

**AN EXPLORATION OF SCHOOL-BASED LESSON STUDY AS A
MEANS OF DEVELOPING PRIMARY TEACHERS' ORIENTATIONS
TOWARDS THE TEACHING OF SCIENCE**

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DECLARATION

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work, and that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: Mary Boyle ID No.: 59265256 Date: December 1st 2025

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TABLE OF CONTENTS

DECLARATION	i
ACKNOWLEDGEMENTS	ii
TABLE OF CONTENTS	vi
LIST OF ABBREVIATIONS	xvi
LIST OF TABLES	xviii
LIST OF FIGURES	xix
ABSTRACT	xxi
CHAPTER 1: INTRODUCTION	1
1.1 Overview	1
1.2 Science Education	2
1.2.1 The Importance of Science Education	3
1.2.2 Science Education and Scientific Literacy	3
1.3 Primary Science in Ireland	4
1.3.1 A Brief History	4
1.3.2 Successes in the Learning of Primary Science in Ireland	6
1.3.3 Challenges to the Learning of Primary Science in Ireland	7
1.3.4 Successes in the Teaching of Primary Science in Ireland	8
1.3.5 Challenges to the Teaching of Primary Science in Ireland	9
1.4 A Time of Change: The Incoming Science Technology and Engineering (STE)	
Curriculum	11
1.5 Role of This Research Study	13

1.6 Overview of Thesis	15
CHAPTER 2: LITERATURE REVIEW	17
2.1 Overview	17
2.2 The Role of Inquiry in the History and Philosophy of Science	17
2.2.1 Induction: A Method of Scientific Inquiry	19
2.2.2 Falsificationism	21
2.2.3 The Philosophy of Thomas Kuhn	23
2.2.4 The Philosophy of Imre Lakatos	25
2.2.5 The Philosophy of Paul Feyerabend	27
2.2.6 The Scientific Theory Profile	29
2.3 Inquiry Based Science Education (IBSE)	31
2.3.1 Defining IBSE	32
2.3.2 IBSE: Critical Perspectives	34
2.3.3 Practices that Support IBSE	36
2.3.4 Summary	38
2.4 Theories Underpinning Science Education	39
2.4.1 Behaviourism	39
2.4.2 Constructivism	40
2.4.3 Social Constructivism	42
2.5 The Knowledge Needed to Teach Science	44
2.5.1 The Development of PCK for Science	51

2.6 Lesson Study	54
2.6.1 An Introduction to Lesson Study	54
2.6.2 Lesson Study Moves Westwards	57
2.6.3 Western Adaptations of Lesson Study	60
2.6.4 Lesson Study in Ireland	65
Research in Primary Education	65
Research in Initial Teacher Education (ITE)	66
Research at Post-Primary Level	68
Research on the Experience of Facilitating LS	69
2.7 Rationale for the use of Lesson Study in this Research Study	70
2.8 Research Purpose and Research Questions	71
2.8.1 Statement of the Problem	71
2.8.2 Purpose Statement and Research Questions	72
CHAPTER 3: RESEARCH METHODOLOGY	74
3.1 Introduction	74
3.2 Conceptual Framework	74
3.3 Epistemological Framework	75
3.4 Research Paradigm	78
3.4.1 Social Constructivism	78
3.4.2 Personal Philosophy of Science	79
3.5 Theoretical Framework	81

3.5.1 Situated Learning Theory	81
3.5.2 Communities of Practice	82
3.5.3 Social Learning Spaces	85
3.5.4 Value Creation in Social Learning Spaces	87
3.6 Case Study	88
3.7 Conclusion	94
CHAPTER 4: RESEARCH METHODS	95
4.1 Introduction	95
4.2 Research Site	95
4.3 Site Selection	95
4.4 Research Participants	96
4.4.1 Insider-Researcher	96
4.4.2 Teacher Participants	98
4.4.3 Pupil Participants	101
4.4.4 External Knowledgeable Others	102
4.5 Data Collection	103
4.5.1 Teacher Meeting Logs	103
4.5.2 Teacher Reflective Logs	104
4.5.3 LS Cycle Teaching-Learning Plan	105
4.5.4 Research Lesson Observation Log	106
4.5.5 Children's Work Samples	106

4.5.6 Focus Group Interviews	107
4.5.7 Researcher Reflective Journal	108
4.6 Data Handling	109
4.7 Data Analysis	110
4.7.1 Aspects of PCK for Science Teaching	111
4.7.2 Development of a Framework for Analysis for Teacher Orientations	113
4.7.3 The Value Creation Framework as an Analytical Tool	118
Types of Value in the Value Creation Framework	120
Loops and Flows in the Value Creation Framework	123
Effect Data and Contribution Data	125
4.8 Trustworthiness	127
4.9 Ethical Considerations	129
4.10 Conceptual Framework associated with this study	131
4.11 Conclusion	134
 CHAPTER 5: EFFECT OF LESSON STUDY ON THE DEVELOPMENT OF TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE	 135
5.1 Introduction	135
5.2 Development of Teachers' Orientations	136
5.2.1 Teachers' Orientations Prior to LS	137
5.2.2 Process Orientation	142
LS1	142
LS2	145

LS3	147
5.2.3 Inquiry Orientation	150
Confirmation Inquiry	151
Structured Inquiry	152
Guided Inquiry	153
Open Inquiry	160
Summary of Inquiry Orientations	161
5.2.4 Unstructured Exploration Orientation	161
5.2.5 Summary of the Development of Teacher Orientations	165
5.3 Development of Teachers' Subject Matter Knowledge	167
5.3.1 LS1	167
5.3.2 LS2	172
5.3.3 LS3	176
5.4 The Impact of LS on Children's Learning	180
5.4.1 LS1	180
5.4.2 LS2	185
5.4.3 LS3	197
5.4.4 Summary	206
5.5 Conclusion	207
CHAPTER 6: FEATURES OF LESSON STUDY THAT SUPPORT THE TEACHING OF PRIMARY SCIENCE	209
6.1 Introduction	209

6.2 Teacher Collaboration as a Feature of CPL (Immediate Value)	211
6.2.1 Collaborative Sharing of Ideas and Vulnerabilities	212
6.2.2 Collaborative Planning	216
6.2.3 Individual Roles within the Collaborative Process	220
6.2.4 The Importance of Collaboration Amongst Colleagues	222
6.2.5 Overall Significance of Collaboration	223
6.3 Extended Duration of the LS Cycle (Immediate Value)	224
6.4 Increased Teacher Confidence (Potential Value)	228
6.5 LS as an Opportunity for Reflection (Strategic Value)	231
6.5.1 Reflection as a Gateway to Developing Teachers' Orientations to Science	231
6.5.2 Reflection on the PSC	233
6.5.3 LS as an Opportunity for Collaborative Reflection and Self-Reflection	236
6.6 Teacher Agency (Enabling Value)	238
6.6.1 Agency within LS	238
6.6.2 Agency as a feature of CPL	241
6.7 The Importance of Mentoring (Enabling Value)	243
6.7.1 The Role of EKO's	244
6.7.2 The Role of IKOs	247
6.8 The Wider Impact of LS (Transformative Value)	260
6.9 Conclusion	264
CHAPTER 7: DISCUSSION AND CONCLUSION	266

7.1 Introduction	266
7.2 Overview of the Study	266
7.3 Summary and Discussion of Key Findings	268
7.3.1 Impact of LS on Science Teaching	269
Teachers' orientations can evolve and expand through school-based LS	269
Identification of a link between SMK and Teacher Orientations	275
Key Role of the Teacher in IBSE	276
7.3.2 Key Findings with regard to LS	277
The Importance of the Study Phase	277
An In-depth Account of the Experience of an IKO	280
Teacher Agency as an Aspect of LS	282
Application of the Value Creation Framework to Lesson Study	283
School-based Collaboration as a Key Aspect of LS	285
7.3.3 Summary of Key Findings	286
7.4 Contribution to Knowledge	287
7.5 Limitations of the Study	287
7.5.1 The Research Site and Participants	287
7.5.2 Data Collection during LS1	289
7.5.3 My Role as Researcher	290
7.6 Recommendations	291
7.6.1 Replicate the Study of LS as a CPL Methodology in Primary Science	291

7.6.2 Further Exploration of the Role of IKO in LS	291
7.6.3 Recommendations for Classroom Practice	292
Scientific Inquiry as a Key Pedagogical Practice	292
Explicit Teaching of Scientific Skills	292
7.6.4 Recommendations for Educational Policy	293
Need for Development of Teachers' Orientations toward Science in tandem with SMK	293
Retention of Sustained CPL for Teachers	294
Need for Collaborative, Reflective, Contextualised CPL	294
7.7 Personal Reflection	295
7.8 Conclusion	297
References:	298
APPENDIX A STUDY PHASE REFLECTIVE LOG	322
APPENDIX B PLANNING PHASE REFLECTIVE LOG	323
APPENDIX C TEACHING AND REFLECTIVE PHASE LOG	324
APPENDIX D LESSON OBSERVATION LOG LS1	325
APPENDIX E CHILDREN'S WORKSHEET LS1	326
APPENDIX F SAMPLE FOCUS GROUP QUESTIONS	327
APPENDIX G LETTER TO PRINCIPAL	328
APPENDIX H LETTER TO BOARD OF MANAGEMENT	330
APPENDIX I PLAIN LANGUAGE STATEMENT FOR TEACHERS	332
APPENDIX J CONSENT FORM TEACHERS	334

APPENDIX K LETTER TO PARENTS	335
APPENDIX L CONSENT FORM PARENTS	337
APPENDIX M CHILDREN’S LETTER	338
APPENDIX N PLAIN LANGUAGE STATEMENT CHILDREN	339
APPENDIX O CHILDREN’S ASSENT FORM	340
APPENDIX P TEACHING LEARNING PLAN LS1	341
APPENDIX Q TEACHING LEARNING PLAN LS2	353
APPENDIX R TEACHING LEARNING PLAN LS2	362

LIST OF ABBREVIATIONS

BOM	Board of Management
CLR	Collaborative Lesson Research
COP	Community of Practice
CPL	Continuous Professional Learning
DCYA	Department of Children and Youth Affairs
DEIS	Delivering Equality of Opportunity in Schools
DES	Department of Education and Skills
EKO	External Knowledgeable Other
IBSE	Inquiry Based Science Education
IKO	Internal Knowledgeable Other
iSTEM	Integrated Science Technology, Engineering and Maths
ITE	Initial Teacher Education
KCS	Knowledge of Content and Students
KCT	Knowledge of Content and Teaching
KO	Knowledgeable Other
LS	Lesson Study
LS1	Lesson Study Cycle 1
LS2	Lesson Study Cycle 2
LS3	Lesson Study Cycle 3
NCCA	National Council for Curriculum and Assessment
OECD	Organisation for Economic Cooperation and Development
PCK	Pedagogical Content Knowledge
PDST	Professional Development Service for Teachers
PISA	Programme for International Student Assessment

PSC	Primary Science Curriculum
REC	Research Ethics Committee
SLS	Social Learning Space
SMK	Subject Matter Knowledge
STE	Science, Technology and Engineering
STEM	Science, Technology, Engineering and Maths
TIMSS	Trends in International Maths and Science Study
TLP	Teaching-Learning Plan

LIST OF TABLES

Table 3.1 Epistemological Framework for this study.....	77
Table 4.1 LS1 Teacher Participants.....	100
Table 4.2 LS2 Teacher Participants.....	101
Table 4.3 LS3 Teacher Participants.....	101
Table 4.4 LS Teacher Participants.....	102
Table 4.5 LS Pupil Participants.....	102
Table 4.6 LS Teacher Meetings.....	105
Table 4.7 Framework for Analysis of Teachers' Orientations.....	115
Table 7.1 Key Findings of this Study.....	273

LIST OF FIGURES

Figure 2.1 The Scientific Theory Profile.....	30
Figure 2.2 The Lesson Study Process.....	56
Figure 2.3 Collaborative Lesson Research Model.....	62
Figure 2.4 Lesson Study Cycle.....	64
Figure 3.1 Case Study Design of this Study.....	93
Figure 4.1 The Value Creation Framework.....	121
Figure 4.2 A learning flow becomes a learning loop.....	125
Figure 4.3 Conceptual Framework for this Study.....	133
Figure 5.1 Model of Effect Data themes identified in this study.....	137
Figure 5.2 Concept Cartoon created by the teachers for LS3 Research Lesson.....	160
Figure 5.3 LS1 Children’s Record Sheet.....	185
Figure 5.4 Diagram showing observations of the Sun made during LS2 Lesson 3...	189
Figure 5.5 Student record of shadow observations made during LS2 Lesson 3.....	191
Figure 5.6 Student record of shadow observations made during LS2 Lesson	192
Figure 5.7 Science Journal Record of LS2 Research Lesson.....	195
Figure 5.8 Science Journal Record of LS2 Research Lesson.....	196
Figure 5.9 Science Journal Record of LS2 Research Lesson.....	198
Figure 5.10 Child’s Reflection Sheet LS3.....	200

Figure 5.11 Child’s Reflection Sheet LS3.....	201
Figure 5.12 Child’s Reflection Sheet LS3.....	202
Figure 5.13 Child’s Reflection Sheet LS3.....	205
Figure 5.14 Child’s Reflection Sheet LS3.....	206
Figure 6.1 Model of Contribution Data themes identified in this study.....	213

ABSTRACT

An Exploration of School-Based Lesson Study as a Means of Developing Primary Teachers' Orientations Towards the Teaching of Science

Mary Boyle

This research stemmed from an authentic practice-based problem encountered by me as a Continuing Professional Learning (CPL) facilitator in the area of primary science: the challenge of transferring engaging CPL opportunities into actual classroom practice. Research highlights a number of concerns regarding the teaching and learning of primary science in Ireland, including a lack of teacher confidence and limited participation in CPL. There is a need for increased levels of Pedagogical Content Knowledge (PCK) and Subject Matter Knowledge (SMK) among teachers as well as greater use of Inquiry Based Science Education (IBSE) methodologies in the classroom and further development of children's scientific skills. Lesson Study (LS) was identified as an effective method of CPL, although most LS research has been in the area of mathematics. This study explored the use of school-based LS as a means of developing primary teachers' orientations towards the teaching of science, an overarching aspect of PCK in science. Furthermore, the study aimed to identify the features of school-based LS that are most effective in supporting the teaching of primary science. In addition, the role of the researcher as an emergent Internal Knowledgeable Other (IKO) was examined.

Research was conducted from a social constructivist viewpoint, underpinned by social learning theory. An evaluative, instrumental, collective case study was utilised to collect data across three cycles of LS. Teacher orientations were analysed based on an emergent framework. The Value Creation Framework (Wenger-Trayner & Wenger-Trayner, 2020) was used to identify the effective features of LS as a CPL methodology in primary science. Findings reveal that LS supported both the development of teachers' orientations and SMK, which combined, positively impacted children's learning. Findings also revealed that effective features of LS as a CPL methodology included opportunities for collaboration, teacher agency, opportunities for reflection, support from mentors and extended duration. A further novel feature of this research study is that it provides an expanded conceptualisation of teachers' orientations towards the teaching of science and an in-depth account of the experience of an IKO in school-based LS. Finally, the research contributes to knowledge regarding Social Learning Space (SLS) as a theoretical underpinning of school-based LS. This study highlights school-based LS as an effective CPL methodology in primary science, which is particularly pertinent at this time of curriculum change.

CHAPTER 1: INTRODUCTION

1.1 Overview

This research study aims to investigate the effectiveness of Lesson Study (LS) as a Continuous Professional Learning (CPL) methodology to support the development of primary teachers' pedagogical content knowledge (PCK) in science. My interest in this area was piqued by a real-practice problem I encountered in my role as facilitator of science CPL to primary school teachers, that is, the challenge of transferring an engaging inquiry-based CPL experience into actual classroom practice. Research substantiates my experience in the field as there is “widespread evidence that primary teachers, in Ireland and worldwide, do not feel confident or competent in implementing more child-centred, inquiry-based approaches to teaching science due to inadequate conceptual and pedagogical content knowledge” (Murphy et al., 2023, p.95). This is especially critical given the onset of a new Science Technology and Engineering (STE) curriculum in Ireland, the draft specification of which (NCCA, 2024) lists scientific inquiry as one its three key pedagogical practices. It is therefore essential for the successful implementation of the STE curriculum that teachers are provided with professional learning opportunities to bolster their conceptual and pedagogical content knowledge. This thesis explores the use of LS as one such method of professional learning for teachers.

This introductory chapter will set the context and provide a rationale for this study. It will begin with a broad outline of the reasons why science is taught in our schools, and the importance of scientific literacy. Following on from this, attention will be focused on primary science in Ireland, currently in a time of curriculum change as mentioned above. A brief history of primary science in Ireland will be provided, which

includes an examination of the outgoing curriculum (Department of Education and Science [DES], 1999a) and its implementation as evidenced in research. This information will provide a context for the successes and challenges to the teaching and learning of primary science in Ireland in recent times. The chapter will conclude with a rationale for this research study.

1.2 Science Education

Scientific and technological breakthroughs can contribute to addressing a range of global social, economic, and environmental challenges (Organisation for Economic Co-operation and Development [OECD], 2025). At the same time, progress in science and technology can contribute to the problems we face, such as when advances in Artificial Intelligence (AI) threaten to intensify the spread of disinformation. In this manner, education “plays a crucial role in building ethical frameworks, shared goals, and skills to ensure scientific and technological progress benefits humanity and the planet while safeguarding collaboration and security” (OECD, 2025, p.34).

Rudolph (2023) states that there are “two larger purposes of science education” (p.64). The first incorporates teaching science to produce future scientists, which Rudolph refers to as the “technical training” goal of science education. The second purpose of science education is for non-scientists, or “science for general education”. It is essential that education provides everyone, not just future scientists, with a broad understanding of the status and nature of scientific knowledge, given that it is all around us, linked from our individual personal lives to the bigger picture of a rapidly changing global society.

1.2.1 The Importance of Science Education

The *Science Education for Responsible Citizenship* report from the European Commission (Hazelkorn et al., 2015) recommends that science education “should be an essential component of a learning continuum for all, from preschool to active engaged citizenship” (p.8). Harlen and Qualter (2018) describe science as important for learners as individuals, as members of society and as citizens of the world. They state that science can help individuals understand the world around them and assist with making personal choices, develop learning skills that are needed throughout life and, thus, become informed citizens. They further assert that science education can support wider society to develop realisation of the widespread consequences of its applications, locally and globally. In order for science education to make this substantial contribution to both individuals and society at large it is necessary for citizens to gain an understanding of science as a result of their interactions with the subject. It is important for members of society to become “scientifically literate”, a term which will now be examined.

1.2.2 Science Education and Scientific Literacy

The aim of scientific education is to develop students’ scientific literacy, leading to improved public understanding of science (Harlen & Qualter, 2018). A statement from the European Federation of Academies of Sciences and Humanities (ALLEA, 2024) notes that there are many interpretations of what the term “scientific literacy” comprises. Furthermore, Deehan et al. (2024) observe that “the embodiment of scientific literacy will vary across nations, regions, schools and classrooms” (p.3). On the other hand, Rudolph (2023) is critical of the use of the term due to this lack of specificity.

According to the OECD Programme for International Student Assessment (PISA), scientific literacy is defined as “the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen” (OECD, 2016b, p.28). The science framework developed for PISA 2015 was used also in PISA 2018 and PISA 2022. It describes how scientific literacy “also requires not just knowledge of the concepts and theories of science but also a knowledge of the common procedures and practices associated with scientific inquiry and how these enable science to advance” (OECD, 2016a, p.18). PISA views scientific literacy as a set of skills that can be acquired to a greater or lesser extent (OECD, 2016b). The onus must be on educators to provide opportunities for children to develop the skills of scientific literacy to the greatest extent that they can, in order to become informed, reflective citizens.

An understanding of science, developed through science education, can lead to the development of a scientifically literate population. Being scientifically literate enables individuals to rationalise the choices they make in their personal lives, and leads them to become engaged and informed citizens of wider society. Having provided an overview of science education in general, and its role in the development of scientific literacy, it would now seem important to consider primary science education in Ireland, which provides the context for this study.

1.3 Primary Science in Ireland

1.3.1 A Brief History

The outgoing Primary Science Curriculum (PSC) (DES, 1999a) was formally implemented in Irish schools in September 2003. Varley et al. (2008) note that it represented a considerable expansion when compared to its predecessor, *Curaclam na*

*Bunscoile*¹ (Department of Education, 1971), given that science was included as a primary subject in its own right for the first time in an Irish context. The earlier curriculum placed emphasis on biological and environmental science, whereas physical science was only a significant component for fifth and sixth classes (Varley et al., 2008).

The PSC aims to develop children's conceptual understanding and procedural understanding of science (DES, 1999a). An understanding of science concepts is developed through engagement with the four strands of the curriculum, namely: Living Things, Materials, Energy and Forces, and Environmental Awareness and Care. Procedural understanding is enhanced through the development of skills, subdivided into “Working Scientifically” skills and “Designing and Making” skills. The PSC envisages that children will develop conceptual understanding and procedural understanding in tandem through participation in science. While the term “scientific literacy” is absent from the PSC, the PISA definition of scientific literacy (OECD, 2019; OECD, 2016a) is widely reflected in its aims and broad objectives. For example, the PSC makes reference to the development of scientific knowledge and skills in the context of everyday life in the local environment before expanding to national and global dimensions.

Since its rollout in 2003, research has revealed mixed findings regarding the implementation of the PSC and its impact on the teaching and learning of primary science in Ireland. An outline of identified successes and challenges will be provided, in order to provide a context for this study.

¹ Curaclam na Bunscoile is the Irish language translation of Primary School Curriculum.

1.3.2 Successes in the Learning of Primary Science in Ireland

Irish primary children hold positive attitudes towards science and appear to have some experience of hands-on investigations (Murphy et al., 2011; Perkins et al., 2020; Varley et al., 2008). They appear to engage in collaborative group work as part of science activities (Murphy et al., 2011; Varley et al., 2008), as envisaged by the PSC. The vast majority of Fourth Class² children who participated in the Trends in International Mathematics and Science Study (TIMSS) 2015 reported feeling confident about science, agreed that they “usually do well in science”, and reported that they experienced engaging science lessons (Perkins et al., 2020).

