefits to the tree? Does it remind them of anything? i.e. helicopters
- Teacher demonstration of the paper helicopter, show what happens when you let it go. Teacher explanation of how to make the helicopters.
- Children make their own paper helicopters and play around with them, comparing and contrasting theirs to others, making observations about speed, spins, accuracy of landing. Teacher circulation to discuss with groups.
- Class discussion about what is happening. Raise questions about what makes 'the best' helicopter and how that might be achieved. Discuss alterations the children could make to their helicopters and what they can measure.
- Each group will fill out three post-its, what they are going to change, how they are going to measure it and their prediction.
- The children will then carry out their investigation, making changes to their spinners, e.g. weight, size, length of wings. They will discuss findings with the circulating teacher before demonstrating their results at the front of the class.
- The children will record their investigation and results on a large piece of coloured paper as a group.

Cycle: 2	Lesson: 2
Strand: Energy and Forces	**Strand Unit: Forces**

Learning objectives:

- Investigate falling objects
- Investigate how the material of a parachute can impact the speed at which it falls
- Investigate the effect of air resistance on a falling object

Skills developed:

Investigating; experimenting; observing; analysing; measuring/timing; recording and communicating

Learning Activities:

- To begin the children will revise what they were doing the previous week in science, we will look at the small and large paper helicopters falling and discuss why the smaller one hits the ground first (air resistance). I will attempt to reiterate this point using two different paper airplanes, one with a larger surface area than the other, but both made from a a4 page.
- Next I will show the children images and videos of different flying objects without an engine, such as paragliders and the Da Vinci parachute video. We will discuss what makes a good parachute (falling slowly to the ground) and why.
- The children will work in groups to create two parachutes from different materials e.g. j-cloth, tinfoil, plastic bag etc. We will discuss everything that must be kept the same and what will be different, i.e. size, weight, length of ties etc. The children will then discuss their investigation with their group and record these on 4 post-its, 1. what different materials will be used (independent variable) 2. What has to stay the same (control variables) 3. What will make the best parachute and 4. Their prediction.
- The children will demonstrate their parachute in-front of the class to establish which one is the best, they will discuss their conclusion/hypothesis. Then they will return to their group to record their investigation and findings on a poster.
- To end the lesson I will explain to the children that each group will be using their parachute for next weeks investigation. I will then show them the 'Candy Bomber' video and explain that they will have to design and make a container to keep an egg safe when falling from a height. I will encourage the children to think about it over the next few days and bring in items that might be helpful to them.

Cycle: 2	Lesson: 3
Strand: Energy and Forces, Design and make	**Strand Unit:** Forces

Learning objectives:

- Design an egg holder to absorb shock
- Investigate falling objects
- Identify the most effective materials to protect an egg and how to use them most effectively
- Work collaboratively to create a design proposal
- Communicate and evaluate the design plan using sketches, models and information and communication technologies
- Develop craft-handling skills and techniques
- Use a range of materials
- Evaluate the effectiveness of the new product and suggest modifications to the designing and making task
- Evaluate the work of peers and propose positive modifications

Skills developed:
Planning, designing, making, evaluating, working collaboratively, investigating

Learning Activities:

- I will introduce the lesson by showing the children a video called the Candy Bomber to set the context. I will then explain that they will be putting the parachutes they made the previous week to the test, by attaching an egg to the bottom of the parachute.
- The children will go back into their groups from the previous week and I will show them the resources I have – cups, egg cartons, cotton wool, bubble wrap, sponges and cloths.
- The children will then have to plan their egg holder collaboratively with an aim of keeping the egg safe from cracking. They will do this through labeled diagrams. Once the diagram is completed they may collect their resources.
- The children will work together in their group to create their egg holder and test it out using a plastic egg.
- Once all the groups have made their egg holders the children will go outside to test them out. They will carry out different stages (heights) of drops in an attempt to get "the best" egg holder. The children will carry out self and peer evaluation to assess any improvements that they could have made.
- The children will record their investigation on a poster, including what they did, how it worked and what they would change.

Cycle: 2	Lesson: 4
Strand: Energy and Forces	**Strand Unit: Forces**

Learning objectives:

- Investigate the pushing force of water
- Predict, investigate and identify items which float and sink
- Adapt items to change whether or not they float or sink
- Hypothesize what causes one item to float and another to sink
- Manipulate plasticine so it will float or sink

Skills developed:

Questioning; observing; predicting; investigating; recording; communicating; interpreting/ hypothesizing

Learning Activities:

- Think pair share followed by class discussion about floating and sinking to elicit prior knowledge. Asking questions such as why do some objects float and others sink? Why can large heavy ships float on water while small coins sink?
- Next the children will move into groups of their choice. They will be provided with a section of items such as fruit, vegetables, bottles, lego piece, cups, pebbles etc. the children will have to predict what items they think will float and what will sink. Once the children have made their predictions they will be given a container of water to test their predictions and record their answers.
- Next the children will be encouraged through questioning to manipulate their items to see if they can change whether or not it floats or sinks. Teacher conferencing about what the children have done and what effect it might have had.
- Teacher demonstration of up-thrust of water, holding a ping pong ball or cork underwater, letting it go and watching it being pushed back to the top. Explaining that the force of the water that's acting on the object is called up-thrust. The children will explore their items to see if this happens with any of their floating objects.
- Next the children will get two balls of plasticine, they will be asked to play around with different shapes to see if they can get it to float. Identifying the shape that floats most effectively. They will then be provided with small weights to test the strength of their floating plasticine. The children will describe to another group what worked well for them and what they had to change to achieve the best 'boat'. The children will then be given the opportunity to adapt their own designs to work best.
- Finally the children will record their results on a poster

Cycle: 2	Lesson: 5
Strand: Energy and Forces	**Strand Unit: Forces**

Learning objectives:

- Design and make a boat from recyclable materials
- Investigate floating and sinking
- Explore the properties of different materials to identify what will work well for the project
- Problem solve to overcome any unforeseen issues with construction
- Work collaboratively to create a design proposal
- Communicate and evaluate the design plan using sketches, models and information and communication technologies
- Develop craft-handling skills and techniques
- Use a range of materials
- Evaluate the effectiveness of the new product and suggest modifications to the designing and making task
- Evaluate the work of peers and propose positive modifications

Skills developed:

Planning, designing, making, evaluating, working collaboratively, investigating

Learning Activities:

- The criteria and expectation for the boats is set out at the beginning of the lesson, with clear guidelines and questions for discussion and for the children to think about. I will show the children any materials I have brought in for the lesson and the children will have their own as well.
- Next the children will sit in the groups (their choice) of 2 to 4 people. Together they will draw a design plan for their boat. I will circulate the room to discuss the plans with the children and question them to explore their reasoning and speculate any possible conflicts or problems.
- Then the children will begin working on their boats, being as creative as they wish but ensuring that they fulfill the specific requirements – float, hold a weight and move with wind. The children will be able to test their boats in the classroom as they work to make any changes necessary.
- When the children are satisfied that their boat is fully operational they will be given time to design the appearance of the boat and add any special features they wish. At this time I will continue to circulate the room and conference with the children about their final product and the process they went through to create it.
- Finally each group will present their project, either to the whole class (depending on time and number of groups) or to one other group that they are paired with.

Cycle: 2	Lesson: 6

Strand: Energy and Forces	Strand Unit: Forces

Learning objectives:

- Develop craft-handling skills and techniques
- Evaluate the effectiveness of the new product and suggest modifications to the designing and making task
- Test the effectiveness of the boat by racing it against others in a local river
- Evaluate the work of peers and propose positive modifications

Skills developed:

Designing, making, evaluating, working collaboratively, investigating, testing, observing

Learning Activities:

- The children will have some time at the beginning of the lesson to make any final changes to their boats. They will be able to test their boats out in buckets of water to ensure they are satisfied
- I will walk the children from the school to the local park where there is a river.
- The children will race their boats in the river. There will be a reasonable distance their boat will have to travel, including flowing over a small waterfall.
- The boats will be caught by a net a the finish line and pulled back in to the bank.
- There will be a class discussion about which boats worked the best and why, and what changes other groups could have made to their boats for a more successful experience.
- There will then be a number of prizes, these prizes will not just be for the fastest boat but will also take into consideration, engineering, design and originality.

Appendix N: Interview Transcript – Post Intervention

I – Interviewer (me)

L – Lara*

A- Alex*

C – Conor*

B – Beth*

*pseudonyms to provide anonymity to participants

I: Thanks you guys for coming back and for agreeing to chat to me again today

B: It was really fun so we obviously would

I: You're okay with doing it again, good! Okay, so do you guys - you can take it in turns to answer - do you like doing science in school?