There is no national assessment of science in Irish primary schools, however Fourth Class children in Ireland who participated in the TIMSS 2023 achieved a mean science score which was significantly above the international average (McHugh et al., 2024). Performance among the highest achieving pupils was significantly higher in 2023 than 2015. Overall, 2015, 2019 and 2023 scores were significantly higher than TIMSS 2011 results which indicates sustained improvement in Irish pupils’ science achievement. Given that Clerkin et al. (2017) noted that Irish pupils received less time on science instruction than their peers in any of the other 55 countries that participated in TIMSS 2015, with no increase in allocation in the meantime, this appears a remarkable achievement. At the same time, Clerkin et al. (2016) proposed the introduction of the National Strategy to Improve Literacy and Numeracy (DES, 2011) and the subsequent improved literacy levels among Irish students made it easier for them to engage with standardised science tests.

² Fourth Class is the sixth year of primary school in Ireland, typically consisting of children who are 9-10 years old.

1.3.3 Challenges to the Learning of Primary Science in Ireland

Research indicates that some children are not afforded regular opportunities to engage with hands-on science inquiries (Varley et al., 2008). Child-led investigations appear to be used infrequently, with teacher demonstration and teacher explanation reported as dominant methodologies (DES, 2012; Murphy et al., 2011; Murphy et al., 2020; Varley et al., 2008). Children appear to have few opportunities to develop their scientific skills (DES, 2012; Varley et al., 2008), with estimating, measuring and questioning specifically identified as areas of weakness (Varley et al., 2008). The skill level of older pupils does not appear substantially different from that of their younger peers (Varley et al., 2008). This raises a concern about the depth of skill development across the 8 years of primary education. Children's experiences of physical science, associated with the curriculum strand Energy and Forces, appear to be rather limited (Varley et al., 2008). Furthermore, lack of pupil achievement in this area of the curriculum has been a recurring theme since the introduction of the PSC (DES, 2012; McHugh et al., 2024).

The mean science achievement of Fourth Class Irish children in TIMSS 2023 was above the international average. However, it is of concern that the score of the lowest-performing pupils in TIMSS 2023 and TIMSS 2019 was significantly lower than that of the same cohort in TIMSS 2015. Results also show that the score of children who attend urban schools in the Delivering Equality of Opportunity in Schools (DEIS)³ programme was significantly lower in TIMSS 2023 than the score of those in non-DEIS and DEIS Rural schools, a pattern retained from TIMSS 2019 (McHugh et al., 2024). The same authors urge caution with these differences however, given the small sample

³ The DEIS Programme provides targeted supports for schools with high concentrations of students at risk of educational disadvantage.

size in each of the three DEIS categories and the large standard errors associated with mean scores. In addition, TIMSS 2023 included a new scale that provided an individual measure of pupils' socioeconomic status (SES). While just 7% of Irish pupils were in the lower SES category, these pupils achieved a significantly lower mean score than those in both higher and middle SES categories. Results suggest that consideration could be given to ways in which supports are provided for individual learners experiencing the greatest degree of educational disadvantage, including those attending non-DEIS schools (McHugh et al., 2024).

1.3.4 Successes in the Teaching of Primary Science in Ireland

A report from the Department of Education and Skills Inspectorate found “much that is encouraging” with regard to the teaching and learning of science in Irish primary schools (DES, 2012 p.41). This included collaborative whole-school planning, linking science to the wider environment and the management of resources. The same report noted that in the majority of lessons observed “teachers demonstrated a good or very good understanding of the particular concepts they were teaching” with “pupils engaged in hands-on practical tasks” (p.41). The *STEM Education 2020* report (Inspectorate, 2020), although including science as part of the four STEM disciplines, alongside technology, engineering and mathematics, noted that 84% of 94 observed lessons at primary level were deemed to be satisfactory or better. Most Irish teachers whose pupils participated in TIMSS 2015 expressed high levels of confidence in inspiring their pupils to learn science and in their capacity to adapt their teaching to engage pupils' interest in science (Clerkin et al., 2017). Furthermore, the same report notes that a higher proportion of TIMSS 2015 participants were taught by newly qualified teachers who reported adopting more inquiry-based methodologies for teaching science. Inquiry-based approaches employ a more child-led approach to scientific inquiry where students

are required to apply and develop a range of scientific and problem-solving skills (Murphy et al., 2020).

1.3.5 Challenges to the Teaching of Primary Science in Ireland

It is evident from research that many Irish primary teachers lack confidence when teaching science (Clerkin et al., 2017, Murphy et al., 2015; Smith, 2014; Varley et al., 2008). Teachers of pupils who participated in TIMSS 2015 revealed lower levels of confidence in teaching science compared to mathematics in general, but particularly in relation to improving the understanding of pupils who were struggling, assessing pupil comprehension, and helping pupils to develop higher-order thinking skills (Clerkin et al., 2017). In addition, it would appear that many Irish primary teachers lack adequate science subject matter knowledge (SMK), particularly in the area of physical sciences (Clerkin et al., 2017; Smith, 2014; Varley et al., 2008). Many Irish primary teachers require further development of their pedagogical content knowledge (PCK) for teaching science (Clerkin et al., 2017; Murphy et al. 2015). These concerns regarding teacher SMK and PCK extend to initial teacher education (ITE). Research has found that many preservice teachers held inaccurate understandings of forces and electricity, frequently holding similar misconceptions to children. Furthermore, students in ITE reported not having sufficient scientific knowledge to teach older classes (Murphy & Smith, 2012). Notwithstanding the increase in teachers adopting more inquiry-based approaches to science in Irish primary classrooms identified by Clerkin et al. (2017), it would appear that, in general, Irish teachers utilise more teacher-directed than child-led methodologies (Murphy et al., 2015; Murphy et al., 2020; Smith, 2014; Varley et al., 2008).

In terms of teacher professional learning, Clerkin et al. (2017) found that attendance at science-related CPL was very low in Ireland, compared to many other countries who participated in TIMSS 2015. It could be inferred that the inadequate levels of science PCK and SMK among Irish primary teachers are further compounded by the lack of participation in science CPL. Clerkin et al., (2017) also revealed that collaborative practices among teachers generally appeared to be less common in primary schools in Ireland than in most countries.

In summary, Irish children remain positively disposed towards science, and have maintained a mean score higher than the TIMSS international average since 2015. However, research has highlighted a number of areas of concern with regard to the teaching and learning of science in Irish primary classrooms. Some of the main findings include lack of teacher confidence, the need for increased levels of SMK and PCK amongst teachers, low levels of participation in science-related CPL and lack of collaborative practice. A reduction in instruction time for science has naturally led to a decrease in the amount of time children spend engaging with scientific activities. When they do, it appears that there is a need for further development of scientific skills, and scope for wider use of IBSE methods, both key features of the *Draft Science, Technology and Engineering Education Specification* (NCCA, 2024).

Clerkin et al. (2017) note that given the limited time allocated to science instruction, it seems important to ensure that the time available is used as effectively and efficiently as possible. Therefore the onus is on teachers to engage pupils in rich learning experiences. However, it is evident that challenges remain to the teaching and learning of primary science in Ireland. This period of curriculum change presents a clear opportunity to address such challenges through the provision of necessary support for teachers.

1.4 A Time of Change: The Incoming Science Technology and Engineering (STE) Curriculum

Research indicates a disconnect between the vision of the PSC and the actual classroom experience of both teachers and pupils. This could be a concern with the ongoing introduction of a new Science, Technology Engineering and Mathematics (STEM) primary curriculum in Ireland. For clarity, although the four disciplines comprise the new primary STEM curriculum area, the Primary Maths Curriculum (Department of Education, 2023) was itself introduced in September 2023. The *Draft Science, Technology and Engineering Education Specification* was published by the National Council for Curriculum and Assessment (NCCA) in 2024, but is still awaiting formal introduction. A need has been identified for high quality learning opportunities in both Science Technology and Engineering (STE) and mathematics, as well as through integrated STEM (iSTEM) (Murphy et al., 2023). It would seem even more critical that teachers are supported to address the identified challenges to the teaching and learning of science in the face of a broadened curriculum which will also encompass technology and engineering. As such, it would seem appropriate to consider curriculum implementation in other countries at this time of curriculum change in Ireland.

Murphy et al. (2023), commissioned by the NCCA, conducted a comparative curriculum content analysis of 11 international science curricula to explore their aims, structure and content, which they believed could inform the development of STE specifications in Ireland. Furthermore, the same authors carried out a review of literature relating to curriculum implementation across the 11 countries. They identified the presence of strong science leaders in schools and teacher engagement in effective professional learning programmes as key features of effective primary science teaching

and learning. At the same time, Murphy et al. (2023) acknowledged that primary teachers in all 11 jurisdictions lacked confidence and competence in teaching science, and found broad evidence that hands-on science activities tend to be more teacher-directed. It is apparent that these challenges align with those found in Ireland. Murphy et al. (2023) recommended professional learning opportunities that support teachers to develop “an in-depth knowledge of science, how to teach science and of how pupils learn” (p.43), in order to ensure that teachers are confident and competent to implement curricula. In addition, they stated that “science curriculum policy should be clear, and curriculum documents need to provide succinct accounts of the overall aims, content and methodologies to effectively implement curricula, and offer precise curricular specifications” (p.44). This would suggest that the new STE curriculum should offer clear guidance to teachers on what content to teach and how to teach it, and that CPL should be provided in order to support teachers with its implementation through developing their SMK and PCK.

NCCA (2024) envisions a Science, Technology and Engineering curriculum at Irish primary level that supports children in “developing the knowledge, skills and dispositions required to make informed decisions about local, national and global challenges” (p.1). This would appear to connect the proposed curriculum framework with the definitions of scientific literacy outlined earlier. The strands include some of the original PSC (DES, 1999a) content such as Living Things, Materials and Energy and Forces. However, Environmental Awareness and Care has been removed from the new specification. In addition, new strands namely Nature of STEM, Technology and Engineering are incorporated. It would seem that through the inclusion of Nature of STEM the new specification explicitly aims for children to build their epistemic

knowledge of science, technology and engineering through exploring “what STEM is, how it works and how it relates to the world around us” (NCCA, 2024, p.34). .

NCCA (2024) identifies three key pedagogical practices which it considers “essential to the provision of meaningful learning experiences” (p.21). These are scientific inquiry, design thinking and computational thinking. In terms of scientific inquiry, the specification outlines how it can advance from teacher-led to guided and increasingly child-led inquiries. It states that children can “build and strengthen scientific skills, scientific content knowledge and their understanding of the Nature of Science by engaging in a variety of types of scientific inquiries” (p.21). This assertion is supported by the research of Murphy et al. (2023), who noted the effectiveness of inquiry-based approaches in developing students’ scientific conceptual knowledge, scientific skills, and understanding about the Nature of Science, resulting in more positive attitudes towards science. Murphy et al. (2023) also observe the importance of explicitly teaching scientific skills which has been identified as a challenge for Irish primary teachers (Clerkin et al., 2017; Murphy et al. 2011). It would appear that alongside the development of teacher SMK and PCK, as described above, it is imperative that Irish primary teachers receive appropriate supports to enable them to engage their students in inquiry-based approaches to science, including the development of scientific skills. It is clear that there is a need for Irish primary teachers to participate in effective science CPL, particularly at this time of curriculum change. The role of this research study in addressing this issue will now be discussed.

1.5 Role of This Research Study

Smith (2014) notes that traditionally in Ireland CPL tends to “be provider-driven ‘one-off’ courses or short modular courses provided by the Department of

Education and Skills” (p.469). Darling-Hammond et al. (2017) conducted a review of literature from the previous three decades to identify seven widely shared features of effective CPL: content focused, incorporates active learning, supports collaboration, uses models of effective practice, provides coaching and expert support, offers feedback and reflection, and is of sustained duration. They note that research shows that effective CPL incorporates most or all of these elements. It would seem prudent, therefore, to pay attention to these identified attributes when designing CPL opportunities for teachers. Furthermore, the *Cosán Framework for Teachers’ Learning* (The Teaching Council, 2016) advocates that teachers should “exercise autonomy in identifying, and engaging in, the types of professional learning opportunities that benefit them and their students most” (p.6). The framework also acknowledges that the teaching profession “is not a homogenous group” (p.7), taking into account the differentiated needs of individual teachers, students and schools. It would seem that a “one size fits all” approach to CPL is to be avoided, and that it is preferable that teachers should have more input in their own professional learning, taking into account the varying contexts in which they work.

This research study seeks to examine the effects of a CPL methodology on the teaching and learning of science for a group of Irish teachers and students. After reflecting on the features of effective CPL, as outlined above, the methodology of Lesson Study (LS) will be investigated as a suitable approach for effective CPL in primary science. Dooley et al. (2014), in a review of research on mathematics learning of children aged 3–8 years commissioned by the NCCA, identified LS as a practice that has been foregrounded in the literature as a significant development in school-based professional development. Research into the use of LS at a time of curriculum reform with post-primary mathematics teachers found that it can act as a powerful model of

CPL which can encourage the introduction of new pedagogical practices (Ní Shúilleabháin & Seery, 2018).

LS as a method of professional development originated in Japan in the early 1900s (Ming Cheung & Yee Wong, 2014), and has since been credited with supporting profound changes in teaching there (Takahashi & McDougal, 2016). In general, it involves a process of goal setting, lesson planning, a live research lesson, post-lesson discussion and reflection (Fujii, 2016). Japanese teachers point to the central role of LS in the improvement of teaching at an individual, schoolwide and even national level (Lewis & Tsuchida, 1998). A more in-depth outline of LS is provided in the next chapter.

Research involving LS in Ireland has up to now mostly focused on the area of mathematics (Brosnan, 2014; Corcoran, 2010; Hourigan & Leavy, 2019; Leavy & Hourigan, 2016; Ní Shúilleabháin, 2015; Ní Shúilleabháin & Seery, 2018). More recently, Flanagan et al. (2024) explored the use of LS as a CPL methodology in the area of iSTEM in a rural Irish primary school. This study aims to explore the use of LS as a CPL methodology for the development of primary teachers' PCK in science, currently an under-researched area. Furthermore, this research is novel given its focus on school-based LS, including the development of my role of local expert, or internal Knowledgeable Other (IKO).

1.6 Overview of Thesis

In this chapter the area of science education was introduced, within which this study is situated. A rationale was provided for this research, through identifying the successes and challenges to the teaching and learning of primary science in Ireland, as identified in the research. The next chapter will examine the literature pertaining to the

core issues examined by this study, namely the nature of scientific inquiry and IBSE methodologies, theories of learning, PCK, and LS. In Chapters 3 and 4 the methodological decisions made in carrying out this research and theory underpinning those decisions will be described. In Chapters 5 and 6 the findings relating to the research questions are outlined. Chapter 7 provides an overall discussion of this research. To conclude the thesis, limitations of the findings presented will be discussed, and suggestions will be made regarding further study that may build upon the research presented here.

CHAPTER 2: LITERATURE REVIEW

2.1 Overview

In this research study the use of LS as a CPL methodology for the development of primary teachers' PCK in science is explored. Furthermore, the features of LS which support the teaching and learning of science, as identified by participant teachers, will be examined. Initially, this chapter will review literature that is relevant to the role of inquiry in science, beginning with a description of what science is as a discipline, viewed through the lens of history and philosophy. Subsequently, a rationale will be provided for the use of inquiry based approaches in science education (IBSE). Following this, the theories of how children learn will be outlined, with a focus on behaviourism, constructivism and social constructivism. Attention will also be focused on the knowledge that is necessary to teach science, that is, teachers' PCK. Finally, an outline of LS as an approach to CPL will be provided, along with a justification for the use of this methodology as a means of developing teachers' PCK to teach science.

2.2 The Role of Inquiry in the History and Philosophy of Science

In modern times science is highly esteemed, both in everyday life and in the academic world (Chalmers, 2013). The introductory chapter highlighted how this belief is still relevant today. An understanding of science enables people to make informed decisions about themselves and the world around them (Jones et al., 2013). However, the central role of science in society is not a new phenomenon. Western science, for example, grew out of a European medieval worldview dominated by Aristotelian philosophy and Christian belief and practice. The Scientific Revolution of the 17th century, encompassing the new science (natural philosophy) of Galileo, Descartes, Huygens, Boyle and Newton, caused a seismic change, not just in science, but in

European philosophy that had enduring repercussions for religion, ethics, politics and culture (Matthews, 2009a). In the wake of the Scientific Revolution, the 18th century philosophers and educators believed that a widespread understanding and appreciation of science would not only promote science, but it would also have positive effects for society and culture (Matthews, 2009b). Science has been held in high regard throughout modern history and has played a pivotal role in society. Science is pervasive in our everyday lives, from the drinking of pasteurised milk to the decision on whether or not to buy a hybrid car, and it is the basis of nearly every tool we use, from a simple can opener to the most advanced space explorer (OECD, 2016b). Many of the challenges that face humanity at present require innovative solutions that have a basis in scientific thinking and scientific discovery (OECD, 2016a).

In light of the powerful influence of science on society, both past and present, it seems appropriate to examine science as a discipline, to ask, what is science? Duschl (1990) states that knowledge about science is knowledge of why science believes what it does and how science has come to think that way. Therefore, in order to gain understanding of science as a discipline, both the philosophy of science and the history of science must be considered. In terms of this research study, emphasis shall be placed on the role of inquiry in the history and philosophy of science. The philosophies of Bacon, Popper, Kuhn, Lakatos and Feyerabend have been selected on the basis of historical context, prominence in the nature of scientific thinking, and as an introduction to a variety of thinking in relation to inquiry to this study. In discussing the perspectives of these philosophers, the work of Chalmers (2013) in his book *What is this thing called science?* will be drawn upon.

2.2.1 Induction: A Method of Scientific Inquiry

Induction, or inductivism, as it is sometimes referred to, was first formalised as a method of scientific inquiry by Francis Bacon in the 17th century. He asserted that facts should be assimilated without bias to reach a conclusion (Bacon, 1620, as cited in McComas, 1998). According to Chalmers (2013), the theory of inductivism suggests that, provided certain conditions are satisfied, it is legitimate to generalise from a finite list of singular observation statements to a universal law. The conditions can be listed as follows: the number of observation statements forming the basis of a generalisation must be large; the observations must be repeated under a wide variety of conditions; no accepted observation statement should conflict with the derived universal law. From an inductivist viewpoint the source of knowledge is experience, not logic.

McComas (1998) acknowledges that the collection and interpretation of individual facts providing the raw materials for laws and theories, is at the foundation of most scientific endeavours. Desroches (2006) argues that to view induction as “a kind of accumulation of facts does not account for its nuanced function” (p.116). He believes that induction can be construed “as a kind of buttressing of the senses, just as the senses are meant to buttress the understanding” (p.118), thus creating a back-and-forth movement between the senses and the intellect. This emphasis on the use of the senses to make observations highlights some of the merits of induction as a philosophy of science, while the fallibility of observations appears to be one of induction’s main shortcomings. Gaukroger (2001) states that although Bacon’s thinking was gradually superseded in the nineteenth and twentieth centuries, his main contribution was how “he inaugurated the transformation of philosophy into science, and philosophers into scientists” (p.221).

Induction as a theory is not without its critics. McComas (1998) notes that “the problem with induction is that it is both impossible to make all observations pertaining to a given situation and illogical to secure all relevant facts for all time, past, present, and future” (p.58). However, a final, valid conclusion cannot be reached without satisfying each of these stipulations. Chalmers (2013) suggests that inductivism is logically invalid due to the ambiguity surrounding the meaning of a “large” number of observations in a “wide variety of conditions”. He asks as to how many observations make up a large number? What is to count as a significant variation in the circumstances? This lack of precision is perceived as a weakness of the inductivist point of view. Chalmers (2013) also criticises the inductivist theory that science begins with observation, saying that this belief is undermined by the argument that theories of some kind precedes all observation statements. Furthermore, observations are as fallible as the theories they presuppose, and therefore do not constitute a solid basis on which to build scientific laws and theories.

Bacon’s 17th century philosophy of scientific inquiry can be linked to science education today through his emphasis on the place of the senses in natural inquiry (Desroches, 2006). The outgoing science curriculum *Teacher Guidelines* describes how “observing (using all the senses separately or in combination) is a fundamental skill in science” (DES, 1999b, p.17). The new *Draft Science, Technology and Engineering Education Specification* (NCCA, 2024) also mentions observation as an aspect of scientific inquiry, while including opportunities for children’s creativity through making inferences. There is also scope for teachers to introduce children to the fallibility of observation, if children make different observations when engaging with the same phenomena. For example, children could construct the same paper spinners but they could observe differences in the way they spin to the ground. This affords the

teacher an opportunity to discuss the fallibility of relying solely on observation during scientific inquiry.

2.2.2 Falsificationism

Karl Popper based his philosophy of science on the principle of falsifiability, which suggests that only those ideas that are potentially falsifiable are scientific ideas. Popper has been referred to as the scientist's philosopher and the philosopher's philosopher (Loving, 1991). According to Popper, science can only advance through a series of what he called "conjectures and refutations". Popper recommends that scientists should propose laws and theories as conjectures and then actively work to disprove or refute those ideas. Popper's example is the statement, "all swans are white", which cannot be proved by any number of observations of white swans, but can be falsified by one observation of a non-white swan (Driver, et al., 1996). The absence of disproof, despite an active programme of refutation, is considered support (McComas, 1998).

The falsificationist demands that theories be stated with sufficient clarity to run the risk of falsification. When a hypothesis that has successfully withstood a wide range of rigorous tests is eventually falsified, a new problem, hopefully far removed from the original solved problem, has emerged. This new problem calls for the invention of new hypotheses, followed by renewed criticism and testing (Chalmers, 2013). From a falsificationist stance, scientific inquiry progresses by trial and error. Only the strongest hypotheses survive the rigorous attempts to falsify them. The aim of science is to falsify theories and to replace them by better theories, theories that demonstrate a greater ability to withstand tests (Chalmers, 2013). Popper's emphasis on attempting to falsify

existing theories, as opposed to focusing on the collection of observations about the world, highlights how his philosophy of science differs to that of Bacon (Parvin, 2013).

Just as the philosophy of induction has limitations, so too has the idea of falsificationism. Chalmers (2013) suggests that theories cannot be conclusively falsified because the observation statements on which they are based are themselves fallible. The same researcher points to history to further highlight the shortcomings of falsificationism, noting that Newton's gravitational theory was falsified by observations of the moon's orbit. It took almost fifty years to deflect this falsification onto causes other than Newton's theory. Chalmers (2013) notes that some of the theories considered to be among the best scientific theories could have been rejected in their infancy if falsificationism was strictly adhered to in the past. Catton and MacDonald (2004) point to the work of Aristarchus, Harvey and Wegener in underlining the importance of deductions from phenomena to science. In this manner they highlight the limitations of Popper's anti-inductivist stance.