All: Yes

I: Conor, why do you like doing science in school?

C: I don't know I just find it really interesting and fun

I: You find it interesting and fun? Good! Alex?

A: I find it interesting and fun, the same as Conor, but I don't like the worksheets. They're boring and they're hard.

I: They're hard, they're boring and you don't like them. So what do you like about science?

A: Emm when we get to do the experiments and we get to like… like the time when we made the filters, we got to design our own filters.

I: Okay so designing things by yourself, yeah great! Lara, did you say you like science? What do you like about it?

L: Yeah, I love science cause I do it a lot, I have like a bazillion factbooks and I really love doing it.

I: Okay and is there anything in school science that you like doing particularly?

L: When we made the parachutes and designed our thingy for eggs.

I: The egg holder, excellent.

L: That was fun

I: And Beth you said you like doing science as well, didn't you?

B: Yes, I really do. I like creating, like designing your own stuff. I don't like the worksheets as much. And I liked, yeah, I really liked the filter, and eh, yeah I really like science, it's really fun!

I: Okay great, thanks Beth! And is there anything you don't like about school science? So you just said about your worksheets and the writing part of it, is there anything else?

L: Well if we were doing science and we had to do worksheets, or if we didn't do science and didn't do worksheets , I would definitely pick do worksheets and do science.

I: Okay, so if it meant not do science at all you'd still rather do science even if it also meant doing the worksheets.

L: Yeah

I: Cause you like it that much?

L: Yeah

I: Amazing! Okay guys, so if I was an alien coming from another planet learning about science, and I'd never sat through a science lessons before. Could you tell me what you do in a science lesson?

L: Yes, well I could.

I: You go for it then Lara.

L: Well I'd tell you that it's fun and show you some experiments.

B: Usually we create our own stuff.

L: Yeah, you'd create your own stuff, and I'd show you my fact-book about science and all.

I: Okay brilliant, is there anything you'd add to that Conor or Alex?

A and C: Nope!

I: Nothing you'd add to that for an alien looking in at a science lesson?

A: Well the only thing I would add is how do we tell the alien the things cause the alien would not understand English

I: Well hopefully they'd understand English or we'd have to use Google translate maybe! Okay so what would you be doing in your science lesson if an alien was to look in?

L: Having fun

B: Emm, I would like to make oobleck

C: I would try to make it more interesting cause then he might get into it and start liking science

I: You'd like him to like it too? Great. And what would your teacher be doing? If the alien was looking in

L: Helping us… helping or showing us how to do it, or giving us supplies

A: And some facts to help

I: And some facts, great. And do I ever read out of the school book? The text book?

All: Mixed responses of yes and no

B: No not really, you usually look it up, you usually just tell us first or you would put a video on

L: I love when you do that it's nice.

I: You like the videos?

L and B: Yeah

A: Remember when we were doing the helicopters and there was the cute cat

L and B: Awh yeah!

I: Okay, and do I ever demonstrate experiments?

All: Yes!

B: Definitely, like the sugar, dissolving sugar, and we had to drink it

I: And what do you think whenever I demonstrate experiments, is that interesting or is that boring?

L: Interesting

B: Yeah it's fun cause like -

A: It's not so interesting since we don't get to do it ourselves

B: I like when we have to… like with the helicopters and we had to show the class what we did

C: We stood up on the chairs

I: When everyone was standing up with the spinners? And what were you saying Conor, that sometimes I'll show you something and then you get to do it yourself after? Okay good. And do you do experiments?

All: Yeah

I: Can you tell me what you did in your last science lesson?

C: Boats

I: Boats, what did you do with boats?

C: We designed and made our own boats and we took them to the park and put them in the river.

B: And watched ours drown

I: and why did we put them in the river? What was the point of that?

C: To test them to see if they floated.

I: And did they?

All: mixed responses "well some"

B: They all did but

L: the waterfall, they just got stuck at the waterfall… Most of them moved back

A: But here's the thing, if your boat would be long enough the waterfall could not catch it cause the boat would just go out like that *hand gesture* and the water would push it down

L: Yeah I was planning to make a big boat at home

A: I was planning to make another Titanic boat but then I watched this video of the Titanic just sinking down after it hit the iceberg

I: Yeah it might have been good if you were in a canoe because then you would have skipped over the little waterfalls and you wouldn't have gotten caught in them. Okay good, and did you like that lesson?

All: Yes

L: That was definitely one of my favourites

B: I think maybe the fruit and vegetable one was kind of a bit boring

L: Well I loved it

All: talking over each other with different opinions about the lesson

I: Okay and when we did the boats in the park did you carry out an experiment during that one?

B: Pardon?

I: Did you do an experiments?

A: Well we kinda did

L: Well we tested if they floated

I: Yeah and you had kinda already done the hard-work as well hadn't you? Cause you had already made your boats

L: Well it wasn't hard it was fun

I: Was there anything you didn't like about that lesson?

L: It was really hot and that was annoying

B: Hot?! It wasn't that hot

L: Well to me it was

B: Yeah when we were running

A: I didn't like it because my boat it wasn't going that way, remember it was going backwards

I: It was going upstream?

A: Yeah but good thing I had an anchor that was pulling it the other way. And here's what I thought was maybe the anchor would hang onto another boat and then it would be floating with that boat together

I: And what did you guys learn in that lesson?

B: How things float

A: How things float

L: Well nothing really, I didn't learn anything

C: And we know what to do next time to make a better

I: Yeah to make changes to do a better boat. Yeah it would have been nice if we'd had time to try them again and make improvements

B: I would like if we could start a different boat and maybe a few more materials

I: Oh yeah like more variety of materials?

B: Yeah like more bottles

L: I wish we still had science…

I: And do you ever work in groups in your science lessons?

All: Yes

L: I always work with Beth

I: Okay and do you like working in groups?

All: Yes

B: But sometimes –

A: But sometimes I don’t because when I was with you two I was planning something different for the filters

I: Okay so not always on the same page?

L and A: Yeah

B: So I think the filters that emm we could go in a group of two – if we were doing the filters again – a group of two emm that you wanted to be with, like I wanted to be with Lara

I: Okay so did you like or did you prefer or did it not bother you that you got to chose your own groups in the last few weeks, so that you were choosing the people that you worked with

B and C: Yeah I liked it

I: You preferred it? Yeah?

All: Yeah

I: Rather than me choosing the groups for you?

All: Yeah

I: So what kind of things have you guys done in your groups?

Overlapping voices “fun”, “just stuff”

B: We’ve done lots of planning out like, we have to plan it, like get a piece of paper –

A: like when we were doing the egg holders we had to draw like what we wanted to put, like say the sponge then the egg like inside it

L: Yeah that was really fun

B: Did yours work?

A: No

B: Ours did

L: We still have ours

B: I have the egg, I have the egg at home

I: Is it not smelly?

B: No, I put a tissue over it so –

L: We called it Little Eggy and we drew a cute face

A: Oh and Lara drew this kinda but don't tell the ticket or else you're gonna cook it

I: So do you work in groups in any other lessons? Or any other subjects in school?

Overlapping "Not really", "sometimes", "for iPads"

I: For iPads you do yeah?

All: Yeah

L: But we don't get to choose and that's just sad

B: I would like if we could get to choose

C: In maths when we were doing capacity we got to go in groups and go to the tub of water and put the measuring cups in

I: Okay so sometimes for maths and always for iPads

A: I would like if we could, emm Ms Dunphy* if we could… be able to, emm, choose our own partners

A: Yeah cause I would like to be with Conor for iPads

I: Okay guys and last time we were here we were talking about having special roles when you're in your groups, so everyone having special jobs. Did we do that this time?

All: No

I: NO, and did you need it or was it alright without it?

All: It was alright

I: Why do you think that was?

L: Because we got to do it together, we didn't have to like fight about it

B: Yeah

I: Okay, and do you think that is because you were working with your friends so you were able to work things out a little more easily?

All: Yes

L: Definitely

I: Okay and so our textbook for science, have we used that at all since the last time we were chatting?

B and C: No

L: Well like once or twice but it's like fill in the blanks so I cant really read it well

I: Did you guys do it with me since the last time we were talking?

B: No

L: We have

I: Because last time we were talking, after that then we did the parachutes and we did the boats so did we use it for any of that stuff?

A and C: No

B: I don't think so, no

L: Wait no, not for that but we have used it

I: Okay so now since Easter time, have we done much writing in science?

All: No

B: Except setting out what were going to do

I: Your plan?