Popper's view of scientific inquiry can be connected to science education today through the emphasis on the development of higher order thinking skills, such as critical thinking. Popper claimed that human beings are principally problem solvers (Parvin, 2013) and problem-solving is at the heart of scientific inquiry in education, which typically begins with a question or challenge for exploration (NCCA, 2024). Popper placed importance on distinguishing between real knowledge and subjective opinion (Parvin, 2013). This can be linked to encouraging children in our classrooms to differentiate between an observation made using the senses and an inference based on a combination of evidence and reasoning in their scientific inquiries such as the "Tricky Tracks" activity (Lederman & Abd-El Khalick, 2002, p.85). Popper believed that science does not always follow a set pattern, it emerges from a process of trial and error,

and of rational, critical discussion, among a community of peers (Parvin, 2013). The present curriculum (DES, 1999a) and new draft STE specification (NCCA, 2024) both envisage that children will work together, sharing ideas and communicating results to others. Furthermore, the new draft specification promotes the pedagogical process of design thinking which supports children to “test and refine their prototypes through collaboration and deliberation” (p.23). Though they may not actively seek to falsify the scientific concepts they engage with, Popper’s understanding of science can be incorporated into classrooms through the development of a problem-solving inquiry based approach to investigations and the promotion of design thinking.

Historical study also reveals that the evolution and progress of major sciences exhibit a structure that is not captured by inductivism or falsificationism. Evidence such as the Copernican Revolution and the challenge to the Newtonian framework of Physics by relativity and quantum theory in the early twentieth century support this idea (Chalmers, 2013). Since the 1960s it has become common to conclude that a more adequate philosophy of science must “proceed from an understanding of the theoretical frameworks in which scientific activity takes place” (Chalmers, 2013, p.97). An outline shall now be provided of two such philosophies of scientific activity, those of Thomas Kuhn and Imre Lakatos, which are grounded in the revolutionary nature of scientific research.

2.2.3 The Philosophy of Thomas Kuhn

Duschl (1990) notes that close scrutiny of historical events in science indicated that science was better characterised as a discipline in which dynamic change and alteration were the rule rather than the exception. Thomas Kuhn emphasised the revolutionary character of scientific progress, where a revolution involves the

abandonment of one theoretical structure and its replacement by another, incompatible one. Kuhn suggested that scientists work within a research tradition known as a “paradigm”, made up of the general theoretical assumptions and laws adopted by a particular scientific community. The following outline of Kuhn’s philosophy of science is taken from Chalmers (2013):

- Workers within a paradigm practise what Kuhn refers to as “normal science”.
- Normal scientists must be uncritical of the paradigm in which they work, while inevitably experiencing difficulties and apparent falsifications.
- If difficulties of that paradigm become insurmountable a “crisis” state develops.
- The “crisis” is resolved when an entirely new paradigm emerges and attracts the allegiance of more and more scientists until eventually the original, problem-ridden paradigm is abandoned.
- The discontinuous change constitutes a “scientific revolution”.
- The new paradigm guides “normal” scientific activity until it reaches a “crisis” resulting in a new “revolution”. And so the cycle continues, from a Kuhnian viewpoint.

McComas (1998) acknowledges that while a paradigm provides direction and focus to research, the existing paradigm may also limit investigation. Examples of scientific ideas that were originally rejected because they fell outside the accepted paradigm include the sun-centred solar system, warm-bloodedness in dinosaurs, the germ-theory of disease, and continental drift. However, McComas (1998) notes that Kuhn’s review of the history of science demonstrates that paradigms are responsible for far more successes in science than delays. Anderson et al. (2006) describe how towards the end of the twentieth century a new generation of sociologists of scientific knowledge embraced Kuhn’s emphasis on the role of research communities in scientific

change. This suggests a link between Kuhn's philosophy of science and a social constructivist approach to scientific inquiry. Social constructivism involves developing an understanding of the world around us through our interactions with others, and incorporates the historical and cultural contexts of the individuals involved (Creswell & Poth, 2018).

Kuhnian philosophy can be linked to the social constructivist approach to scientific inquiry in the classroom described by Russell and Osborne (1993). Using this approach, the teacher sets the context for a new topic through the use of a resource, for example a story, which is relevant to the children's prior experiences. The children are encouraged to share their thoughts on the theme, grounding them in the reality they have experienced thus far. The teacher engages the children in scientific inquiry which can lead them to confirm or refute their earlier beliefs. This approach can be linked to Kuhn's philosophy, where scientists accept the paradigm in which they work until insurmountable difficulties emerge with the accepted belief. The importance of the social aspect of Kuhn's philosophy could be explored through sharing the results of other children who engage in the same scientific investigation. One would assume that such collective sharing of results would naturally lead to a confirmation or adjustment of the idea a child had at the beginning of an inquiry.

2.2.4 The Philosophy of Imre Lakatos

Chalmers (2013) describes Lakatos as an avid supporter of Popper's approach to science who perceived some limitations of falsificationism. Lakatos tried to modify these limitations through drawing on some aspects of Kuhn's philosophy. A major difference between Kuhn and Lakatos is the importance of sociological factors in Kuhn's theory (Chalmers, 2013). According to Kuhn, later paradigms are superior to

their predecessors because the scientific community judges them to be so. Lakatos was dissatisfied with this analysis. Lakatos (1978) outlines his scientific philosophy as follows:

- Scientific activity takes place within a framework, a “research programme” as opposed to a paradigm.
- The fundamental principles of a research programme are its “hard core”.
- Additional hypotheses which supplement the hard core are known as the “protective belt”.
- A “progressive” research programme will be one that retains its coherence and at least intermittently leads to novel predictions that are confirmed.
- A “degenerating” programme will be one that loses its coherence, and/or fails to lead to confirmed novel predictions.
- The replacement of a “degenerating” programme by a “progressive” one constitutes Lakatos’ version of a scientific revolution.

Lakatos (1978) believed that continuity in science “can only be explained if we construe science as a battleground of research programmes, rather than isolated theories” (p.78). Loving (1991) notes that the “sophisticated falsificationism” (p.16) of Lakatos depends on theories being appraised by how well they hold up when new facts are purposely introduced. Lakatos differs from Popper in his emphasis on confirmation of theories rather than their falsification. Lakatos emphasised the importance of historically related theories, whereas a falsificationist viewpoint deems it irrational to persist with a falsified theory (Larvor, 1998). For example, he reported that there were several occasions when Newton’s astronomy was at variance with the facts. Falsificationists would have abandoned their theory at these points. However, Lakatos believed that to abandon a progressive research programme over a few details would

have been a terrible waste of the potential of the programme, when there was a possibility that the problems could eventually be solved (Larvor, 1998). This highlights the difference between Lakatos and a Popperian philosophy of science: whereas from a Popperian point of view a theory which has been falsified is not worthy of further inquiry, Lakatos advocated further investigation when problems arise in a research programme.

Larvor (1998) notes that Lakatos was conscious of the dangers of entrenched dogma in all areas of inquiry and this concern helped to mould his work. When this is considered in terms of science education, Lakatos' view of inquiry could be applied in the classroom through encouraging the children to develop their questioning skills. In addition, his belief that research programmes should proceed even when they encounter problems, could transfer into encouraging children to persevere with investigations and be open to changing their approach when they encounter challenges. This particularly connects to the design thinking element of the new draft STE specification (NCCA, 2024) which aims to foster "perseverance and creative risk-taking as children encounter challenges or setbacks in the design process" (p.22). Finally, Lakatos did not think that human inquiry must necessarily terminate in absolute knowledge (Larvor, 1998). This belief could encourage teachers and children alike to focus on the process of inquiry, placing value on the skills of inquiry, as opposed to solely focussing on obtaining the "right answer".

2.2.5 The Philosophy of Paul Feyerabend

Paul Feyerabend, a contemporary of Popper, developed an "anarchistic theory" of science (Chalmers, 2013, p.138), by arguing that there is no scientific method and, indeed, that science does not possess features that render it necessarily superior to other

forms of knowledge. Feyerabend takes examples of scientific change, which his opponents consider to be classic instances of scientific progress and shows that, as a matter of historical fact, those changes did not conform to the theories of science proposed by those opposing philosophers of science. His main example involves the advancements in physics and astronomy made by Galileo (Chalmers, 2013).

In distinguishing between Feyerabend and Kuhn, Chalmers (2013) notes that Kuhn appealed to social consensus to restore law and order during times of change, a perspective with which Feyerabend disagrees. Feyerabend was highly critical of Kuhn's description of the accepted validity of the paradigm, in "normal science". For a critical rationalist such as Feyerabend this was unacceptable, for "if one decides not to test certain hypotheses, one ceases to do science" (Hoyningen-Huene, 2000, p.109). Furthermore, wary of the high regard in which science is held, he advocated a free society in which science does not receive preference over other forms of knowledge. Perhaps this gives basis to the label of "enfant terrible" which has been attributed to Feyerabend in philosophy of science (Loving, 1991).

Connecting Feyerabend to science education is a challenge. If one accepts the idea that increasing the scientific literacy of individuals will lead to informed citizenship, this naturally gives science an important role in society. Perhaps Feyerabend is noteworthy due to his difference, in his scepticism towards attempts to rationalise science (Chalmers, 2013). Knowledge of his critique of science can encourage educators to engage their students in debate in classrooms, allowing children to assert their opinions on the role of science in society.

It has been shown that different philosophies of science and differing views of the nature of scientific inquiry can each connect to the approaches we use in science

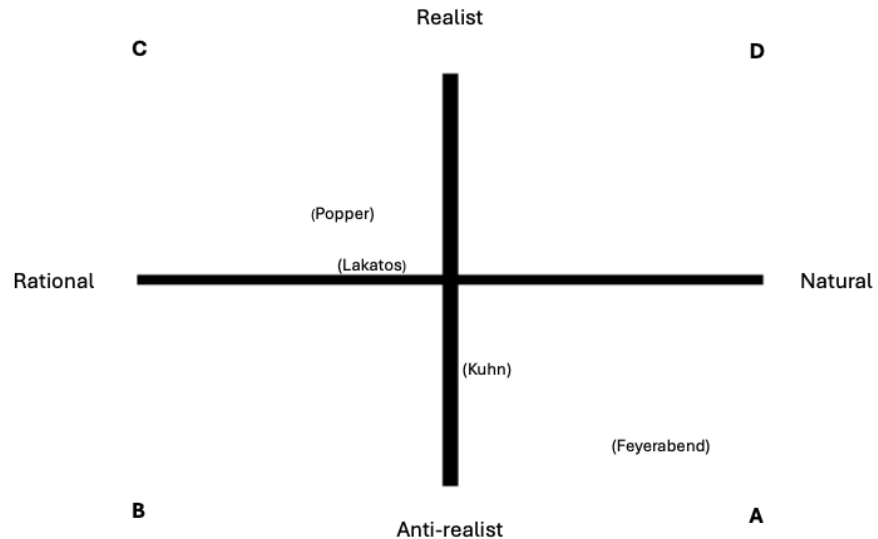
education. Matthews (2009a) argues that “philosophy is inescapable in good science” (p. 702), and as a result philosophy is inescapable in good science education. Loving (1991) suggests that knowing the range of views by well-known thinkers on how theories are judged and represented can lead to clearer perceptions about what science is and what it is not. Some of the varying philosophies of science can be compared using The Scientific Theory Profile (Loving, 1991).

2.2.6 The Scientific Theory Profile

The Scientific Theory Profile (Loving, 1991, p.11) provides a model to compare the philosophers outlined above on key questions about the nature of scientific theories. Not all 12 philosophers on the model have been discussed here, given the constraints of a small scale piece of research such as this. Therefore, Figure 2.1 below is an adaptation of Loving’s work, highlighting the four philosophers of science whose theories have been examined in this research. The Profile consists of an x, y-axis grid, where the x-axis measures whether theories are judged rationally (purely intellectual, based on logical thinking), naturally (with significant psychological, historical or sociological dimensions) or in some combination of both. The y-axis measures whether theories represent an external truth and reality (realist), or an individual human construction (anti-realist) or somewhere in between (Loving, 1998).

Figure 2.1

The Scientific Theory Profile (Loving, 1991)



Kuhn is placed near the y-axis, as his method for judging theories is a practical rationality, involving numerous social and psychological (natural) factors. He is more anti-realist than realist since he places value on scientific theories only in the particular context in which they are put forth. Popper is placed in the rational-realist quadrant, owing to his view that scientific theories are not completely verifiable, they are only falsifiable. Lakatos stands in the middle of Popper and Kuhn on such issues as the rationality of faith in one's beliefs (Loving, 1991). Perhaps it should come as no surprise that Paul Feyerabend with his radical viewpoint is far from the origin of the graph, where balance between the viewpoints is indicated (Loving, 1998). The profile allows a visual comparison of the philosophers outlined above, in terms of their beliefs.

Matthews (1994) believes that whenever science is taught, philosophy is also taught, as the teacher's own epistemology of science is conveyed to students and contributes to the image of science that they develop in class. Cobern and Loving (2002)

suggest that primary teachers “are not known to be science types” (p.1016), suggesting that regarding knowledge and attitudes to science they have more in common with the general public than secondary science teachers and others with science degrees. Cobern and Loving (2002) also note that society places great demands on primary teachers. As a result, it could be viewed as unrealistic to expect that primary teachers should have an awareness of the major philosophies of science. This would suggest that they should have an awareness of the background philosophies of all curricular areas. However, as scientific inquiry has been deemed a key pedagogical practice (NCCA, 2024), teachers should be supported in their general understanding of what it is and why it is important for the teaching and learning of primary science.

Consideration of some of the philosophies of science above has highlighted links to classroom activities today, including the importance of observation and how it differs to inference, the problem-solving nature of inquiry, and the trial and error nature of how scientists work. This could be used as the basis for developing teachers’ knowledge of how to teach children to engage in inquiry and work like scientists themselves in the classroom. It would seem appropriate, therefore, to examine scientific inquiry in the classrooms of today. Accordingly, Inquiry Based Science Education (IBSE) will now be discussed.

2.3 Inquiry Based Science Education (IBSE)

Attempts to achieve a balance between the needs of the majority of students who will not become scientists and the minority of students who will, have led to an emphasis on teaching science through inquiry (OECD, 2016a). Indeed Hazelkorn et al. (2015), in a report for the European Commission, recommend that students of all ages should “adopt an inquiry approach to science education as part of the core framework

of science education for all” (p.8). Inquiry in science education has a long and complex history (Constantinou et al., 2018). The term “inquiry” is grounded in the ideas of educators such as John Dewey. Dewey (1938) defined inquiry as “determination of an indeterminate situation” and described it as “the lifeblood of every science...constantly engaged in every art, craft and profession” (p.4). He stated that “if inquiry begins in doubt, it terminates in the institution of conditions which remove need for doubt” (p.7). Dewey’s view of inquiry is not without criticism, such as Nissen (1966) who asserts that it is “too narrow” and emphasises “successful inquiry” to the extent that an unsuccessful undertaking could not be identified as inquiry. Constantinou et al. (2018) argue that IBSE can be connected, although not limited, to the constructivist theory of learning proffered by Piaget and Vygotsky. They also ascertain that although there is no generally accepted clear definition of IBSE, common core elements do exist. These will form the basis of defining IBSE below.

2.3.1 Defining IBSE

A European Commission report (Rocard et al., 2007), describes how historically there have been two pedagogical approaches to teaching science. The first method, traditionally used by teachers is the “Deductive Approach” also known as “top-down transmission”. This consists of the teacher presenting scientific concepts to pupils. It would seem to align with a behaviourist approach to learning, as outlined later in the chapter. The second method, called the “Inductive Approach” or “bottom up” approach to teaching science involves observation, experimentation and construction by the child of his/her own knowledge, supported by teacher guidance. This highlights a link between the Inductive Approach and a constructivist view of teaching and learning. Rocard et al. (2007) note how changes in terminology have led the Inductive Approach to be referred to as IBSE.

IBSE “comprises experiences that enable students to develop understanding about the scientific aspects of the world around through the development and use of inquiry skills” (Harlen & Allende, 2009). The same authors, citing the National Research Council (1996), include making observations, posing questions, planning investigations, gathering, analysing and interpreting data, proposing answers, explanations and predictions, and communicating results as inquiry skills. However, Harlen and Allende observe that not all skills will be used in every inquiry, and certain skills, such as how to use equipment, are best taught in other ways. They state that “not all science involves inquiry, but it is essential where the aim is to develop understanding” (p.11). Sjøberg (2019) describes IBSE as teaching science based on inquiry methods, “where the learners get actively involved in formulating ideas, designing and performing experiments, discussing results and drawing conclusions, acting very much like ‘real scientists’” (p.2).

Cuevas et al. (2005) explain that there are three approaches to scientific inquiry: student-centred or open, teacher-guided, and teacher-centred or explicit. Student-centred or open is when students generate a question and carry out a scientific investigation. Teacher-guided is when the teacher selects a question and both students and teacher decide how to design and carry out a scientific investigation. Teacher-centred inquiry involves the teacher selecting a question and carrying out a scientific investigation through direct instruction or modelling. Banchi and Bell (2008) further subdivide teacher-centred inquiry into confirmation inquiry and structured inquiry. In confirmation inquiry students are provided with the question and the procedure, and the results are known in advance. On the other hand, in structured inquiry, the teacher provides the question and the procedure, but the students themselves generate their own

explanations, supported by the evidence they have collected as part of the scientific investigation.

The National Research Council (2000) outlines how students with little experience in conducting scientific inquiries will probably need more teacher-directed support. As the students' skills develop, however, the teacher should be enabled to provide more opportunities for student-centred or open investigations. While there is variance among the definitions of IBSE described above, in general they appear to align to the description of Capps and Crawford (2013), who describe IBSE as “an important teaching strategy that involves supporting students in investigating questions and using data as evidence to answer these questions” (p.498).

2.3.2 IBSE: Critical Perspectives

IBSE has been associated with increased conceptual understanding in science (Chang & Mao, 1999; Ellwood & Abrams, 2018; Murphy et al., 2023; National Research Council 2000; Rocard et al., 2007). It has also been linked with a positive impact on children's interest in learning science (Chang & Mao, 1999; Ellwood & Abrams, 2018; Murphy et al., 2023; Rocard et al., 2007). Research has shown that IBSE can support students to understand the work of scientists (National Research Council, 2000), and to acquire the skills of inquiry (Murphy et al., 2023; National Research Council, 2000; Rocard et al., 2007). It has been identified as an effective methodology with students of all abilities (Rocard et al., 2007). Cuevas et al. (2005) found that IBSE instruction increased students' ability to ask appropriate questions as a starting point for scientific inquiry. In terms of teaching science, an IBSE approach has been linked to stimulating teachers' motivation to teach science (Rocard et al, 2007).

Notwithstanding the positive impact of IBSE on the teaching and learning of science as highlighted above, the approach is not without its critics. Sjøberg (2019), citing a review of nearly 500 empirical studies of IBSE by Rönnebeck et al. (2016), notes how the results varied strongly. Sjøberg concludes that a main cause for this variety is “simply the lack of clarity of what is meant by inquiry-based teaching” (p.7) which leads to various conceptualisations of inquiry from one study to another. At the same time he observes that “it is fair to say that most research studies report a positive relationship between inquiry-based science teaching and science achievement” (p.10).

Perhaps of most concern is the finding of PISA 2015, where “in no education system do students who reported that they are frequently exposed to inquiry-based instruction...score higher in science” (OECD, 2016c, p.36). On the other hand, the same report found that being exposed to IBSE was positively related to students’ epistemological beliefs about science, their attitudes towards science and their interest in pursuing science later in life. Sjøberg (2018) argues that “such results may in the long run be more important than answering correctly on a test at age fifteen” (p.199). Furthermore, he suggests that a “written (or digital) test like PISA can hardly measure the skills and competencies acquired in experimental work in a lab or on an excursion; neither can it capture the kind of interest, curiosity and enthusiasm that may be the result of argumentation, inquiry, and the search for solutions to questions that the students have formulated themselves” (p.200). Similarly, Rudolph (2023) is critical of the manner in which international science assessments such as PISA and TIMSS, “typically end up assessing the recall of basic facts” (p.111). An examination of evidence from high and low performing education systems in PISA 2015 by Aditomo and Klieme (2020) found that it would be “misguided to use PISA findings to support arguments to scale back inquiry and other constructivist approaches to teaching

science” (p.504). Rather, they found that inquiry is positively associated with outcomes when it is associated with teacher guidance, and negatively when it does not. This highlights the importance of teacher scaffolding as part of IBSE which is supported by this study and will form part of the discussion chapter.

2.3.3 Practices that Support IBSE

Scientific inquiry is characterised as beginning with a question or challenge for exploration. NCCA (2024) outlines how children can advance from teacher-led to guided and increasingly child-led inquiries in the classroom. The TIMSS 2023 Science Framework (Centurino & Kelly, 2021), in its assessment of both primary and secondary students, incorporates five practices that are fundamental to science inquiry. They are: asking questions based on observations and theories; designing investigations and generating evidence; working with data; answering research questions and making arguments from evidence (p.43). These five practices are reflected in the list of activities students engage in during IBSE provided by Harlen (2021):

- raising questions, identifying problems and considering how they might be investigated;
- engaging in exploring events and objects – often, but not always, manipulating material and using equipment;
- working in collaborative groups in which students share and construct ideas together;
- proposing possible explanations based on their previous experience and using these hypotheses to make predictions;
- developing plans for investigations to test predictions;

- conducting investigations, collecting data by observation and experimentation as appropriate and recording results;
- drawing conclusions from the results about the ideas being tested, and communicating what they have done and found;
- reflecting on the process of inquiry and on any changes in their ideas (p.8).

Ellwood and Abrams (2018) also advocate for opportunities to engage in critical discourse, debate and peer review, as part of IBSE. They believe that the inclusion of such activities “broaden student experiences to more accurately reflect acting like scientists” (p.422).

Along with examining what students do during IBSE, it is also crucial to examine the role of the teacher in the process. Harlen (2021) provides a set of teacher activities which support the promotion of IBSE in the classroom:

- providing materials, equipment and access to sources of information for students to use and help in using them;
- facilitating group work and collaborative learning, by arranging space for group discussion and working and encouraging students to share and listen to each other’s ideas;
- asking open questions that elicit students’ ideas and encourage the use of inquiry skills;
- encouraging dialogue and talk in which students develop and extend their understanding;
- asking students to make predictions and plan investigations, helping where necessary to ensure that the planned actions are safe and productive;

- providing a supportive environment for students' investigations, listening to them and taking their ideas seriously;
- scaffolding alternative ideas that could help students explain the results of their investigation;
- encouraging students to reflect on what they have found and how they found it (p.9).

The *Draft Science, Technology and Engineering Education Specification* (NCCA, 2024) lists scientific inquiry as one of its key pedagogical practices, alongside computational thinking and design thinking. The specification outlines how teachers can help promote scientific inquiry in a list that strongly reflects the aspects of teacher activity identified by Harlen (2021) above. Furthermore, it advocates that teachers will draw “children’s attention to the scientific skills they are using and how they are working ‘like a scientist’” (p.22). In addition, it suggests that teachers should provide children with opportunities to engage in different types of inquiry, and encourage them to be aware of scientific inquiries in the news, online and in the world around them. Such teaching practices should support students in building and strengthening scientific skills, scientific content knowledge and an understanding of the Nature of Science through IBSE (NCCA, 2024).

2.3.4 Summary

It can be seen that IBSE methodologies are worthy of inclusion in primary science, given the identified benefits to both students and teachers and despite concerns noted in international assessments such as PISA 2015. However, research, such as that of Murphy et al. (2023), indicates that primary teachers, in Ireland and worldwide, do not feel confident or competent in implementing more child-centred, inquiry-based

approaches to teaching science due to inadequate SMK and PCK. In order for teachers to increase their use of IBSE methodologies, it would seem imperative to address these issues. However, as well as focusing on how teachers teach, which will occur later in the chapter, it is also important to consider the manner in which children learn, and the theories underpinning science education in general. Therefore, the next section will examine such theories.

2.4 Theories Underpinning Science Education

The major philosophies of scientific inquiry have been discussed above, given their relevance to this research study. However, it is equally important to address the philosophies of how children learn and retain information. To this end, this section will outline some of the major theories of learning: behaviourism, constructivism and social constructivism and how they connect to the manner in which children learn science.

2.4.1 Behaviourism

Carr (2003) describes how behaviourism has usually been associated with the animal experiments of Ivan Pavlov. In this case, Pavlov discovered that dogs could be made to salivate in response not only to food, but to a sensory impression that they came to associate with food, such as the ringing of a bell when no food was present. However, critics argue that rather than a learned behaviour, the dog exhibited a “neurophysiologically engendered reflex” to the bell ringing (Carr, 2003, p.88). At the same time, Brennan (2022) states that the work of Pavlov influenced other leading learning theorists such as John B. Watson. Watson (1924) asserted that behaviourism contends that we should not study our own selves, but rather our neighbour’s behaviour. In this manner humans can build an understanding of our own behaviour, through studying what other human beings do and why they do it.

Behaviourism as a learning theory was further developed by B.F. Skinner. Skinner, in his 1953 work *Science and Human Behaviour*, states that “what a man does is the result of specificable conditions and that once these conditions have been discovered, we can anticipate and to some extent determine his actions” (p.6). He argues that a sense of order emerges from any sustained observation of human behaviour, while acknowledging that predictions of what average individuals will do cannot be applied to each individual in particular. Skinner states that we use reinforcement to establish and shape the behaviour of others, particularly in education. He refers to positive reinforcers and negative reinforcers of behaviour. Such rewards and sanctions adapt and reinforce behaviour which leads to learning (Howard, 2018). For example, when a child’s correct answer is rewarded with praise or a smile from a teacher, this would be an example of positive reinforcement, which the child will most likely seek to achieve again. In terms of learning science, from a behaviourist viewpoint the focus of learning is on content acquisition, building an understanding of scientific concepts. Pedagogical approaches place emphasis on teacher direction and a preference for oral and written tests as a means of assessment (Howard, 2018).

2.4.2 Constructivism

Behaviourism as a learning theory falls short, from an educational viewpoint, of explaining the processes by which students develop understanding of the activities in which they partake (Carr, 2003). On the other hand, Carr describes how constructivist theory explains learning in terms of the active construction and imposition of principles or rules on experience. A constructivist views learning in terms of the individual constructing meaning through relevant practical experiences that reconstruct thinking (Howard, 2018). In other words, the individual has a more active role in their own learning from a constructivist stance, compared to arguably a more passive role in

behaviourist theory, whereby the emphasis is on building knowledge through observing the behaviour of others and responding to stimuli. Furthermore, constructivism places children's existing ideas and prior experience as the starting point for new learning. The constructivist theories of Piaget and Vygotsky share similar, rather than identical, views of cognitive development (Howard, 2018). Piaget's work is associated with cognitive constructivism while Vygotsky is linked to social constructivism. Each will now be examined.

Piaget's theory suggests that children move through four different stages of cognitive development: the sensorimotor stage, pre-operational stage, concrete operational stage and formal operational stage (Piaget, 1959). The sensorimotor stage is associated with children from 0-2 years of age whose simple reflexes develop into sensory and motor skills that are used to explore the world. Knowledge is based on limited physical experiences. During the pre-operational stage (2-6 years) symbols are used to represent objects and events. The world is viewed from an egocentric perspective which is reflected in egocentric speech. The child can group or sort objects based on observable features. Language is used to describe thoughts but thinking is not logical or reversible. The concrete operational stage (7-11 years) incorporates the emergence of logical and systematic thinking, with egocentric thoughts diminishing. Conservation of number is possible. The child can make assertions and claims based on observation. The formal operational stage (12+ years) includes an ability to reason and hypothesise beyond actual experience. The child can understand reversibility such as when water turns into ice and vice versa.

From a Piagetian perspective, information is assimilated and incorporated into a cognitive scheme (Piaget, 1959). A schema is a representation of a plan or theory in the form of an outline or model, a basic building block of intelligent behaviour. Driver

(1983), in the context of science education, outlines how Piaget suggested that as children learn more about their environment they become better adapted to it, in a process called equilibration. This takes place when a person assimilates an experience and in doing so adjusts or accommodates his knowledge structure, or existing schema, to it. To Piaget, learning is essentially an active process in which the learner constructs their knowledge through interaction with the environment and the resolution of cognitive conflict which may occur between expectations and observations. If the conflict is too great, assimilation will not take place at all. If there is no conflict between an experience and a learner's cognitive schema then the information is assimilated, without a change in the schema taking place at all. Through these processes of disequilibrium and subsequent equilibration, new intellectual structures are developed which incorporate the preceding structures and consequently development is through an invariant sequence of hierarchically ordered stages (Driver, 1983). It can be seen that learning is an active process, with the learner involved in the construction of their own knowledge. It would appear that Piaget's theory of learning aligns with Kuhn's philosophy of science as described in the previous section. From both viewpoints knowledge is reconstructed as a result of a "crisis" in the accepted paradigm or schema, which results in a "scientific revolution" or adaptation of the schema. While Piagetian theory focuses on the learner actively constructing their own knowledge, another theory of learning, social constructivism, centres on how through collaboration with a more knowledgeable other person, new meaning can be co-constructed (Howard, 2018). Social constructivism will now be outlined.

2.4.3 Social Constructivism

Vygotsky (1978) states that "the most significant moment in the course of intellectual development...occurs when speech and practical activity, two previously

completely independent lines of development, converge” (p.24). He concludes that children solve practical tasks with the help of their speech as well as their eyes and hands. This can manifest as egocentric speech, such as when a child describes and analyses a situation independently. However, it may transition to social speech if, when unable to solve a problem, an adult is turned to for support, which adds a cooperative element to the development of knowledge.

Vygotsky (1978) introduced the concept of a zone of proximal development to the concept of learning. He defines it as “the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (p.86). According to Vygotsky, the actual developmental level characterises mental development retrospectively, on what has been accomplished already. On the other hand, the zone of proximal development characterises mental development prospectively, focusing on cognitive functions that are in the process of formation. Vygotsky asserts that the zone of proximal development is an essential feature of learning as the development of internal processes which initially are only able to operate when the child is interacting with adults or in cooperation with peers subsequently become internalised by the child and part of the level of independent achievement. In this manner, Vygotsky’s theory highlights the central role of social interactions to the development of knowledge. In terms of science education, this points to the importance of the teacher acting as guide in the learning process, and also to the potential benefits of collaborative learning with peers for individual children.

It has been stated that in most classrooms a strong influence from behaviourism and constructivism will be present in some shape or form (Howard, 2018). However,

evidence proffered in the first chapter shows that in many science classrooms there remains a tendency to utilise a teacher-directed, behaviourist approach to science more often than a child-led constructivist style. Indeed, the large body of evidence which shows that primary teachers, in Ireland and worldwide, do not feel confident or competent in implementing more child-centred approaches to teaching science was highlighted in the introductory chapter. This is of concern when research, such as a scoping review of interventions in primary science over the past 20 years conducted by Deehan et al. (2024), highlights a connection between student-centred interventions and improvements in science content knowledge, skills and attitudes. It would appear that teachers require support to develop their knowledge of how to teach science. To this end, the next part of the chapter will focus on teacher PCK. An outline will now be given of the knowledge that is necessary to teach science, why this knowledge is important and how this knowledge can be developed with teachers.

2.5 The Knowledge Needed to Teach Science

Shulman (1986) distinguishes between three types of content knowledge necessary for teaching, namely subject matter content knowledge, curricular knowledge and pedagogical content knowledge (PCK). Shulman describes subject matter content knowledge as “going beyond knowledge of the facts or concepts of a domain”, and includes a wider understanding of why these facts and concepts are central to the domain (p.9). In terms of science, this would suggest that teachers need to possess not only knowledge of science concepts, but also an understanding of why these concepts are accepted by the scientific community. This would suggest that teachers should possess a general understanding of the nature of scientific inquiry.

Curricular knowledge is identified as “the full range of programs designed for the teaching of particular subjects and topics at a given level” (Shulman, 1986, p.10). However, curricular knowledge is extended through familiarity with the topics that have been taught in preceding years and familiarity with topics that will be taught to the pupils in the future. This would mean that teachers should have an awareness of the variety of teaching approaches outlined in the PSC (DES, 1999a), as well as knowledge of the prior content and skills that pupils should have developed in earlier years and the future content and skills they will engage with.

Shulman (1986) describes PCK as “the ways of representing and formulating the subject that make it comprehensible to others” (p.9), in other words, an awareness of how to teach the content so that others may understand it. In science education, this could, for example, include an understanding of the preconceptions, or misconceptions, that children often have regarding science concepts, and a knowledge of what teaching strategies will best challenge the children to reconsider their initial viewpoint. Cochran et al. (1993) state that PCK concerns the manner in which teachers relate their subject matter knowledge (what they know about the content of what they teach) to their pedagogical knowledge (what they know about teaching). Ball et al. (2008) describe the appeal of PCK as the notion that it bridges the gap between content knowledge and the practice of teaching.

Magnusson et al. (1999) conceptualise PCK for science teaching as consisting of five components: orientations towards science teaching, knowledge and beliefs about science curriculum, knowledge and beliefs about students’ understanding of specific science topics, knowledge and beliefs about assessment in science, and knowledge and beliefs about instructional strategies for teaching science. Orientations towards science teaching refers to teachers’ knowledge and beliefs about the purposes and goals of

teaching science at a particular class level. Magnusson et al. (1999) identified differing orientations that teachers may have from literature, for example, process, didactic, inquiry, and guided inquiry.

Teachers' orientations influence the goal of teaching science, as they see it, and influence the instruction strategies they utilise. For example, a "process" orientation aims for students to develop science process skills, and teachers engage students in activities that develop the skills which scientists use to acquire new knowledge. An "inquiry" orientation aims to represent science as inquiry and leads the teacher to support students in defining and investigating problems. Magnusson et al. (1999) note that it is possible for teachers of science to hold multiple orientations. Although primary teachers may not be aware of the major philosophies of science, it does seem that, as noted earlier, their own orientations towards science will influence both the teaching and learning of science in their classrooms.

Similar to the curricular aspect of content knowledge for teaching unpacked above, knowledge of science curriculum is divided into knowledge of goals and objectives, and knowledge of specific curricular programmes (Magnusson et al., 1999). In terms of primary science in Ireland, this could be described as knowledge of the PSC objectives for an individual class level, as well as an awareness of the curriculum objectives of preceding and subsequent levels. In terms of specific curricular programmes, perhaps this could include an awareness of external support services that are available, such as Discover Primary Science and Maths, and Oide.⁴

⁴ Oide is a support service for teachers and school leaders in Ireland, funded by the Department of Education and launched in 2023.

Knowledge of students' understanding of science consists of knowledge of requirements for learning specific science concepts, and knowledge of areas of student difficulty. Knowledge of the requirements for learning specific concepts can include knowledge of the skills students require to develop their understanding of a particular concept, such as the skill of reading a thermometer when learning about temperature (Magnusson et al. 1999). It also includes knowledge of the varying abilities of students, and appropriate strategies for supporting them. Knowledge of areas of student difficulty includes having an awareness of topics that students find challenging, perhaps because they are abstract concepts disconnected from everyday life, challenges of developing problem solving strategies, and also the misconceptions that students may have in relation to science concepts.

Knowledge of assessment in science consists of knowledge of the dimensions of science learning that are important to assess, and knowledge of the methods by which that learning can be assessed. Magnusson et al. (1999) argue that "it is important for teachers to be knowledgeable about some conceptualisation of scientific literacy to inform their decision-making relative to classroom assessment of science learning for specific topics" (p.108). Perhaps in an Irish context, this could lead teachers to assess children in terms of their conceptual knowledge, and in their development of scientific skills. Knowledge of the methods by which learning can be assessed includes an ability to select an appropriate activity or approach in order to assess a particular concept or skill. For Irish primary teachers this could include an awareness of the assessment strategies outlined in the PSC (DES, 1999a), and an ability to match an appropriate assessment methodology to a particular concept or skill.

Knowledge of instructional strategies is subdivided into knowledge of subject-specific strategies, and knowledge of topic-specific strategies. Magnusson et al. (1999)

describe subject-specific strategies as those which are specific to teaching science, as opposed to other subjects. Topic-specific strategies apply to teaching particular topics within a domain of science. Subject-specific strategies are related to the teacher's orientations toward teaching science. For example, a teacher with an "inquiry" orientation towards science might tend to engage students in IBSE methodologies. Topics-specific strategies refer to teachers' knowledge of specific strategies that are useful for helping students comprehend specific science concepts. Within this type of knowledge there are two subcategories: representations and activities. Knowledge of representations can lead to the selection of illustrations, examples, models or analogies, which facilitate student learning. Knowledge of activities consists of having an awareness of the problems, investigations, experiments or demonstrations that can support student understanding of a specific topic.

Magnusson et al. (1999) state that effective teachers need to develop knowledge with respect to each of the five components of PCK that they have identified. They also assert that the individual components function as part of a whole, and that a lack of coherence between components can be problematic in developing and using PCK. They assert that while it is useful to understand the particular components of PCK, it is also necessary to understand how they interact with each other and how this interaction influences the teaching of science. So it would seem that each individual component is a necessary contributor to the development of PCK for science, but the relationship among the components is also important for the development of teachers' PCK.

Ball et al. (2008), focusing on mathematics as their area of interest, subdivide PCK into knowledge of content and students, and knowledge of content and teaching. Knowledge of content and students (KCS) is defined as "knowledge that combines knowing about students and knowing about mathematics" (Ball et al., 2008, p.401).

KCS incorporates having an awareness of what students are likely to think about a topic initially, what examples will motivate and interest them, whether they will find a task easy or hard, and being able to interpret students' emergent thinking. Ball et al. (2008) suggest that KCS requires an interaction between specific mathematical understanding and familiarity with students and their mathematical thinking.

If applied to science, KCS could entail teachers having an awareness of what preconceptions, including misconceptions, that children are likely to have regarding different scientific concepts. It could include the teacher having an awareness of the appropriate context in which to introduce a new theme, and a knowledge of what level is appropriate for the scientific tasks the children will engage in. KCS could also enable teachers to interpret children's emergent thinking as they express their thoughts both before and after a scientific activity. In this manner, KCS could include interaction between specific scientific understanding and familiarity with students and their scientific thinking.

Knowledge of content and teaching (KCT) combines "knowing about teaching and knowing about mathematics" (Ball et al., 2008, p.401). The same researchers report that many of the mathematical tasks of teaching require a mathematical knowledge of the design of instruction. This includes the selection of a particular sequence of instruction, including which examples to start with, and which examples to use to take students deeper into the content. KCT includes selecting appropriate procedures and methodologies, knowing when more clarification is needed and when to pose a new task to further students' learning. Ball et al (2008) describe KCT as coordinating the mathematics at stake and the instructional options and purposes at play.

If KCT is transferred to science, it could be interpreted from Ball et al.'s reference to mathematics as knowledge about teaching and about science. This could include an awareness of what approach is best suited to a particular topic, for example, is a teacher-directed task or a child-led investigation most appropriate? KCT could enable a teacher to plan a progressive unit of work, building on the children's prior experiences. For example, in relation to electricity, this could include beginning with engaging the children in the construction of simple circuits, moving on to the identification of conductors and insulators, and culminating in the inclusion of a switch in a circuit. KCT also includes knowledge of what scaffolding children need through appropriate questioning. Drawing on Ball et al.'s description of KCT in mathematics, it would seem that KCT in science education involves combining scientific concepts and skills with appropriate teaching methodologies.

Comparing the PCK concepts of Magnusson et al. (1999) and Ball et al. (2008) in terms of science, it can be seen that knowledge and beliefs about students' understanding of specific science topics correlates to KCS. Similarly, knowledge and beliefs about instructional strategies for teaching science links to KCT. However, Magnusson et al. (1999) widened their conceptualisation of PCK to include orientations towards science teaching, knowledge and beliefs about science curriculum, and knowledge and beliefs about assessment in science. Knowledge of the curriculum and knowledge of what to assess and how to assess it would appear to be necessary factors in effective science teaching. Knowledge of orientations towards science teaching, including the possibility of multiple orientations, should bring an awareness of teachers' personal views of science teaching, the overarching goals that they aim to address through their science lessons and an identification of suitable strategies that will support them to do so.

Ball et al. (2008) state that teachers must know the subject they teach, as if they do not have sufficient knowledge of the subject themselves, it is unlikely that they will have an awareness of how to help students develop knowledge of the subject. However, they note that content knowledge in itself is not enough, it is important that teachers have a knowledge of how to teach the subject content. Lucenario et al. (2016) assert that emphasis on PCK is justified based on the assumption that PCK can make a significant impact on the quality of instruction that students receive, and thus the quality of learning that students experience in the classroom. Hill et al. (2008) describe how CPL focused on the development of PCK can result in changed classroom performance and improved student learning. Magnusson et al. (1999) state that PCK is critical to understanding effective teaching. In the next section the development of teacher PCK for science will be discussed.

2.5.1 The Development of PCK for Science

A lack of PCK has been identified as one of the challenges to teaching primary science (Clerkin et al., 2017; Murphy et al. 2015). As a result, it is important to consider research which has addressed this issue. Nilsson (2008) found that engaging pre-service science teachers in a team-teaching project with a focus on reflection on their own teaching of science helped to initiate the development of PCK. Data also hinted at a foundation for PCK being influenced by the sharing of experiences and understandings of practice with fellow participants. This suggests that social constructivism could play a role in the development of PCK. Nilsson highlighted that both experiences of teaching, and reflection on those experiences were necessary to develop SMK, pedagogy knowledge and contextual knowledge, which she identified as constituent elements of PCK. Zembal-Saul et al. (2001) also found that teaching experience alone is not enough to develop PCK, it needs to be coupled with thoughtful reflection on

action. Thus it would appear that classroom experience and reflection on those experiences are critical components of PCK development.

Appleton (2008) investigated the impact of a CPL programme involving mentoring by a university professor on the development of primary teachers' science PCK. Findings showed that the two participant teachers increased their usage of "more appropriate science PCK" (Appleton, 2008, p. 539). The author suggested that this was enabled by improved self-confidence in science, and a greater willingness to find out science and science teaching ideas for themselves. Interestingly, Appleton (2008) stated that he had never before witnessed the extensive teacher-change which emerged from this study, however he was cognisant of the cost-inefficiency of this approach to CPL.

Hanuscin (2013) explored the significance of critical incidents to the development of a prospective teacher's PCK for Nature of Science. She described critical incidents as events which occur in practice and lead teachers to reflect and critique their professional values, which can in turn lead to changes in practice. Hanuscin found that the support of a mentor and the use of approaches which focus initially on learners, as opposed to instructional strategies, may be fruitful in helping prospective teachers to develop their PCK for Nature of Science. However, as Hanuscin mentored one pre-service teacher, the cost-inefficiency of this approach can be noted, similar to Appleton (2008).

Leavy and Hourigan (2016) found that engaging 25 pre-service primary teachers in Lesson Study (LS) promoted mathematics PCK development, most notably in KCS and KCT. They found that reflecting on classroom teaching facilitated growth across both PCK subdomains and resulted in highly integrated and robust pedagogical understandings that transferred beyond the study context. Leavy and Hourigan

identified features of LS which they believed contributed to the development of PCK among the preservice teachers. These included opportunities for both individual and group reflection, mentor supported reflection and group dialogue as a means to analyse noteworthy events, and a shift in focus from what the teacher is doing to what the students are thinking and saying. Although this study focussed on mathematics, links can be made to the research of Nilsson (2008), Appleton (2008) and Hanuscin (2013) in science, through the identification of the benefits of mentor support, opportunities for reflection and focus on student thinking.

LS was also utilised by Lucenario et al. (2016) as a means to develop the PCK of two chemistry teachers in the Philippines. Analysis of data found that there was a significant difference in the PCK of the teachers who engaged in LS compared to teachers who did not participate in the intervention. Furthermore, the students of the LS participants showed a significant increase on mean scores in terms of conceptual understanding and problem solving. Similar to Leavy and Hourigan (2016) this research showed that LS can be an effective tool to develop teachers' PCK.

To summarise, research has shown a lack of PCK for teaching science in both in-service and preservice Irish primary teachers (Clerkin et al. 2017; Murphy & Smith, 2012; Murphy et al. 2015). An outline has been given of the meaning of PCK, including reference to Shulman's (1986) introduction to the term and further exploration of the topic as defined by Magnusson et al. (1999) and Ball et al. (2008). The development of PCK is necessary for effective teaching, which in turn should lead to meaningful learning for students. Research has shown that PCK can be developed through the use of mentor support, opportunities for reflection on classroom experiences, and through focus on student thinking. "Lesson Study" has been identified as an effective methodology for increasing PCK (Leavy & Hourigan, 2016), and as such has been

chosen as a methodology for this research. It is in this context that an in-depth review of the literature on LS will now be presented.