B: Yeah

I: So that's mostly drawing and writing together?

B: Yeah I like the drawing and writing. I don't really like the worksheets cause sometimes it's hard when it says explain your answer, I don't know what to do.

All in agreement

L: Like it's hard, if you disagree but you're like I don't know why I disagree that's just like hard

A: And I wish the worksheets – I'm saying the worksheets are fun but if it would have like do not explain your answer like you don't need to explain your answer you just circle like "Do things float in water? Like somethings or nothing"

B: I wouldn't mind the worksheets if –

A: You could like circle something and you wouldn't have to explain your answer

L: But I see why it does say it cause like people would read it and be like *why* do you disagree

I: Mmm hmm, okay. And then did I put much writing on the board as well?

All: No

B: Little bit of the dissolving

C: A little bit but…

I: A little bit, yeah, just some times, a few words but maybe not as much as I was writing before

B: Like that we had to explain the method, that was just… I didn't really like that

I: There was a lot of writing in that. Okay so guys, before Easter we did the kind of dissolving experiment, and we did the things with heat as well. remember we did the kind of spoons in the water with butter on them and the ice melting in hot water or cold water

B *speaking over I*: Yeah that was kinda boring

I: And then for the materials we did a lot of dissolving and that kind of thing. And then since Easter we've done the parachutes and the boats. Did you find there was a difference between the lessons we did before Easter and the lessons we did after?

All: Yes

B: I liked, I well, not everything, but I kind of liked some lessons that were before Easter? I liked the filters

L: Yeah I liked that but I liked the eggs, definitely liked them

B: Yeah definitely liked them

C: The last interview we did we said we'd prefer to do some science lessons outside and you said "yeah" and we did two outside, we did the parachutes and the boats

I: And were you happy to do that?

All: Yeah

B: That was good I *really* liked the boats

I: Okay so boats were your favourites and filters Beth. Eggs were your favourite Lara

L: Yes, well everything was my favourite

I: What was your favourite Alex?

A: Well mine I think was the boats as well.

I: The boats as well. Conor?

C: I think the parachute, the boats and the filters

I: Okay those three you liked

A: I liked the ones Conor said but I didn't really like boats since John or Jason took my little boat and squished it into the water, especially cause it was made out of cardboard

I: Yeah that was silly. And guys, so why do you think you liked those ones best? What was it about those that you liked?

B: I just think it was because we got to go outside and kind of –

L: Yeah it was fun, and also because we still have our egg

A: I would like it if we had went and did the boats and then got to go to the playground

I: We should have maybe gone to the playground, I should have allowed more time

B: Yeah we really should have

C: I think because all of those three we got to design and make our own ones and well my filter didn't work out but my parachute worked and my boat did

I: Great yeah! And then how did you feel when it worked?

C: Happy

L: Happy, proud

I: Yeah you might be a little bit proud as well exactly. Because something you've made and you've designed worked

L: Yeah

I: And did you get to pick your own resources for those things? Your own materials?

All: Yes

I: Okay good

L: But what I love about science, what I also love about science is when it works, that's cool

B: but what I also love, I like when, umm you have no idea how to do it and it doesn't work and then you get, you know, you're like "Oh how does this work?" and then you explain it and we're like "Oh"

I: Do you know what that can be called? So that can be called trial and error too, so you try something out, it doesn't work, you make a change and then it works the next time. And then you might keep making changes until you get it perfect. And so guys, if I was to be your teacher next year, what things would you want me to do more of in science?

L: Go outside

B: Oobleck, the playground

L: Us being the teacher

I: Okay what do you mean by that Lara, you being the teacher?

L: So for homework we could search up some facts about what we're doing

I: Okay good

L: And then we could explain to the class

I: Ahh okay, so you'd learn about something in science and then you could explain to everyone else about it?

L: Yeah and we could be in like partners so I could be with Beth and we could do it together, like a project

B: I would like more projects on science, like, or even, anything else where for your homework instead of just doing sentences, it's kind of a bit boring, doing a project about whatever

L: Or doing science, the way we did the thingys and that was fun

I: Okay cool, so more science at home as well. Alex? Conor?