2.6 Lesson Study

2.6.1 An Introduction to Lesson Study

Lesson Study (LS) originated in Japan in the early 1900s (Ming Cheung & Yee Wong, 2014), and has been credited with supporting profound changes in teaching there (Takahashi & McDougal, 2016). It centres on the collaborative study of live classroom lessons (Lewis et al. 2006). Japanese teachers point to the central role of LS in the improvement of teaching at an individual, schoolwide and even national level (Lewis & Tsuchida, 1998). An outline will be provided of LS in Japan, its spread westwards beginning in the United States in the late 1990s, culminating in a description of LS as it has appeared up to now in Ireland. Consideration will be given to the strengths and challenges attributed to this method of professional development, through the lens of how it may be included in the approach to this piece of research based on science in the Irish primary classroom.

Fujii (2016) states that, “for Japanese educators, Lesson Study is like air, part of everyday school life” (p.411). This sentence leaves us in no doubt as to how inherent LS is to teaching and learning in Japan. LS is a translation of the Japanese words *jogyuu* (instruction, lessons, or lesson) and *kenkyuu* (research or study). The term *jogyuu kenkyuu* encompasses a large family of instructional improvement strategies, the shared feature of which is live classroom lessons (Lewis et al. 2006). Indeed there are three types of LS in Japan: school-based, district-based and national-based LS (Fujii, 2016).

School-based LS is most common whereby all staff, or nearly all, participate in a school-wide project aimed at addressing a common teaching-learning challenge

(Takahashi & McDougal, 2016). On a national scale, Lewis and Tsuchida (1998) note how two days of research lessons at a national elementary school attracted nearly five thousand educators. Japanese teachers sometimes travel hundreds of miles to attend research lessons (Lewis, 2002). This underlines the importance of LS as a means to develop teaching and learning in Japan.

Fujii (2016) provides the diagram shown below (Figure 2.2) to explain the LS process as undertaken by Japanese teachers. It should be noted that this is just one depiction of LS, and that others may have a slightly different approach. According to Fujii (2016), the first step is to start with a question or research theme which is developed through consideration of the students' present attainment and the identification of long-term goals for them. Consultation of research relating to the research theme, standards and curricula are also part of this step. Following this, the focus turns to lesson planning – the development of an instructional plan for the selected unit (based on the research theme) and a detailed plan for one of the lessons in that unit.

Figure 2.2

The Lesson Study Process (Fujii, 2016)



The third and fourth steps in the above diagram occur on the same day, typically on a half day where one class of students stays for the research lesson while the other classes are dismissed so that every other teacher can observe the research lesson. At the end of the post-lesson discussion usually there will be final comments from a “knowledgeable other”, an invited expert from outside the school. As part of the final step teachers reflect on the process, usually in written form, and published records of LS activities are included in the school bulletin (Fujii, 2016).

Lewis and Tsuchida (1998) interviewed Japanese teachers to explore the impact of research lessons. They found that teachers were often very specific about the role of research lessons in their professional development. In relation to improved classroom practice, for example, “comments from other teachers helped them to see things about their teaching that might otherwise have escaped them” (Lewis & Tsuchida, 1998, p.15). LS supported teachers in the spread of new content and approaches and connected classroom practice to the broader goals of education. It was described as a means for teachers to explore conflicting ideas. It created demand to enhance practice amongst teachers, giving them momentum for improvement.

LS was viewed as a means of formative research in which national policy could be informed by actual classroom practice. This directly links to the recognition, through LS, of the central role of Japanese teachers to Japanese education. Lewis and Tsuchida note how “teachers are not expected to be passive recipients of whatever new reform comes along; they help to shape and change classroom education” (1998, p.18). Perhaps this is the reason for the prevalence of LS in Japanese education – it enables teachers to collaboratively assess the needs of their students in a local context and attempt to improve teaching and learning as a result. The teachers themselves are the agents for change.

2.6.2 Lesson Study Moves Westwards

Elliott (2019) outlines how the performance of Japanese students in international comparisons, such as TIMSS, at the end of the twentieth century led to the movement of LS westwards from Japan. Of particular influence was a book written by Stigler and Hiebert (1999) entitled “The Teaching Gap”, which compared teaching methodologies in mathematics in Japan, Germany and the United States. Elliott (2019) explains that, for Stigler and Hiebert, the phrase “teaching gap” refers to gaps between teaching strategies and standards that are internal to the learning process. The process of LS incorporates the identification of such a “gap”, in light of curriculum standards, and casts teachers in the role of researchers attempting to bridge the divide. Elliott’s consideration of Japanese LS concludes that it “enables teachers to close the teaching gap, whilst resisting the temptation to teach directly to the prevailing system of tests and examinations” (2019, p.180).

Ming Cheung and Yee Wong (2014) note that LS drew the attention of the United States in the late 1990s with Lewis (2002) commenting on the substantial interest in LS there at that time. An examination of nine studies in Hong Kong, Japan and the United States from 2000 to 2010 found that “all reviews identified positive evidence supporting the benefits of Lesson Study and Learning Study as powerful tools to help teachers examine their practices and enhance student learning” (Ming Cheung & Yee Wong, 2014, p.137). The authors recognised the small sample of cases as a limitation of the research and stated that “many classroom-based research papers which are perceived to be very powerful by educationalists and teachers are rejected by indexed journals that are more inclined to accept studies with experimental study” (p.147).

Lewis and Tsuchida (1998) remarked that LS is centred on the practice of ordinary teachers in ordinary classrooms. Perhaps the very nature of localised, organic, classroom-based research does not naturally lend itself to controlled experimental research. It is interesting to note that Lewis et al. (2006) warned against summative trials of LS at that time, given how little was known about its nature. They wished to avoid premature conclusions that LS doesn't work, based on immature versions of the process, which they feared would contribute to making it a fad. At the same time, it is noteworthy that the *International Journal for Lesson and Learning Studies* has been published since 2012.

LS has not enjoyed a seamless transition westwards from Japan. Takahashi and McDougal (2016) state that the effectiveness of LS outside of Japan has been “uneven” (p.513). They do, however, point to the success of the Lesson Study Group at Mills College, where researchers conducted a randomised, controlled trial of LS supported by mathematical resource kits, and found a significant impact on both teachers' and students' mathematical knowledge. Lewis (2002) feared that the sudden interest in LS evoked “worrisome memories of other once-promising innovations that were superficially understood, hastily implemented, and consequently pronounced ineffective” (p.6). In an effort to avoid this scenario she named a number of essential features of LS which are listed below:

1. A shared long-term goal.
2. Important lesson content.
3. Careful study of students.
4. Live observation of lessons.

Even when Japanese teachers focus on a particular subject area, they usually have a broad long-term goal for their students, which contrasts with the advice often given to U.S. teachers – to focus on short-term, concrete, measurable outcomes. In relation to this research, one could argue that this contrast is also present in Irish education, where teachers create short-term, concrete learning outcomes and learning objectives, focused on a fortnightly plan and a measurable *cuntas míosúil*.⁵ How, then, can we measure a long-term goal such as “students to learn science with desire”, a Japanese example provided by Lewis (2002)? Following on from the selection of a long-term goal, Lewis (2002) explains how Japanese teachers also focus learning on a particular content area. She notes that most LS in the U.S. focuses on mathematics, which is hardly surprising as this was the subject area through which U.S. teachers first engaged with the process (Elliott, 2019).

Lewis (2002) points out that the ultimate focus of LS observation in Japan seems to be the development of student learning, whereas in the United States there is a long tradition of observation based on teacher behaviour and indeed evaluation of teachers. There is a similar tradition here in Ireland where teachers associate classroom observation with evaluation of their performance, both as pre-service teachers and in-service teachers. Perry and Lewis (2009) comment on how participants in a U.S. LS cycle initially focused on teacher behaviour during observation and when they began to realise that their observations should focus on student thinking, they struggled with how to collect useful evidence. Criticism of a lesson in Japan is not typically focused on the individual teacher who taught it, the critique is shared with colleagues due to the collaborative nature of LS (Lewis & Tsuchida, 1998). Indeed there is a tradition of

⁵ A *cuntas míosúil* is an individual teacher’s written record of the work covered with students over the course of one month in Irish primary schools.

collaboration and self-criticism (*hansei*) in Japan (Lewis, 2002) which is not as prevalent in western education. These changes of mindset and classroom culture are challenging for participants in LS outside of Japan.

The live observation of lessons is referred to as the heart of LS by Lewis (2002). She comments that teachers observe much more than the lesson itself, they observe the students' demeanour towards learning and towards each other. Whereas it would seem obvious that student learning and development cannot be assessed from reading a lesson plan, it is interesting to note that the "live" aspect of the research lesson is deemed crucial, a video of a lesson is insufficient in itself. At the same time video may capture important elements of the innovation, enabling it to be enacted and studied more easily at new sites (Lewis et al. 2006). However, it is essential to remember that while the research lesson is the keystone of the process, the true purpose of LS is not the creation of a perfect lesson plan, it is to gain new knowledge of teaching and learning (Takahashi & McDougal, 2016).

Perhaps most importantly in terms of the globalisation of LS, Lewis (2002) asserts that in order for the methodology to be successful in the United States, it should be reinvented and thoughtfully adapted to suit the education system and culture there. The process cannot simply be borrowed from high-performing nations like Japan without bringing about changes in the context of its use (Elliott, 2019). This advice seems worthwhile in an Irish context also.

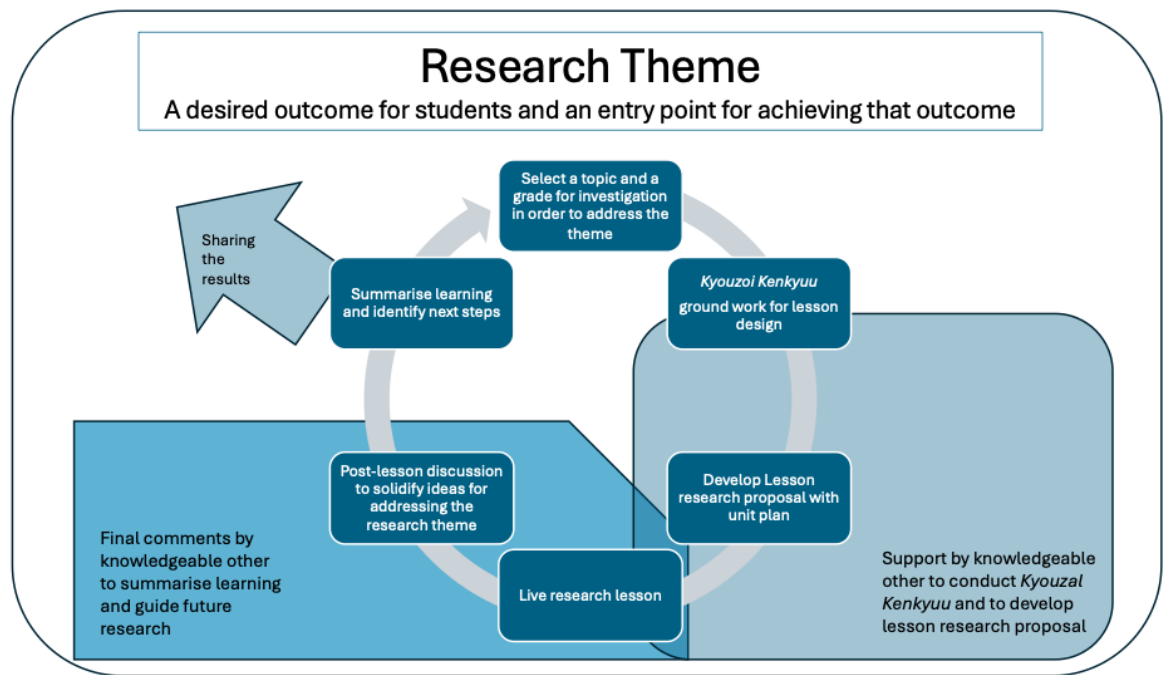
2.6.3 Western Adaptations of Lesson Study

One such adapted take on LS is Collaborative Lesson Research (CLR) developed by Takahashi and McDougal (2016) and shown in Figure 2.3 below. The approach aims to incorporate effective features of Japanese LS in a U.S. context. CLR

begins with a research theme that comes naturally from a difference between the school’s educational goals and standards on one hand, and the achievement of their students on the other. Teachers then spend significant time on *kyouzai kenyu* or research of academic content and teaching materials related to the research theme which leads them to develop a written research proposal. This proposal includes learning goals for a unit, an overview of the unit, a detailed teaching–learning plan for one particular lesson within the unit (the research lesson), a rationale for the design of the unit and research lesson, and a clear statement of how the research lesson aims to address the research theme and the learning goals (Takahashi & McDougal, 2016).

Figure 1.3

Collaborative Lesson Research Model (Takahashi & McDougal, 2016)



The next phase of the programme is the live research lesson whereby one member of the team teaches the lesson while the additional members observe and collect data on how the lesson impacts the students, relative to the research goals (Takahashi & McDougal, 2016). The researchers reiterate how a video can be useful,

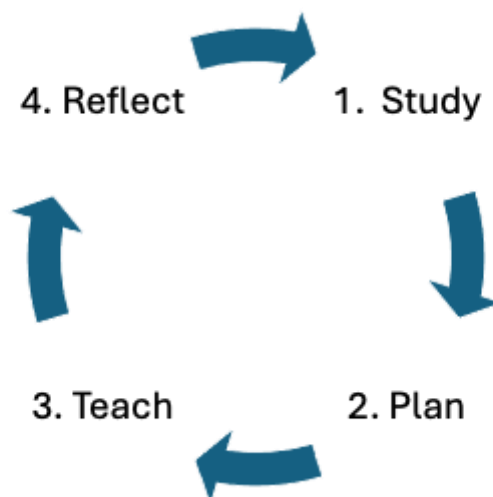
but is not a substitute for live observation. The post-lesson discussion should take place as soon as is practical after the lesson, with an emphasis on gaining insights into teaching and learning and informing future lesson design. The focus is not to revise the lesson plan. Takahashi and McDougal (2016) advocate the participation of two knowledgeable others (KO) in the process, one during the planning phase to support proposal development and the other to provide final comments at the end of the post-lesson discussion. They acknowledge that many LS cycles in the U.S. lack a KO, but note that this is rarely the case in Japan.

Through the final step in CLR, Takahashi and McDougal (2016) recommend the sharing of results to a larger community. They provide examples such as inviting teachers from outside the planning team to attend the research lesson and discussion, and distributing the research lesson proposal to other educators, accompanied by a reflection noting lesson observations and points from the post-lesson discussion. The CLR model seems an attractive approach to LS, given its basis in research from Japan and outside it. The model combines what the researchers consider the essential features from Japanese *jugyou kenkyuu* with adaptations to the United States.

Another adapted version is that of Lewis et al. (2019), from The Lesson Study Group at Mills College in California, who outline four phases of LS: Study, Plan, Teach and Reflect, shown in Figure 2.4 below:

Figure 2.4

Lesson Study Cycle (Lewis et al., 2019)



The Study Phase consists of a team of teachers collaborating to identify long-term goals for students. They choose the subject and unit to investigate, study standards, research and curricula. Using insights gained, the LS team proceeds to the Plan Phase where they examine the unit chosen for investigation and choose one lesson to plan in depth. They articulate the lesson goals, try the lesson task in a mock lesson and anticipate student thinking. They identify data to be collected during the lesson. During the Teach Phase one member of the team teaches the lesson while the other team members observe and record student thinking and learning. The LS team then continues on to the final Reflect Phase. This includes meeting after the research lesson to discuss data on student thinking and learning, having an outside specialist, or knowledgeable other, provide further commentary. Finally, the LS team reflects on what they learned during the LS cycle as a whole. Both the Takahashi and McDougal (2016) model of

LS, and the interpretation of Lewis et al. (2019) above appear to demonstrate fidelity to the roots of LS in combination with changes to suit the local context.

Ding et al. (2024) examined 75 recent studies (2015-2022) to understand how LS is implemented in mathematics education, and the pathways by which LS can impact teaching practice and student learning. They found that LS was often undertaken without a clear research question. Many studies combined the study and planning phases, a practice which Ding et al. state “does not seem to align with the essence of Japanese LS, which regards studying teaching materials as a critical separate phase” (p.91). Studies shared a consensus that it is most critical to focus on students’ thinking and learning, yet reported challenges in maintaining that focus (Ding et al., 2024). Although KOs play a crucial role in LS, in some studies there were no KOs, particularly outside Japan and China. In studies that had KOs present, Ding et al. (2024) report room for this role to improve, in terms of recognising and supporting teachers’ learning needs. Collaboration among teachers was widely reported as a challenge. There were large variations in the duration of LS, with some identified as overly brief. In terms of the impact of LS, Ding et al. (2024) note that the effects on teachers’ professional knowledge, beliefs and dispositions were the most reported outcomes. Less reported outcomes included the impact on student learning, instructional practice, curriculum and teachers’ learning communities. Ding et al. (2024) call for deeper, culturally relevant understanding of LS, and point to the importance of LS of adequate duration, focus on study materials, and the inclusion of KOs. They state that there is a need to clearly document whether changes have occurred in teaching and student learning after LS has been implemented, and to identify the aspects of LS which have contributed to the observed change.

2.6.4 Lesson Study in Ireland

In Ireland, the practice of LS has been recommended for teachers in research reports on the teaching and learning of mathematics published by the NCCA (Dooley et al., 2014). In this section an outline will be provided of research conducted at primary level, in ITE, and at secondary level in Ireland.

Research in Primary Education

The former Professional Development Service for Teachers (PDST), which is now part of Oide, supported Irish primary teachers to engage in cycles of LS (PDST, n.d.). The PDST invited participant schools to attend an annual “Shared Learning Day” and shared the LS posters developed by schools, giving an account of their LS cycles, on its website. The vast majority of schools chose to focus on mathematics for their LS cycle. Of the 19 posters shared from 2019 participants, just 3 involved LS in the area of primary science. Similarly in 2020 there were 21 participants, with just four schools engaging in a science-focused LS. So while LS has been conducted in primary science in Ireland, it would appear to have been done so on a limited basis.

More recently, Flanagan et al. (2024) explored the potential of LS as a vehicle to support CPL in a rural Irish primary school in the area of integrated STEM lessons with 4-7 year old children. Findings suggested that LS supported the development of a culture of collaboration and provided an opportunity for teachers to share their knowledge. Furthermore, LS appeared to have motivated teachers to reflect on their role within the classroom and enabled them to move away from teacher-led approaches. Flanagan et al. state that although teachers perceived LS to be a beneficial form of CPL, their engagement was constrained by issues such as time, cultural shift and sustainability of LS.

The focus on mathematics in Irish cycles of LS is also a common theme in research. Hourigan and Leavy (2023) introduced 19 Irish primary teachers to an alternative problem solving approach in mathematics, using LS as the CPL model. Teachers reported an “awakening to students’ problem solving potential” (p.921), and “enhanced problem posing understandings” (p.921). Hourigan and Leavy (2024) examined the perceptions of Irish primary teachers about LS as a CPL methodology. Findings suggest that teachers were eager to engage in LS and welcomed many of its characteristics, most notably the focus on teacher collaboration as well as the merits of exploring pupils’ thinking when planning and observing research lessons. However, teacher engagement was hampered by the barrier of time. Teachers proposed adaptations to the LS approach to promote its sustainability. These included changes to LS group membership, LS timing, a whole-school approach and more flexible meeting arrangements.

Research in Initial Teacher Education (ITE)

Hourigan and Leavy (2019) explored the perceived effects on learning of a LS model with a large sample of 225 pre-service Irish primary teachers, focusing on mathematics, over a 10-year period. Participants reported an increased awareness of the importance of deep content knowledge as well as enhanced professional knowledge and skills in the area of mathematics. They also reported the adoption of a learner-centred approach to their practice. In addition, the study found that many participants reported increased confidence in their ability to effectively teach mathematics, as a result of their content knowledge development. In light of the identification of a lower level of confidence among Irish teachers in relation to teaching science in the TIMSS 2015 report (Clerkin et al. 2017), the perceived connection between greater confidence and

increased subject matter content knowledge in the work of Hourigan and Leavy (2019) is noteworthy. While Hourigan and Leavy (2019) acknowledge the limitations of the self-reported data gathered in their study, they point out that research proposes that interventions will fail if participants judge them to be ineffective.

Engagement with LS was found to increase the SMK of pre-service Irish primary teachers, specifically specialised content knowledge (SCK), again in the area of mathematics education (Leavy & Hourigan, 2018). The study found that participants gained a raised awareness of the complex relationships between early number concepts that contribute to developing robust early number understandings, and that participants developed expertise in identifying the nature and source of children's mathematical errors. The use of LS to increase teachers' SMK could therefore be useful in the area of primary science education, given the need for the development of pre-service teachers' conceptions of science, as highlighted by Murphy and Smith (2012).

The same researchers, Leavy and Hourigan, found an increase in the PCK of pre-service Irish primary teachers following participation in LS related to early years mathematics education (2016). They found that reflection on classroom teaching facilitated the development of PCK that transferred beyond the LS context. Interestingly, the authors noted that the observed growth in PCK related to content and pedagogical practices that had already been part of the participants' initial teacher education programme prior to the LS study. However the collection of baseline data "indicated that this knowledge had remained in some ways inert" (p.173). It appeared that LS was successful in triggering the development of explicit PCK.

Corcoran (2010) also reported on a study trialling the use of LS to promote the teaching and learning of mathematics among a group of pre-service primary teachers,

by researching children's responses during mathematics lessons. Six student teachers participated in the research as part of a year-long elective course to develop mathematics for teaching. They engaged in three full cycles of LS and findings indicated an enhancement in the teaching of mathematics among student teachers with a recommendation to further investigate the potential use of LS by practising teachers at all levels of education.

Research at Post-Primary Level

Brosnan (2014) presented an analytic and evaluative account of the challenges involved in introducing LS to post-primary schools in Ireland, following research involving 250 in-service teachers as part of the pilot Project Maths⁶ project. She found that the cultural shift to a shared professional culture through collective participation from “insulation and isolation proved a step too far, too quickly” (p.242). Many of the teachers felt that participation in LS was an add-on to their workloads and that producing a lesson plan collaboratively produced a product for the system rather than engaging in a process that would improve their students' understanding of mathematics. The lesson plans themselves became models of the new curriculum in action rather than research lessons in the style of LS. Although substitute cover was provided for the teachers, many were reluctant to miss their classes and in many cases lessons were planned before or after school instead. It could be argued that the introduction of a new curriculum can be challenging enough for teachers, without the additional introduction of a simultaneous new CPL model.

⁶ Project Maths was an initiative which involved the complete revision of the mathematics curriculum at junior and senior cycles at post-primary level in Ireland.

As noted earlier, in relation to the United States, cultural differences with Japan were challenging for teachers in Ireland – peer observation proved intimidating and teachers did not have the skills to reflect critically on the lesson (Brosnan, 2014). Disappointingly, all teachers reported that the activity was too time-consuming and 80% saw little value in the exercise. The findings of this study are pertinent to the approach taken in this research, given the local context and author’s presumption that Irish primary teachers may face similar challenges to their post-primary counterparts.

On the other hand, Ní Shúilleabháin (2015) found an increase in the PCK of 12 post-primary mathematics teachers following completion of a number of cycles of LS over the course of one academic year. Furthermore, Ní Shúilleabháin and Seery (2018) concluded that the engagement of five post-primary mathematics teachers in LS over an academic year encouraged the development of new pedagogical practices both inside and outside LS. The samples involved in these two studies are much smaller than the number of teachers involved in the research by Brosnan (2014), and perhaps another crucial distinction is that they were volunteers. Engagement in the cycle of Lesson Study proposed by this research is also voluntary and will involve a small sample of participants.

Research on the Experience of Facilitating LS

In a change to the focus on teacher participants, Hourigan and Leavy (2021) examined two mathematics teacher educators’ first experience of facilitating LS with Irish primary in-service teachers in a self-study. Despite their vast experience as teacher educators and LS facilitators of pre-service teachers, they noted the “complexity” of the role of being a teacher of in-service teachers. This included a change in dynamics, and adjusting to teachers “who were more forthright and willing to engage in questioning

and critique” (p.12) than their pre-service counterparts. Furthermore, they became aware of varying degrees of engagement with LS practices among the groups who participated, which resulted in limited teacher learning for those who partially engaged in the project. Their research documents potential challenges associated with working in the role of facilitator and KO with in-service teachers on extended, school-based LS. Their findings are particularly relevant to the researcher's dual roles of facilitator of LS and emergent Internal Knowledgeable Other (IKO) in this research study. Hourigan and Leavy (2021) recommended that further research could explore the experiences of both facilitators and in-service primary teachers who engage in a more bespoke form of LS, to identify the impact of various factors on the LS experience. It is anticipated that this research study will contribute to that body of knowledge.

2.7 Rationale for the use of Lesson Study in this Research Study

LS would appear to encompass the core features of effective CPL as outlined by Darling-Hammond et al. (2017), namely: content focused, incorporates active learning, supports collaboration, uses models of effective practice, provides coaching and expert support, offers feedback and reflection, and is of sustained duration. In terms of content, LS has been found to increase both the SMK and the PCK of teachers, despite this being a challenge in CPL, as noted by Desimone and Garet (2015). It incorporates active learning through engagement with a research theme and the design and observation of a research lesson, culminating in reflective discussion. Lewis and Tsuchida (1998) outline how in LS the teachers themselves are the agents for change, it is a method of CPL grounded in actual classroom practice, while being cognisant of national policy. LS is described as “particularly beneficial when enacted by a community of educators working in their own setting” (Dooley et al., 2014, p.123). Desimone and Garet (2015) highlight the importance of linking CPL to teachers’

classroom lessons, noting that this alignment is a powerful aspect of coherence. It would appear that LS enables teachers to connect CPL directly to classroom practice. In terms of duration, LS takes time, which can be viewed as a limitation (for example Brosnan, 2014) but can also lead to in-depth lesson design and meaningful reflection. Finally, by its very nature, LS leads to collective participation and collaboration between a group of teachers. It would appear to have all the hallmarks of an effective methodology for CPL.

The research outlined above mostly incorporated LS in the context of pre-service primary teacher education and in-service second level teachers. Despite the PDST's support for LS in Irish primary schools, there appears to be a lack of research involving the inclusion of LS as a method of CPL for in-service Irish primary teachers. In addition, Irish studies conducted this far have been predominantly in the area of mathematics, meaning that LS in the area of science education, in an Irish context, is timely. Furthermore, the current research study provides a unique insight into the development of the role of IKO in a school-based Irish LS context. In light of the context for this study which was outlined in the previous chapter, and consideration of pertinent literature in this chapter, the research purpose and research questions of this study will now be outlined.

2.8 Research Purpose and Research Questions

2.8.1 Statement of the Problem

Research highlights areas of concern regarding the teaching of primary science education in Ireland. A lack of teacher confidence, low levels of participation in science-related CPL and a lack of collaborative practice (Clerkin et al., 2017), as well as the need for increased levels of PCK and SMK amongst teachers (Murphy and Smith,

2012; Murphy et al., 2023), have all been identified as factors which hinder the teaching of primary science. Research has also revealed that there is a need to develop opportunities for CPL of longer duration, a requirement to increase the use of IBSE teaching methodologies, and a greater need for collaborative approaches and opportunities for reflective practice (Murphy et al. 2015; Murphy et al., 2023). The development of teachers' PCK has also been linked to greater confidence in teaching science (Appleton, 2008; Smith, 2014).

LS is a CPL methodology involving collaboration amongst teachers which can lead to in-depth lesson design and meaningful reflection. It has been found to increase confidence in pre-service Irish primary teachers' ability to effectively teach mathematics, as a result of the development of their PCK (Leavy and Hourigan, 2016). The PDST (now Oide) has supported Irish primary teachers to engage in cycles of LS, in mathematics and, to a lesser extent, science. However, research involving the inclusion of LS as a method of CPL for in-service Irish primary teachers has been predominantly in the area of mathematics. This means that LS in the area of primary science education, in an Irish context, is particularly novel and timely.

2.8.2 Purpose Statement and Research Questions

The purpose of this study was to explore the use of LS as a CPL methodology in primary science education. The study was guided by the following broad questions:

1. What is the effect of school-based Lesson Study on the development of primary teachers' pedagogical content knowledge (PCK) in science?
2. What features of school-based Lesson Study are most effective in supporting the teaching of primary science?

Following consideration of Magnusson et al. 's (1999) conceptualisation of PCK in science, specific focus was placed on teacher orientations as an overarching aspect of science PCK. Therefore, the following sub-question is attached to the first research question:

What is the effect of school-based Lesson Study on the development of primary teachers' orientations towards science?

Furthermore, this research is novel given its focus on the development of my role of local expert, or Internal Knowledgeable Other (IKO) in school-based LS. This led to the development of a sub-question from the second research question:

What is the experience of an IKO in school-based LS?

Having outlined the context and rationale for this study over the previous two chapters, as well as the identification of two main research questions, the next chapter will provide an identification of the methodology associated with this research.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

The preceding chapters provided an overview of primary science education in Ireland, along with an outline of the successes and challenges encountered by teachers through the teaching and learning of primary science. Research highlighted the lack of teacher participation in science CPL in Ireland, while also noting some of the features of effective CPL that has taken place. LS was identified as having attributes which could contribute to a meaningful science CPL experience for Irish teachers.

The next two chapters provide an outline and justification for the methodology and design of the research, taking into consideration the guiding principle of “methodological coherence” advocated by Mayan (2023, p.47). Methodological coherence is described by Mayan as the process of designing and conducting a study so that there is congruence between aspects including the research paradigm, epistemological, ontological and axiological perspectives, the chosen theoretical framework, methodology, data collection and analysis. This chapter starts with consideration of what a conceptual framework entails. Following this, an outline of the epistemological framework and social constructivist paradigm which underpin this study are shared. Subsequently, I will provide the theoretical framework associated with this research. Finally, I will discuss case study as the research design adopted for this thesis. In the next chapter details of the research methods will be provided.

3.2 Conceptual Framework

A conceptual framework has been described as “the logical master plan for [an] entire research project” (Kivunja, 2018, p.47). Hill and Wheat (2019) assert that by crafting conceptual frameworks from reflections on their own experiences, combined

with theory from literature, research students gain an understanding of the rationale for the study they propose. Imenda (2014) defines a conceptual framework as an end result of bringing together a number of related concepts to give a broader understanding of a phenomenon of interest, or research problem. He describes the manner of arriving at a conceptual framework as “akin to an inductive process whereby small individual pieces (in this case, concepts) are joined together to tell a bigger map of possible relationships” (p.189). Sale and Carlin (2025) assert that the formation of a conceptual framework in such an inductive manner incorporates “accumulating knowledge and experience against which to lay new information” (p.3). At the same time, they caution that conceptual frameworks can limit the potential of the researcher to remain open to the new and unexpected, and tend to confine data into predetermined categories and relationships. They believe it is imperative that “students understand that data may extend beyond and not fit the chosen framework” (p.3). Ultimately a conceptual framework shapes what we look for, and what we see in our data (Sale & Carlin, 2025). A pictorial representation of the conceptual framework associated with this study will be presented at the end of Chapter 4, following discussion of the research methodology in this chapter and the research methods in the next chapter.

3.3 Epistemological Framework

The epistemological framework guiding this qualitative research study is based on three philosophical assumptions: ontology, epistemology and axiology (Mayan, 2023). It is summarised in Table 3.1 below:

Table 3.1

Epistemological Framework for this study

Ontology	Epistemology	Axiology
Multiple realities. Reality is subjective. Use participant quotes to show different perspectives.	Presence of “insider researcher”. Research conducted in the field. Researcher and participants co-create meaning.	Acknowledge that research is value-laden and biases are present. Acknowledge the role of ethics in the study.

Ontology is concerned with the nature of reality, and from a social constructivist approach assumes the presence of multiple realities, which in this study connects with the varying perspectives of participants. Reality is subjective. Epistemology is concerned with the relationship between the researcher and that being researched. In a qualitative study the researcher attempts to lessen the distance with those being researched, becoming an “insider”, and conducting studies in the field (Creswell, 2007). This aligns with my position as a participant researcher, conducting research with a group of teaching colleagues in my own school. A social constructivist approach to qualitative research, detailed later in this section, implies that the researcher and participant interact with and influence each other through the research process (Mayan, 2023) to co-create meaning. This corresponds with the collaborative aspect of LS.

Axiology acknowledges the role of ethics and values in inquiry, which are reflected in the questions we ask, our own personal values and our participants’ values (Mayan, 2023). It is therefore important that I recognise the impact of my own values on the design of this research study, such as the social constructivist paradigm I align myself with and its influence on this thesis. In addition, I will later outline my own philosophy of science, given its potential to impact the LS process. I will discuss the

ethical considerations pertinent to this research in the next chapter. As well as ontology, epistemology and axiology, Creswell (2007) includes rhetoric as a philosophical assumption that guides a qualitative approach to research. My use of the personal voice, the use of “I” throughout my research, aligns with this aspect of qualitative research.

Taylor et al. (2016) explain how qualitative researchers are concerned with the meaning people attach to their lives, and how all perspectives are worthy of study. Again, this corresponds with the descriptive data gathered in this thesis, representative of participants’ own written and spoken words. Taylor et al. (2016) note how qualitative researchers are concerned with how people think and act in their everyday lives, and this enables them to obtain first-hand knowledge of social life. This study enabled me to explore LS as a potential CPL methodology for the development of teachers’ PCK to teach science with a group of in-service teachers in their own school, while they went about their daily teaching. I was provided with first-hand knowledge of their experiences.

Taylor et al. (2016) also refer to the inductive nature of qualitative research, which corresponds to the manner in which I developed concepts, insights and understandings from patterns that developed in the data. They note the flexible nature of this approach to research, which was present in this study with its emergent design. Taylor et al. (2016) note how qualitative research looks at settings and people holistically, and studies people in the context of their past and the situation in which they find themselves. It would appear that the lists of traits attributed to qualitative research by Creswell (2007) and Taylor et al. (2016) correlate to the social constructivist paradigm. Whereas social constructivism was discussed in the previous chapter in relation to how children learn, it will now be outlined as the paradigm which guides this research study.

3.4 Research Paradigm

Staller and Chen (2022) state that choosing a research design sits at “the crux of philosophical views and the actionable interpretation of those views” (p.69). They propose that exploration of a researcher’s own philosophical worldview can provide a starting point for choosing a research design. Creswell and Poth (2018) argue that a researcher should make explicit the larger philosophical ideas, or worldviews, that they espouse, as this will help to explain why a particular approach was chosen. This research is grounded in a social constructivist worldview whereby knowledge is socially constructed among people engaged in the research process (Mayan, 2023).

3.4.1 Social Constructivism

Social constructivism, as discussed in the previous chapter, is grounded in the work of Vygotsky (1978). It is based on the idea that through collaboration with a more knowledgeable other person, new meaning can be co-constructed. From a qualitative research perspective, Creswell and Poth (2018) describe how a social constructivist viewpoint holds “assumptions that individuals seek understanding of the world in which they live and work” (p.8), and develops subjective meanings of their experiences. These subjective meanings are often connected to interactions with others, as well as the historical and cultural settings of the individuals. The aim of this research study is to “rely as much as possible on the participants’ views of the situation being studied” (Creswell & Poth, 2018, p.8). Social constructivist researchers recognise that their own backgrounds shape their interpretations of the data. I am placing myself in the research, acknowledging how my own social, historical and cultural experiences influence my interpretation of the data (Creswell & Poth, 2018). I am an engaged participant whose critical and analytic observation of the culture is integral to the research activity. I can

be viewed as the interpreter between the community I describe and the audience to which I report my findings (Brannick & Coghlan, 2007).

This study links to a social constructivist worldview through my attempt to understand the impact of LS on a group of teachers in my workplace. The data collected consist of the participants' interactions during LS meetings, as well as personal interpretations of their experiences of LS through reflective logs and focus group meetings. I expect that collaboration among participants themselves as well as my exchanges with them during the LS process will influence their experiences and therefore impact the data collected. I am aware that my own background will shape my interpretation of the data. I am placing myself in the research, and I am conscious of my own background as both a teacher in the school for the past 15 years, and a part-time student who holds a Master of Education degree specialising in science education. I am also a part-time facilitator of science education within ITE, and have experience facilitating science CPL for in-service primary teachers. I believe that my own background will assist me during both data collection and data analysis but I am conscious that it could also lead to bias. It would seem important to share my own philosophy of science and to be aware of the potential influence I could wield on the LS planning process, as a result of my own beliefs regarding the scientific enterprise.

3.4.2 Personal Philosophy of Science

Matthews (1994) asserts that whenever science is taught, philosophy is also taught, as the teacher's own epistemology of science is conveyed to students and contributes to the image of science that they develop in class. It would seem that this idea could also apply to those who facilitate science CPL for others, the facilitator's own view of science is conveyed to participants. I identify with the philosophy of

science espoused by Thomas Kuhn, outlined earlier in the literature review. Kuhn suggested that scientists work within a research tradition known as a paradigm where they practise “normal science”. When scientists encounter insurmountable difficulties a “crisis” state develops which leads to a “scientific revolution” (Chalmers, 2013).

Kuhnian philosophy can be linked to a constructivist approach to scientific inquiry in the classroom, which is the approach that I advocate in the classroom. This approach begins with setting the context for a new topic through the use of a resource which is relevant to the children’s prior experiences. The children are encouraged to share their thoughts on the theme, grounding their thoughts in the reality they have experienced thus far. Engaging the children in scientific inquiry can lead them to confirm or refute their earlier beliefs. This approach can be linked to Kuhn’s philosophy, where scientists accept the paradigm in which they work until insurmountable difficulties emerge with the accepted belief. Whereas a collaborative approach to planning means that the group creates the research lesson outline together, I am conscious that my bias towards a constructivist approach to science, as well as the possibility that participants may be influenced by their perceptions of my expertise in this area, could lead to my view of science having an impact on the research lesson design. I will reflect on this later in the final chapter.

Denscombe (2008) notes how Kuhn’s research paradigms are characterised by four attributes. First, they centre on a specific problem or set of problems that are regarded as particularly significant in relation to the advancement of knowledge. Second, they are about shared practice. Third, these paradigms involve a sense of shared identity. Finally, these paradigms operate through groups of practitioners operating in research communities. Denscombe (2008) states that Kuhn’s version of research paradigms “resonate closely with the concept of ‘communities of practice’” (p.276). He

asserts that it is crucial that a community of practice (COP) comes into existence through the need to collaborate “with those who face similar problems or issues for which new knowledge is required” (p.277). Taking into consideration my own Kuhnian perspective towards science teaching and learning, and the use of LS as a collaborative approach to addressing a perceived “gap” in teaching and learning, it would seem that the concept of COP also resonates closely with this research project. The development of COP as a social learning theory will now be outlined as a component of this study’s theoretical framework, and the concept will be linked to this research study and the methodology of LS.

3.5 Theoretical Framework

A theoretical framework refers to the theory that a researcher chooses to guide a piece of research which can offer an explanation of an event or shed some light on a particular phenomenon or research problem (Imenda, 2014). Anfara et al. (2009) suggest that underpinning LS is Situated Learning Theory, which proposes that learning is a social activity. Situated Learning Theory is a key aspect of the theoretical framework for this research study. It is a theory of learning that can occur in the context of a “Community of Practice” (COP), (Lave & Wenger, 1991). More recently, the context of a “Social Learning Space” (SLS) has been developed as an extension of COP (Wenger-Trayner & Wenger-Traynor, 2020). An outline of Situated Learning Theory, and its associated contexts of COP and SLS, will now be provided.

3.5.1 Situated Learning Theory

Lave and Wenger (1991) suggest that learning is a social process in which individuals co-construct knowledge rather than transmit knowledge from one individual to another. Their theoretical perspective is based on “the relational character of

knowledge and learning...the negotiated character of meaning...and the concerned (engaged/dilemma-driven) nature of learning for the people involved” (p.34). They place emphasis on “comprehensive understanding involving the whole person...on activity in and with the world and on the view that agent, activity and the world mutually constitute each other” (p.34). Lave and Wenger assert that their theory of learning is a dimension of social practice which is “realised in the lived-in world of everyday activity” (p.14). In this manner, Lave and Wenger focus on the individual as a member of a sociocultural community.

Lave and Wenger (1991) describe how “learning in terms of participation focuses attention on ways in which it is an evolving, continuously renewed set of relations” (p.49). They believe that participation is “always based on situated negotiation and renegotiation of meaning in the world” (p.51), and suggest that “social reproduction implies the renewed construction of resolutions to underlying conflicts” (p.57). They see change as a fundamental characteristic of situated learning theory. This echoes the research paradigm of Kuhn outlined above, that is, a scientific revolution takes place when scientists reach a point of “crisis”.

3.5.2 Communities of Practice

COP have been identified as a context in which situated learning can occur. Lave and Wenger (1991) define a COP as “a set of relations among persons, activity and world, over time and in relation with other tangential and overlapping communities of practice” (p.99). They highlight how a COP is an “intrinsic condition for the existence of knowledge, not least because it provides the interpretive support necessary for making sense of its heritage” (p.99). Wenger (1998) notes three dimensions of COP: mutual engagement of participants, practice as a joint enterprise and the presence of a

shared repertoire of resources. Mutual engagement of participants means that practice does not exist in the abstract. It exists because people are engaged in actions whose meanings they negotiate with one another. A joint enterprise does not mean that everyone must agree with everything or believe the same things, but rather that meaning is communally negotiated (Wenger, 1998). From a practical perspective, a community of practice does not depend on a fixed membership, people can move in and out. This trait is applicable to this study, whereby there were changes to the membership of the LS group across the three cycles of data collection.

Wenger (1998) discusses the theme of boundaries in relation to communities of practice, which also seems relevant to this study, given my role as participant researcher. I have two roles in the LS, that of group participant and, separately, IKO. In this manner I could be perceived as a broker, part of the LS group at the teachers, while also separate, part of the KO community, along with my two supervisors, the EKO's. Wenger (1998) notes how brokers are able to make new connections across communities of practice, but also how "the job of brokering is complex" (p.109). He cites the example of how, for a supervisor, spanning the boundary between workers and management is not always comfortable because "she belongs at the same time to both practices and to neither" (p.109). The challenge of walking the boundary is applicable to me in this study, as it could lead to an experience of "being marginal in both groups", as per the supervisor Wenger describes (1998, p. 168). He notes how multi membership may involve "ongoing tensions that are never resolved" (p. 160), making reconciliation between different communities of practice a significant challenge for those who experience this.

On the other hand, Wenger (1998) also describes how membership of two communities, or multimembership, can be viewed in a positive manner. Since

multimembership and reconciliation are central to the concept of identity, the work of reconciliation becomes “an active, creative process” (p. 161). When applied to this research study, it could mean that, for me, walking the boundary could provide me with a rich learning opportunity. If, as according to Wenger (1998), building an identity consists of negotiating the meanings of one's experience of membership in social communities, it is possible that through the creation of a boundary practice for myself, I could be provided with the chance to explore my own identity.

Lave and Wenger (1991) contend that there is an effectiveness in the circulation of information among peers in a COP. This connects to the findings of Murphy et al. (2015) and Smith (2014), who noted that a collaborative approach to science CPL had a positive impact on participant teachers. Collaboration among teachers has been highlighted as an aim of the Irish *STEM Education Policy Statement 2017-2026* (DES, 2017). It would appear that LS, as it is based on collaboration amongst a group of teachers, offers an opportunity to participate in a developing COP. Furthermore, Lave and Wenger suggest that “engagement in practice, rather than being its object, may well be a condition for the effectiveness of learning” (1991, p.93). This also connects COP to LS, whereby teachers themselves are given a chance to help shape and change classroom education (Lewis and Tsuchida, 1998).

Wenger-Trayner and Wenger-Trayner (2020) describe how, on a theoretical level, they had seen the concept of COP used in two distinct ways. On one hand, the term “COP” was being used to describe a history of social learning over time which results in a repertoire of practice, and a regime of competence by which members recognise each other in terms of their ability to engage in their practice. On the other hand, COP was being applied to a certain mode of learning interaction in which people engage with each other as learning partners. Wenger-Trayner and Wenger-Trayner

(2020) chose to split these two sides of COP, using the term COP to describe an ongoing learning partnership which over time has resulted in a shared practice and a regime of competence. They introduced the concept of social learning space (SLS) to describe a mode of mutual engagement that people have often called COP. It would appear that SLS is a term that could apply to this research study and therefore a more in-depth description of SLS will now be provided.