C: If you did a science experiment at home and then you could come into the class and do it, and show the class and see if they could do it

I: Okay yeah! So again like being the teacher and you could come in and show the science experiment

B: I would really like it if you could be our teacher

A: If you were our teacher, if we were doing science I wish we could go up to the computers and search up facts and then you could record us and let everyone hear about what each one of us says about science. Like, say like, we're saying a fact, starting with Lara and she's saying a fact like she searched something up. And she tells it into the microphone and then we're all going to hear like me, and everybody in the class.

I: So I know you weren't there for this one Alex, but a little bit like whenever you searched up about the Titanic, that day, and lots of people got facts about the Titanic and they put it into an iPad. That's a good idea

L: I'd like if we had science books or something and we could bring them in, and then we could pass them around the class

I: That would be nice yeah and that some other people might be interested in the content of your science book

A: I've got 502 science experiments in my book

L: Yeah I've got a really good one and it includes experiments. Sometimes they're hard but they work and they're really good.

A: If you were our teacher I wish we could do elephants toothpaste

C: Awh that's hard

B: It's kinda dangerous

I: Is that a kinda explosion type of thing?

B: Yeah it goes up and up so high. Probably higher than Homebase

C: I think it gets hot or something

I: Yeah, I think I've only ever seen that done in like a school lab, like a proper science laboratory

A: And if we couldn't do that I wish we could just do Coca-Cola and Mentos

All: Yeah!

B: And I think what we should do is taste testing loads of different food. Not basic foods

L: And like different tastes like sweet, sour, bitter and there's like a spicy one…

I: And so guys is there anything then, if I was your science teacher next year, that you'd want me to do less of?

B, C and A: Worksheets

L: Writing

B: I wouldn’t like you to be our science teacher next year; I’d want you to be our teacher.

L: Also I would want to go on like school trips

A: Me too

L: Where we could do experiments on the way

I: So like science trips?

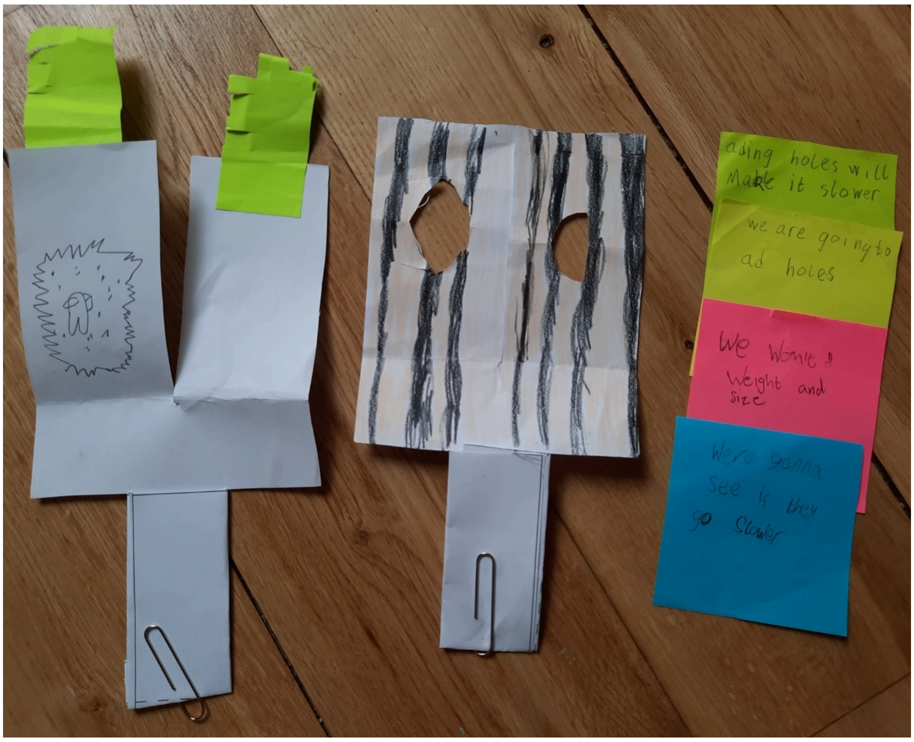
L: Or like a hunt

B: Science trips yeah!