3.5.3 Social Learning Spaces

Wenger-Trayner and Wenger-Trayner (2020) argue that SLS retain some of the fundamental characteristics associated with COP: the focus is on people and their participation, members drive the learning agenda, learning is rooted in mutual engagement, and engagement pushes the participants' edge of learning. Meaning and identity remain central, as per COP, but they are based on caring to make a difference, rather than competence in a social practice associated with COP. Wenger-Trayner and Wenger-Trayner (2020) shed some of the characteristics of COP from SLS: identification with a shared domain, commitment to developing and improving a shared practice, longevity and continuity as a social structure, and a defined regime of competence which members recognise and identify with. SLS, according to Wenger-Trayner and Wenger-Trayner (2020), are "simpler, more pervasive structures than communities of practice" (p.32). A social learning space is not necessarily a community, and it is not necessarily about a specific practice, although it is possible for a social learning space to evolve into a community of practice over time if it starts to establish a regime of competence (Wenger-Trayner & Wenger-Trayner, 2020).

A SLS involves participants learning together to make a difference to what happens in practice. SLS are created through the convergence of three dimensions:

caring to make a difference, engaging uncertainty and paying attention (Wenger-Trayner & Wenger-Trayner, 2020). “Caring to make a difference” means that the aim of participants is to enhance their ability to do something to affect their world in a way they care about. It is not necessary that all participants wish to make the same difference, what matters are the mutually relevant interactions that take place and the learning partnerships formed. The “engagement of uncertainty” is defined as “a state of being in tension between caring to make a difference and having a clear path to get there” (Wenger-Trayner & Wenger-Trayner, 2020, p. 21). Once again it is mutual engagement with each other’s uncertainty, leading to a feeling of making progress, or deepening an existing understanding, or triggering some new idea, that can give rise to a social learning space. The third dimension of social learning spaces involves “paying attention”, for example, to what happens to theory in practice, to whether a difference has really been made. Wenger-Trayner and Wenger-Trayner (2020) believe that the three characteristics of caring to make a difference, mutual engagement of uncertainty and paying attention all together constitute the development of a social learning space.

Wenger-Trayner and Wenger-Trayner (2020) note that a SLS is not designed directly, rather it is something that participants create together. Emphasis on agency is described as one of the most subtle and profound characteristics of a SLS. Wenger-Trayner and Wenger-Trayner (2020) identify agency as key to driving forward the process of learning towards the end goal of making a difference. Indeed, participants find value in a SLS to the extent that their participation is seen as leading to a difference that matters. It is individual participants who collectively generate value, recognise value and translate it into making a difference. In this way, agency is intertwined between the individual and the collective.

3.5.4 Value Creation in Social Learning Spaces

Wenger-Trayner and Wenger-Trayner (2020) link agency to value creation in social learning spaces. They base this on four social learning modes over which participants have agency: *generating value* through participating and aspiring to make a difference, *translating value* identified into something closer to the desired change, *framing the creation of value* through developing a perspective on what counts as value, and finally *evaluating* whether a difference has really been made. This appears to link to the LS framework whereby teachers identify a gap and progress through four phases (Study, Plan, Teach, Reflect) before reflecting on whether a change has occurred. Lewis and Tsuchida (1998) identified teachers themselves as the agents for change in LS, and it would appear that this concurs with the characteristics of a SLS.

This project could be considered an example of a SLS, given how LS provides teachers with an opportunity to identify something which they care to make a difference about. They then, through mutual engagement with study materials, collaborate to develop a plan to address the identified gap. Through observing a research lesson and participating in a post-lesson reflection meeting, they pay attention to the lesson designed and evaluate the extent to which a difference has been made. I, as participant researcher, try to engage the participants in identifying their uncertainties, invite them as co-researchers to each LS cycle, thus opening a mutually created SLS.

It has been shown how situated learning theory forms the basis of the theoretical framework of this study. An outline has been provided of how situated learning theory has evolved and extended from COP to include SLS, which has been identified as the environment in which this LS project operated. Further detail on the role of situated learning theory in data analysis will be shared in the following chapter. At this point I

will return to the methodological approach selected for this study and provide a rationale for the selection of case study.

3.6 Case Study

Given that case study research provides a unique example of real people in a contemporary context (Creswell & Poth, 2018), it was deemed the most appropriate type of qualitative study for this research project. Blaxter et al. (2010) describe how a case study is ideally suited to the needs and resources of the small-scale researcher, which makes it an appropriate choice for this study. However, case study consists of multiple approaches in itself, which therefore warrants further examination in order to identify the most suitable design for this study. Yazan (2015) provides a comparison of three approaches to case study, the interpretations of Yin (2002), Stake (1995) and Merriam (1998). This enabled me to hone in on the style, or combination of styles which best suited my research design.

From an epistemological viewpoint, Yin (2002) is identified as aligning with a more positivist view of case study, with a focus on construct validity, internal validity, external validity, and reliability. On the other hand, Stake (1995) and Merriam (1998) share a constructivist view of case study, whereby knowledge is constructed rather than discovered. They argue that qualitative case study researchers are interpreters themselves, and gatherers of the interpretations of others. Stake (1995) includes an extra level of interpretation - the construction of knowledge by the reader of the final report. This aligns with my own constructivist worldview, whereby I believe that this thesis represents my own interpretation of the world around me, combined with my interpretation of the constructed reality of the group of participant teachers. Arising from Stake's understanding of case study, this thesis also affords the reader an opportunity to develop their own interpretation of this report.

According to Stake (1995), a precise definition of case study is not possible, although he does identify attributes of qualitative research which are valid for qualitative case studies. He describes how qualitative case studies are holistic as they consider the interrelationship between the phenomena and its contexts, and how they are empirical, given their emphasis on observations in the field. He identifies case studies as interpretive, noting the interaction between researcher and subject, and empathic since researchers reflect the vicarious experiences of the subjects in an emic perspective. These qualities correspond to this research whereby observational data were collected in the field, and interpreted by me as researcher in an effort to accurately depict the participants' experiences in this thesis. Merriam (1998), defines a qualitative case as being particularistic, descriptive and heuristic. These features align with this research given the focus on one particular group of teachers, providing a rich description of their experiences of LS, aiming to illuminate the reader's understanding of the potential use of LS for the development of PCK in primary science.

For Stake (1995), a case is a "bounded system", a specific thing which has a boundary. He asserts that a case study is a good approach when the inquirer has clearly identifiable cases with boundaries and seeks to provide an in-depth understanding of the cases or a comparison of several cases. For Merriam (1998), the defining characteristic of case study research is the delimitation of the case, in line with Stake's bounded system. However, she asserts that a case can be a person, a programme, a group, a specific policy and so on, which represent a more comprehensive list than Stake's. These definitions informed the decision to view each LS cycle as a case, bounded by its four stages: Study, Plan, Teach, Reflect. Analysis was conducted of each individual case, followed by comparison of the three cases. The inclusion of multiple

cases indicates that, according to Stake's interpretation, this thesis is representative of a collective case study.

Having decided on case study as the approach to undertaking this research, influenced by the definitions of both Stake (1995) and Merriam (1998), it was then necessary to explore what type of case study best applied. Yin (2002) advocates the creation of a detailed design at the outset of the research process, whereas Stake (1995) argues for a flexible approach which allows researchers to make major changes even after they proceed from design to research. The Stakeian viewpoint corresponded to this research, which underwent many adjustments, including reconsideration of research questions, and the inclusion of analysis tools such as the Value Creation Framework during the process.

The only initial design Stake suggests concerns the issue and issue questions. This research developed from a real-practice issue I identified through previously facilitating primary science CPL for teachers in my school - the challenge of transferring an engaging CPL experience into actual classroom practice. The manner in which the study unfolded thereafter aligns with Stake's adoption of "progressive focusing" which Parlett and Hamilton (1972) first put forward. This notion builds upon the assumption that "the course of the study cannot be charted in advance" (cited in Stake, 1998, p. 22), which Yin would definitely oppose. Parlett and Hamilton comment that the "transition from stage to stage, as the investigation unfolds, occurs as the problem areas become progressively clarified and redefined" (cited in Stake, 1998, p. 22). This connects to my Kuhnian construction of scientific knowledge, whereby scientific revolutions occur when a problem cannot be overcome, and leads to a redefinition until the next insurmountable problem occurs and the cycle begins again.

This flexibility is at odds with the more defined approach advocated by Yin (2002). Merriam (1998), while flexible in her design, is not as flexible as Stake (1995).

Stake (1995) further subdivides case studies into intrinsic case studies and instrumental case studies. In intrinsic case studies, the case is dominant, it is of highest importance. Applied to this study, this would indicate that the overall focus was on each LS cycle. However, in an instrumental case study, the issue is dominant. We start and end with a focus on the issue that the case illuminates. This thesis reflects an instrumental case study. As the case, each LS cycle is examined mainly to provide an insight into the impact of LS on the development of primary teachers' PCK in science, with particular focus on teachers' orientations, connecting to the first research question and its sub-question. In reference to the second research question each LS cycle is considered in terms of the features of effective CPL it espouses.

This thesis is also identified as an evaluative case study (Merriam, 1998). She notes how this type of case study weighs information to produce judgement. Each of the identified research questions has an evaluative focus - the extent to which LS as a CPL methodology can support the development of primary teachers' PCK in science, with a specific emphasis placed on teacher orientations, and the extent to which LS encapsulates the features of effective CPL, accompanied by an examination of my experience of becoming IKO. Indeed, Merriam (1998) states that case study is the best form for evaluation. Figure 3.2 below provides a representation of the case study design associated with this research study.

Figure 3.1

Case Study Design of this Study

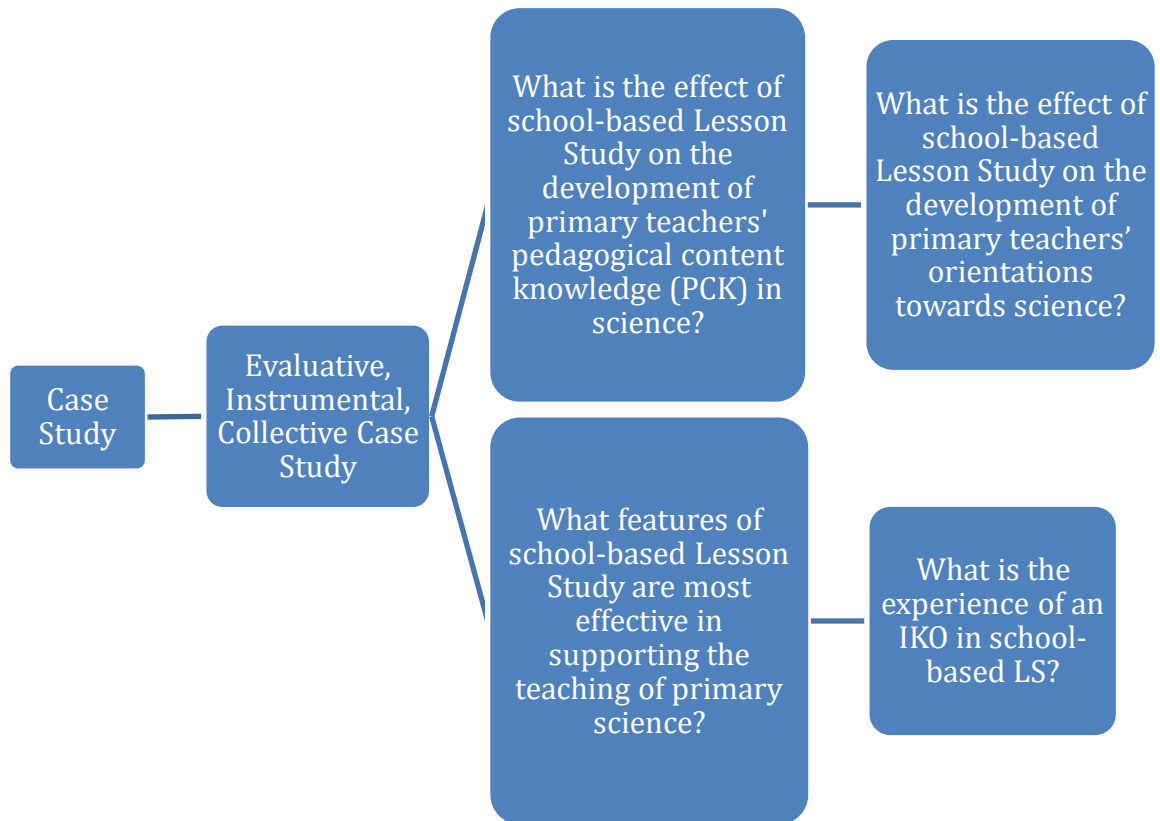


Figure 3.2 highlights how once a case study approach was selected, the specific type of case study was identified, and how this connected to the broad research questions and, by extension, the sub-questions, as outlined above.

Case study is not without criticism. Stake (1995) suggests that the study of more than one case dilutes the overall analysis, as it reduces the depth of any one case. This could be viewed as a disadvantage of this piece of research. On the other hand, Merriam (1998) asserts that in multicase study research, the single case is of interest because it belongs to a particular collection of cases which share a common characteristic. From

this perspective, there is a strength in collective case study such as this one. Each individual case contributes to the overall story represented in the final report.

Kyburz-Graber (2004) notes that case studies can sometimes be criticised for lacking scientific rigour, and cites Yin (1994) in the identification of quality criteria for case studies. The case study should have a theoretical basis, including explicit research questions. Triangulation should be ensured through the use of multiple methods of data collection. A chain of evidence should be designed with traceable reasons and arguments, as in, there should be a clear outline of the data collection and data analysis. The case study research should be fully documented. Finally, the case study report should be compiled through an iterative review and rewriting process. This research study aimed to fulfil these quality criteria through its identification of a problem from the literature review and explication of research questions. Multiple methods of data collection were utilised and a clear outline of the data collection and analysis is provided. Review and rewriting informed the final report.

Blaxter et al. (2010) identify some of the advantages and disadvantages of a case study approach. In terms of advantages, case study data is drawn from people's experiences and so is seen to be strong in reality. The data can therefore be more persuasive and more accessible. As they build on actual practices and experiences, case studies can be linked to action and changing practice. Blaxter et al. (2010) note that some of the disadvantages of case study are linked to its advantages. For example, given the holistic nature of case study, it may be difficult to analyse the data as everything can appear relevant. It can be difficult to know where the "context" begins and ends. Yin (2009) notes that case studies can be prone to bias if an investigator seeks only to use a case study to substantiate a preconceived position, although my research questions were evaluative and therefore not based on hypotheses that I was trying to prove or

disprove. I considered the identified advantages and disadvantages of case study during data analysis.

3.7 Conclusion

This chapter explored the philosophical underpinnings of this research study, identifying a social constructivist worldview which links to a Kuhnian philosophy of science. Kuhnian philosophy of science in itself connects with social learning theory and the concept of COP. Closer examination of COP led to SLS, a more recent extension of COP. SLS appears to resonate with this research on LS, given its characteristics of being a simpler version of COP, and one which has a focus on the agency of participants at its heart.

Having explored the nature of qualitative research in general, case study was selected as the most suitable approach to this research. This led to an exploration of the work of three prominent advocates of case study, Stake (1995), Merriam (1998) and Yin (2002). The alignment of Stake and Merriam with my constructivist worldview influenced my decision to follow their approaches. This led to an identification of an evaluative collective case study, subdivided into an instrumental case study approach to two broad research questions and two associated sub-questions. The next chapter will serve to discuss the research methods applied to this study, and the tools of analysis which developed from the philosophical underpinnings identified here.

CHAPTER 4: RESEARCH METHODS

4.1 Introduction

The previous chapter identified the philosophical underpinnings of the research. This chapter further outlines the research methods applied to this study through describing the research site, participants, data collection and analysis utilised in this research study. A framework of analysis for teacher orientations, specifically designed for this research study, based on literature consulted in Chapter 2, will be outlined. The value-creation framework of Wenger-Trayner and Wenger-Trayner (2020) will also be discussed and considered for application as an analysis tool in this study. Consideration of trustworthiness and ethics will be included in this chapter. It will culminate with a pictorial representation and discussion of the conceptual framework associated with this research study.

4.2

The research took place in Greenwood School (pseudonym). It is a co-educational vertical primary school located in a Dublin suburb whose provision includes three classes for children with autistic spectrum disorders. The school has 32 mainstream classes. As of September 2020 the school had an enrolment of 799 pupils and 53 teaching staff.

4.3 Site Selection

The research site was selected as it is the school where I worked during data collection. Ease of access was a determinant of site selection, as I was a full-time teacher in the school and a part-time student. Moreover, given my central role in the research as an insider researcher, familiarity with the research site and participants was a key factor in my ability to examine the role of IKO in school-based LS. It was also

hoped that this “insider knowledge” (Blaxter, et al., 2010) would also be an advantage in gaining permission from the principal and Board of Management to carry out the research and in seeking teachers to volunteer as participants. In addition, familiarity with me, the researcher, could also be advantageous when seeking parental consent and child consent to participate in the research study.

I am aware of the limitations of conducting research in the workplace, most notably the difficulties in maintaining anonymity for participants (Blaxter et al., 2010), if readers are aware of the location of my workplace. Blaxter et al. (2010) note the risks associated with the researcher being overfamiliar with the research site. For example the researcher may overlook the significance of things that seem obvious. Overall, it was determined that the advantage of ease of access for me as a part-time student was too great to ignore. In addition, familiarity with the research site and participants enabled me to facilitate LS, and develop my role of IKO as a key feature of this research study, in an authentic manner. It was also hoped that the research study would benefit both the teacher and pupil participants in their teaching and learning of science. Ultimately it was hoped that the findings of the research study would benefit the wider school community.

4.4 Research Participants

4.4.1 Insider-Researcher

I assumed the role of insider-researcher in this research study. I was a participant teacher in the LS process, while also assuming the role of Internal Knowledgeable Other (IKO). I wished to experience the LS process as a participant in order to gain a deeper understanding of LS as a CPL methodology. I also assumed the role of IKO, given my experience as a facilitator of science education workshops for both in-service

and pre-service primary teachers, and my Master of Education degree which specialised in science education. During LS1 I developed my IKO skills through observing the external knowledgeable others (EKO). In LS2 and LS3 I acted independently as IKO, and the EKOs did not attend the planning meetings.

Dwyer and Buckle (2009) note that an insider role status frequently allows researchers “more rapid and more complete acceptance by their participants” (p.58), which in turn leads to greater openness from participants, which can lead to a greater depth to the data gathered. On the other hand, there is a risk that participants will make assumptions of similarity and therefore fail to explain their individual experiences fully (Dwyer & Buckle, 2009). In a similar manner, the researcher may assume too much during an interview and not probe as much as an outsider (Brannick & Coghlan, 2007). The same authors describe a criticism of insider research as the researcher being “too close and thereby, not attaining the distance and objectivity deemed to be necessary for valid research” (p.60). However, they conclude that “insider research is not problematic in itself and is respectable research in whatever paradigm it is undertaken” (Brannick & Coghlan, 2007, p.72).

Dwyer and Buckle (2009) discuss the idea of the “space between” for researchers - a third space that allows researchers the position of both insider and outsider, acknowledging both the similarities and differences that the researcher shares with the group. In this instance, I was naturally an insider given my position as a teacher in the research site, and a colleague of the participants. However, I could also be viewed as separate to the group through my work as a facilitator of science education workshops for both in-service and pre-service teachers, and my engagement with research on science education and LS as part of my literature review. So, while I shared commonalities with the other teacher participants, it could be argued that I still

remained on the periphery of the group, given my role as researcher. This connects to Kanuha's (2000) description, that "the native researcher is the margin" (p.441) as she attempts to separate herself from those she researches. As Dwyer and Buckle (2009) describe, I was an "insider-outsider" in the process.

4.4.2 Teacher Participants

This research study used a voluntary sample as the participants self-selected to take part, which is an example of a non-probability convenience sample (Blaxter et al., 2010). I recognise that this volunteerism could be viewed as a limitation of the research in terms of generalisability of the findings (Cohen & Arieli, 2011). All teachers in Greenwood School were informed of the opportunity to partake in the research study in February 2020, prior to the commencement of LS1. A message was placed on the internal school communication portal outlining that teachers were welcome to take part in a Lesson Study cycle based on the science curriculum. Links were provided to The Lesson Study Group at Mills College (<https://lessonresearch.net/>) and to a Lesson Study Cycle description handout from the same website (The Lesson Study Group at Mills College, 2022a). This was to enable the teachers to gather information on LS before deciding if they wished to take part. Teachers were invited to contact me in order to express their interest in joining the research study, or to seek further information. Initially seven teachers volunteered to participate in the Lesson Study and attended an introductory meeting which was held at the research site in March 2020, just before the Covid-19 period of school closure was announced. Subsequently, three teachers decided to withdraw from the cycle, which left four teachers, plus me, the researcher, as the participants of LS1. Background information on the LS1 participants is provided below in Table 4.1.

Table 4.1*LS1 Teacher Participants*

Participant Name	Years of Teaching Experience	Teaching Position during LS1
Anna	6 years	Special Education Teacher
Brian	16 years	Special Education Teacher
Caroline	8 years	Special Class Teacher
Darren	6 years	4th Class Teacher *Science Graduate
Researcher	15 years	Special Education Teacher

The LS group conducted all LS1 meetings remotely due to school closure. When schools reopened in September 2020, albeit with social distancing measures in place, the group decided to proceed with the LS1 research lesson. It took place in October 2020. LS2 commenced in March 2022, 19 months after the completion of LS1 in October 2020. It was completed in June 2022. One teacher (Anna) left after LS1 due to family circumstances. LS2 data were gathered from the four participant teachers (including me as IKO). Background information is included in Table 4.2 below. It can be seen that Caroline had moved from her role as Special Class teacher to 5th Class teacher and Darren had shifted from 4th Class teacher to 6th Class.

Table 4.2*LS2 Teacher Participants*

Participant Name	Years of Teaching Experience	Teaching Position during LS1
Brian	18 years	Special Education Teacher
Caroline	10 years	5th Class Teacher
Darren	8 years	6th Class Teacher *Science Graduate
Researcher	17 years	Special Education Teacher

LS3 commenced in January 2023, 7 months after LS2 ended, and was completed in March 2023. Darren left the study after participating in LS1 and LS2, due to additional commitments. LS3 data were gathered from three participant teachers (once again including me as IKO), and is outlined in Table 4.3 below. Other teachers in the school were invited to join the project for LS2 and LS3, but none did so.