A: Like in a bus and then we’d all like get our own things that we want four our experiment and go to a park and like do it there

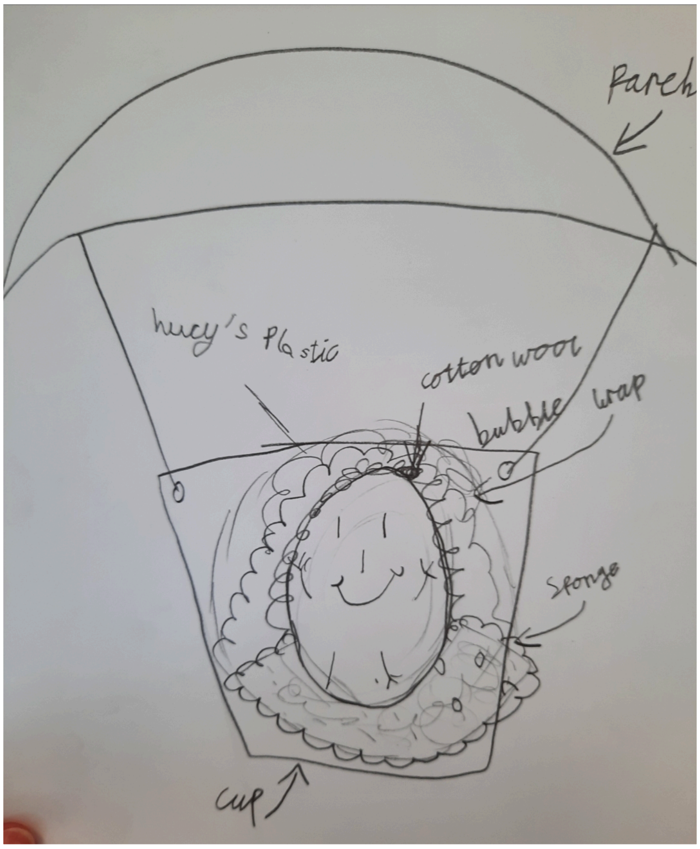
L: Or like I’d want to go *inaudible* or something and we could do like a hunt or a scout thing or whatever

Appendix O: Images of children working during IBSE lessons and examples of their work



Example of alterations made to children's paper helicopters and post-it's explaining their thought processes

Children working collaboratively to make a parachute

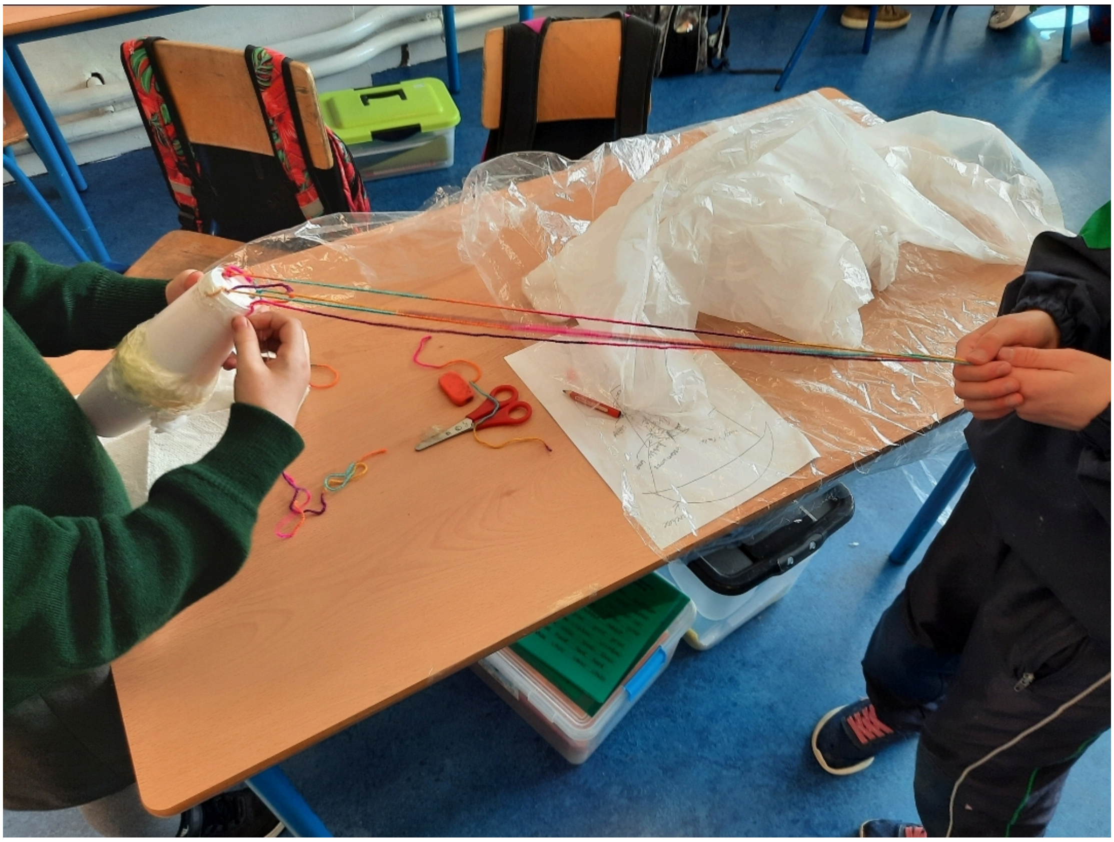


Children’s plan for parachute and egg holder


Children making a protective holder for an egg (Cycle 2)

Children working collaboratively to create their parachute and egg holder

Children’s plan and finished egg holder



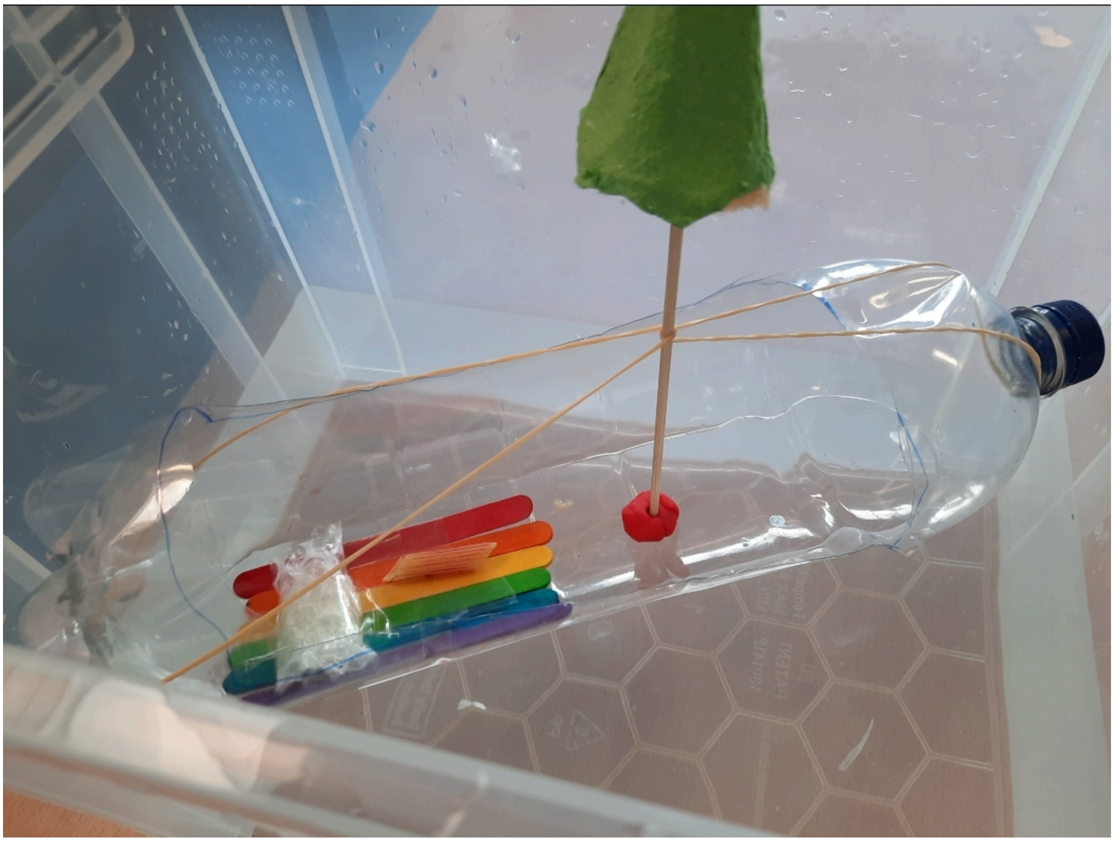
Children working collaboratively to complete their parachute and egg holder

Children's final parachute and egg holder

Children investigating different boat shapes using tinfoil

Children investigating adding weight to floating tinfoil boats

Children creating their boat



Children investigating how the boat floats in water

Children’s finished boat

Children’s boats racing in local river

Children following the progress of their boats

Children's boats crossing the finish line