Table 4.3*LS3 Teacher Participants*

Participant Name	Years of Teaching Experience	Teaching Position during LS1
Brian	19 years	Special Education Teacher
Caroline	11 years	5th Class Teacher
Researcher	18 years	Special Education Teacher

Data collection from the beginning of LS1 to the end of LS3 took three years.

This information is represented in Table 4.4 below.

Table 4.4

LS Teacher Participants

LS1 March - October 2020	LS2 March - June 2022	LS3 January - March 2023
Anna Brian Caroline Darren Researcher (Michelle)	Brian Caroline Darren Researcher (Michelle)	Brian Caroline Researcher (Michelle)

4.4.3 Pupil Participants

The pupil participants in LS are also an example of a convenience sample as they attended Greenwood School. Details regarding the pupils in each LS cycle are presented below in Table 4.5.

Table 4.5

LS Pupil Participants

LS1 Darren's 4th Class	LS2 Caroline's 5th Class	LS3 Caroline's 5th Class
26 Children (12 Boys, 14 Girls) 10/11 years old *15 Children participated in the Research Lesson due to Covid-19 social distancing measures	23 Children (10 Boys, 13 Girls) 11/12 years old	18 Children (7 Boys, 11 Girls) 11/12 years old

LS1 pupil participants consisted of Darren's mainstream 4th class. These same children, who were by then Caroline's 5th class, participated in LS2. A different group of 5th class children, again taught by Caroline, partook in LS3. Each child was invited to participate in each LS cycle, and all parents were invited to give consent (Appendix K). All parents and most children agreed to take part. Shaw et al. (2011) state that children have a right to be involved in research about issues of concern to them. The Plain Language Statement given to the children (Appendix N) explained that the teachers would use the lesson to find out how science teaching can be improved. Additionally, Shaw et al. (2011) seek to involve children in research in order to improve the quality of the research itself. In terms of this study, a live research lesson is an integral part of LS. The data obtained from the children's work samples is an important component of the triangulation of data in this study.

4.4.4 External Knowledgeable Others

Each of my two supervisors acted as External Knowledgeable Other (EKO) in this research study. Takahashi (2014) found that, through their final comments at the post-lesson discussion, the Knowledgeable Other (KO) brings new knowledge from research and the curriculum to the process; shows the connection between theory and practice; and helps others learn how to reflect on teaching and learning. One supervisor has expertise in the area of primary science education and the other supervisor has expertise in the area of LS. During LS1 both EKOs provided expertise throughout the process. The LS KO gave a presentation on LS at the initial meeting and guided the group throughout the four stages of the cycle, often directing the LS planning meetings. The science KO also supported the group throughout the process with guidance on study materials suitable for the research theme, and analysis of the emergent Teaching

and Learning Plan. The LS KO facilitated the post-lesson discussion meeting and the science KO provided final comments on the lesson from a science teaching perspective.

Takahashi (2014) notes the Japanese custom of inviting a KO to the research lesson who will then provide final commentary at the post-lesson discussion. This research study differs in that the EKO had direct involvement throughout LS1. In LS2 and LS3, I acted as IKO, with the EKO remaining available to me as support but without direct involvement in the LS process.

4.5 Data Collection

A variety of data collection methods were used in this research study, representative of the various research participants - the teacher participants, the pupil participants and me, the insider researcher. The research is an example of a longitudinal study (Cohen et al., 2007), as data were collected over an extended period of time. Cohen et al. (2007) identify strengths of longitudinal studies which include the opportunity to chart growth and development, and the opportunity to analyse change on an individual level. The same authors also identify some of the weaknesses of longitudinal studies, including the time-consuming nature of the approach, and the risk of participants leaving the study before data collection has been completed. It would seem that each of the strengths and weaknesses mentioned above applies to this research study.

4.5.1 Teacher Meeting Logs

During LS1, informal anecdotal notes were kept of each LS Teacher Meeting during the study, planning and reflective stages of the process. When the EKO was present and facilitating the meetings it was possible for me as a researcher to maintain more detailed notes. However, when I hosted the meeting as IKO, without the presence

of the EKO's there was a significant reduction in the amount of notes kept. In order to keep a more detailed record of the meetings for data analysis, ethical approval was obtained to record the meetings during LS2 and LS3. These recordings enabled me to obtain a detailed account of each meeting, while simultaneously facilitating it. These meeting logs were analysed as part of data triangulation. Details on the number of meetings per LS cycle are detailed below in Table 4.6.

Table 4.6

LS Teacher Meetings

LS1	LS2	LS3
4 Study Phase Meetings 7 Planning Phase Meetings 1 Post-Lesson Reflection Meeting Total = 12 Meetings	3 Study Phase Meetings 3 Planning Phase Meetings 1 Post-Lesson Reflection Meeting Total = 7 meetings	4 Study Phase Meetings 6 Planning Phase Meetings 1 Post-Lesson Reflection Meeting Total = 11 Meetings

Study Phase Meetings consisted of the early parts of the LS cycle, where the teachers confirmed the research theme, decided on a topic and studied materials associated with it. The Planning Phase incorporated designing the unit plan and research lesson. The Post-Lesson Reflection Meeting occurred via Zoom in LS1 due to Covid-19, but face-to-face for LS2 and LS3.

4.5.2 Teacher Reflective Logs

Larrivee (2000) notes that “journal writing is a reflective process that allows teachers to chart their development and become more aware of their contributions to the experiences they encounter” (p.296). While the teachers did not complete journals, their reflective logs recorded any impact that LS had on their own interpretation of

science and their approach to science teaching. Each teacher participant in this research study was invited to write a reflective log based on the phases of the LS cycle (see Appendices A, B and C). The decision was taken to combine the Teaching Phase and Reflective Phase logs, as both of these events occurred on the same day. Teachers were invited to reflect on the phase in terms of ways in which their own views of science had been confirmed or challenged, and whether their approaches to teaching science had been confirmed or challenged. They were also invited to consider, in practical terms, if there were aspects of the phase they would change going forward. During LS1 the teachers were also asked to reflect on the impact of Covid-19 restrictions, as they perceived it, on the LS phases.

4.5.3 LS Cycle Teaching-Learning Plan

Each LS cycle included the collaborative preparation of a Teaching-Learning Plan (TLP) (Appendices, P, Q & R). The template was adapted from the example provided by The Lesson Study Group at Mills College (2022b). Each TLP recorded the group's process of LS, beginning with the initial identification of the research theme, or long-term goal. It contained a rationale for the research theme, along with information on the resources studied during the Study Phase. The detailed research lesson plan, developed during the Planning Phase was also included. The TLP concluded with notes from the collaborative end of cycle reflection, which took place after the research lesson. Each TLP provided evidence of how each LS cycle aimed to identify and plan a lesson based on a perceived gap in the teaching and learning of science in Greenwood School. The collaborative nature of the TLP tied in with the social constructivist approach to this study.

4.5.4 Research Lesson Observation Log

During each LS live research lesson, one LS teacher taught the lesson while the remaining teachers observed pairs of students. Each observing teacher completed an observation log (Appendix D) where s/he noted what the children said as they completed the lesson tasks. Shaw et al. (2011) describe the importance of agreeing on how to observe children without disrupting ongoing activities and routines. Each log listed observation goals which placed an emphasis on listening to the children and recording their thoughts. The observing teachers were also asked to reflect on the significance of what the children said. In addition, the teachers were invited to note any conclusions they determined as a result of observing the children. These records were used during the post-lesson reflection meeting to determine the impact of the lesson on children's scientific thinking. Ethical approval was sought, but not granted, to video record the research lessons. I acted as teacher for LS1 and the remaining teachers observed the lesson and completed the observation logs. Caroline taught the LS2 research lesson which afforded me an opportunity to act as observer, a role I resumed in LS3 when Brian taught the research lesson.

4.5.5 Children's Work Samples

The children who participated in the research lesson were invited to voluntarily share their work samples with the researcher. It could be considered a limitation of the research that data collection took place in school - children may not feel in a position to dissent, simply because most, if not all, tasks and activities in school are compulsory (Morrow & Richards, 1996). However, in each cycle a small number of children elected not to share their work, and this choice was respected. Obtaining children's work samples enabled connections to be made between the children's individual/paired responses to the lessons and the observation logs of the teacher participants. This

assisted in the determination of the impact of LS on children's learning of science. Children's inquiry sheets (Appendix E) were piloted during the mock lesson of LS1, which took place prior to the research lesson itself.

It is important to consider the effect that the data collection environment may have had on the responses of the children taking part. Shaw et al. (2011) note that children may feel pressure to only provide "right" answers in a school setting. The same researchers also describe that it is important to recognise the natural power imbalance between adult (researcher) and child (participant) and the effect that this is likely to have on the data collected. They suggest that steps can be taken to minimise the impact of this power imbalance, such as creating a relaxed atmosphere prior to data collection, and avoiding formal seating or room layout. It should be acknowledged that this was a challenge for LS1 in light of the Covid-19 social distancing requirements during the LS1 research lesson. The lesson had to take place in the unnatural environment of the P.E. hall to enable children to work at a safe distance from each other and the observing teachers. Equipment could not be shared which meant the children had to work on an individual basis. LS2 and LS3 research lessons took place in the natural classroom environment after Covid-19 restrictions, allowing for paired/group work and the sharing of resources.

4.5.6 Focus Group Interviews

Millward (2012) describes a focus group as a discussion-based interview that produces verbal data generated via group interaction. In this study the participant teachers were invited to participate in a recorded focus group interview at the end of each LS cycle. The interviews were conducted online via Zoom for LS1, and in-person for LS2 and LS3. Each interview was moderated by me, the researcher, who posed a

list of open questions which formed the interview schedule (Appendix F). Teachers were asked to consider what impact they perceived LS had on science teaching and learning, and how they viewed it as a method of CPL. They were asked whether they felt the process had an impact on their competence and confidence to teach science, and to consider if the LS impacted the development of children's scientific thinking and skills. Each interview lasted approximately one hour and the teachers were thanked for their participation at the end. The focus groups aimed to supplement the teacher reflective logs and research lesson observation logs, in order to create a more complete picture of the impact of LS on the teaching and learning of science. From a social constructivist perspective, Millward (2012) describes focus groups as "communication events in which the inter-play of the personal and the social can be systematically explored" (p.419).

4.5.7 Researcher Reflective Journal

I kept two separate journals, which enabled me to reflect on my role duality (Brannick & Coughlan, 2007) in the research study. One journal was for my reflections on being a teacher participant in the LS cycles and the other encompassed my reflections on being an IKO. The journals aimed to reduce potential concerns associated with insider membership of the group, through becoming aware of, and reflecting on issues such as my own personal biases and perspectives (Dwyer & Buckle, 2009). Furthermore, it was hoped that the journals could "provide a safe haven for...working through internal conflicts, recording critical incidents, posing questions...solving problems, identifying relationships, seeing patterns" (Larrivee, 2000, p.297). Breakwell (2012) identifies the greatest advantage of a diary approach as the natural sequencing of events which provides the researcher with a profile of actions, feelings and thoughts over time. The researcher's reflective journals provided me with a chronological

account of my experiences of being both a teacher participant and IKO, including challenges I encountered. When reporting on data collected in relation to myself, I chose to refer to myself as “Michelle” when acting as participant teacher and “Researcher” when participating as IKO, thereby differentiating between each role.

4.6 Data Handling

Although discussed separately in this thesis, Merriam and Tisdell (2016) explain that data collection and analysis should be a simultaneous process in qualitative research. Cohen et al. (2007) describe how qualitative data analysis involves “making sense of data in terms of the participants’ definitions of the situation, noting patterns, themes, categories and regularities” (p.461). Making sense of the data in a qualitative way can raise issues of subjectivity on the part of the researcher. It is important to be aware that the data analysis incorporates the researcher’s interaction with data which itself is already an interpretation of a social encounter (Cohen et al., 2007). It is necessary for the researcher to try to separate her own experiences and subsequent analyses from those of study participants, especially as an insider researcher (Kanuha, 2000).

Cohen et al. (2007) present ways of organising data analysis by people, by issue and by instrument. Organising data by issue includes organising data by research question, which has been selected for this study. This will include organising data which connects to the development of teachers’ orientations for teaching science and identifying data which connects creation of value to LS. Furthermore, data will be organised into that which sheds light on my experience of becoming IKO. This approach will naturally connect the data to the issues raised as a result of the literature review, and cohesively link the findings to the earlier part of the study.

4.7 Data Analysis

This research study incorporated reflexive thematic analysis, a particular type of thematic analysis, located in a qualitative paradigm, which centres on researcher reflexivity (Braun et al., 2022). Braun and Clarke (2019) state that the researcher's role in knowledge production is at the heart of reflexive thematic analysis, in other words, the researcher's subjectivity is central to the process. Having outlined my own constructivist worldview in the previous chapter, I believe that this thesis represents my own interpretation of the world around me, combined with my interpretation of the constructed reality of the group of participant teachers. Braun and Clarke (2022) outline a six-phase process involved in reflexive thematic analysis. The phases are:

1. Familiarisation with the dataset: Become deeply familiar with the content of the dataset through reading and re-reading in a process of immersion.
2. Coding: Identify segments of data that appear interesting, relevant or meaningful for the research question. Collate the code labels and compile the data relevant to each code.
3. Generating initial themes: Start identifying shared pattern meanings across the dataset. Themes are constructed by the researcher, based around the data, the research questions, and the researcher's knowledge and insights, in an active process. Collate all coded data relevant to each potential, or candidate, theme.
4. Developing and reviewing themes: Check that themes make sense in relation to both the coded extracts, and then the full dataset. Consider the relationship between the themes, and existing knowledge, and/or practice in the research field, and the wider context of the research.
5. Refining, defining and naming themes: Ensure that each theme is clearly demarcated, and is built around a strong core concept or essence.

6. Writing up: Finesse and finish the writing process, aiming to weave together the analytic narrative and compelling, vivid data extracts, to tell the reader a coherent and persuasive story about the dataset that addresses the research question.

In this study, data analysis took place after each LS cycle. This enabled the identification of themes grounded in the theory in the data set which were then further scrutinised in subsequent cycles. Cohen et al. (2007) describe how word data can be laborious to process, however this approach was applied after LS1 and retained for LS2 and LS3. Familiarisation took place through reading and re-reading the teacher meeting logs (including audio transcripts after LS2 & LS3), teacher reflective logs, the LS TLP, research lesson observation logs, researcher reflective journal and transcripts of focus group interviews. Children's work samples were also examined.

A deductive orientation to coding (Braun et al., 2019) was applied whereby I approached the data with preconceived ideas and concepts based on my literature review. Through my reading of Magnusson et al.'s description of PCK for science (1999), I came across five components of PCK for science teaching which I then looked for in my data set, before focusing specifically on teachers' orientations. Following engagement with Wenger-Trayner and Wenger-Trayner's outline of value creation in SLS (2020) I was introduced to their Value Creation Framework which I used as a tool of analysis in this research. An outline of each analytical tool will now be provided.

4.7.1 Aspects of PCK for Science Teaching

Magnusson et al. (1999) conceptualise PCK for science teaching as consisting of five components:

- Orientations towards science teaching.
- Knowledge and beliefs about science curriculum.
- Knowledge and beliefs about students' understanding of specific science topics.
- Knowledge and beliefs about assessment in science.
- Knowledge and beliefs about instructional strategies for teaching science.

Each of the five components was initially identified as a theme for analysis within the data set. However, it became apparent that this focus was too broad. Rather, teacher orientations were chosen for exclusive focus given the “hypothesised central role of this component of PCK in decision-making relative to planning, enacting and reflecting upon teaching” (Magnusson et al., 1999).

As a result of placing explicit focus on teacher orientations as an aspect of PCK, it was necessary to revisit the first research question:

What is the effect of school-based Lesson Study on the development of primary teachers' pedagogical content knowledge (PCK) in science?

It can be seen that this is a central question, a broad question that asks for an examination of the effect of school-based LS on teachers' PCK in science. Creswell and Creswell (2023) state that qualitative sub-questions narrow the central question by dividing the central phenomenon into sub-topics focused on learning more about the central phenomenon. Applied to this study, it seemed appropriate to devise a sub-question which focused on teacher orientations as an aspect of PCK:

What is the effect of school-based Lesson Study on the development of teachers' orientations in science?

In order to answer this question, it was necessary to devise a framework for analysis of teachers' orientations. This framework will now be outlined.

4.7.2 Development of a Framework for Analysis for Teacher Orientations

Magnusson et al. (1999) identified different orientations which teachers of science may possess, as listed above. Some of the orientations, such as process, didactic and guided inquiry were in evidence in the data gathered for this study. However, it became apparent when examining the data that not all of the orientations listed by Magnusson et al. were relevant to this research. Research discussed in the literature review, including Banchi and Bell (2008) and Lederman (2009) indicates that inquiry-based learning encompasses several approaches from teacher-directed to child-led. On the other hand, Magnusson et al. (1999), while acknowledging guided inquiry, do not specifically refer to other types of IBSE. It was determined that an expansion of the inquiry orientation presented by them was warranted for this research. Furthermore, additional orientations not listed by Magnusson et al. (1999) were identified in the dataset. As a result a framework for analysis of teacher orientations was designed based on the literature review and data gathered in this study. In this manner, while analysis of orientations began in a deductive manner through the use of Magnusson et al.'s conceptualisation, it developed inductively as a result of the dataset. The framework is shown below in Table 4.7.

Table 4.7

Framework for Analysis of Teachers' Orientations

Orientation	Characteristics of Instruction	Examples in Practice
Unstructured Exploration.	This orientation is one whereby the teacher provides the students with resources and affords them the freedom to explore concepts themselves. They do not have a particular problem to solve or question to investigate. The approach affords the students the	Addressing the children during science lessons in the manner of "Here are your materials, figure it out!" (Caroline, LS2, Meeting 1).

	<p>opportunity to share their ideas and ask questions. This allows teachers to build awareness of students' prior knowledge of a topic. This approach is typically employed at the beginning of a new unit of work. (Adapted from Lederman, 2009).</p>	<p>A desire to include opportunities for the children to explore light materials and pulleys in an unstructured manner (LS2 & LS3)</p>
Process	<p>This orientation is one whereby the teacher focuses on the acquisition of skills such as observation, prediction, questioning, discussion, analysis, prediction, analysis, exploration, investigation and experimentation (DES, 1999).</p> <p>Evidence of this kind of orientation in the classroom is seen where students are engaged in hands-on activities that specifically focus on the development and application of scientific process skills. The students do not have to solve a problem or answer a question in the particular activity. But they are engaged in hands-on activities that support them in developing and applying science skills. (Adapted from Magnusson et al., 1999)</p>	<p>"I was interested in seeing how we could make the scientific skills...more real and more attainable for the children" (Brian, LS1, Focus Group)</p> <p>LS1 TLP: particular focus on skill of predicting.</p> <p>LS2 TLP: particular focus on skill of analysing.</p> <p>LS3 TLP: widened to more than one skill - predicting, observing, analysing and questioning.</p>
Didactic	<p>This orientation is one whereby the teacher transfers scientific knowledge to the students, generally in a lecture or explanation style. Students are passive learners. It is a more traditional approach to science. (Adapted from Magnusson et al., 1999)</p>	<p>Students respond through "question and answer" style regurgitation of knowledge presented by the teacher.</p>
Confirmation Inquiry	<p>This orientation is one that is a "recipe" type approach whereby students are following instructions from their teacher. The students follow the teacher's instructions to engage in hands-on activities while using resources selected by the teacher for them. The teacher decides what steps they should take, what they should observe and measure. It is a more traditional approach whereby students follow directions to confirm a predetermined "right answer". (Adapted from Banchi & Bell, 2008).</p>	<p>Darren's expectation prior to LS that "if you do a science experiment, it has to have this outcome" (LS1, Focus Group)</p> <p>Caroline's belief before LS that an unexpected result in an experiment meant she had "obviously done something wrong" (LS1, Focus Group)</p>

<p>Structured Inquiry</p>	<p>This orientation involves the teacher posing a question or problem to the students, as well as a prescribed procedure for them to use to solve the problem or to answer the question. However, it differs from a Confirmation Inquiry as students have opportunities to include their own ideas when analysing data themselves and arriving at their own conclusions. (Adapted from Banchi & Bell, 2008).</p>	<p>Caroline’s description of her approach to teaching science prior to LS: “OK, here's how you do the experiment: Step 1. Follow me, Step 2. Follow me”. (LS2, Meeting 1)</p> <p>Predict, Observe, Explain (POE) approach to exploring paper spinners in LS1.</p>
<p>Guided Inquiry</p>	<p>This orientation involves the teacher giving the students a question to answer or problem to solve. The students use their own ideas as the basis for planning and carrying out the investigation, Teacher acts as a facilitator/guide, e.g. supporting them to consider the validity of their approach before they carry out their investigation. Differs from Confirmation and Structured Inquiry as students are given autonomy to select the materials they want and their own procedures for carrying out the inquiry.</p>	<p>The creation of a model during LS2 to represent the different shadows made at various times of day.</p> <p>Exploration of compound pulleys: students were provided with necessary materials but given autonomy to design their own compound pulley without a guiding diagram. Teacher scaffolding through emphasis on the meaning of “compound” prior to students undertaking the task.</p>
<p>Open Inquiry</p>	<p>In this orientation students propose and pursue their own question or problem. They decide what procedure they will follow to carry out the investigation, including what they will observe, what data they will collect, how to analyse and record their data, and how to present their findings. The entire process is centred on students’ own ideas.</p>	<p>LS1 Unit Plan, Lesson 2: Objective was that the children would investigate the questions they devised themselves about paper spinners as a result of participation in Lesson 1.</p>

Data highlighted the presence of an unstructured exploration orientation, not present in the work of Magnusson et al. (1999), and adapted from Lederman (2009).

This orientation is one where the teacher provides the students with resources and affords them the freedom to explore concepts themselves. They do not have a particular problem to solve or question to investigate. The approach affords the students the opportunity to share their ideas and ask questions. This allows teachers to build awareness of students' prior knowledge of a topic.

Process and didactic orientations, referenced in the data, are incorporated in the work of Magnusson et al. (1999). A didactic orientation is one where the teacher transfers scientific knowledge to the students, generally in a lecture or explanation style. Students are passive learners. It is a more traditional approach to science. Students respond through "question and answer" style regurgitation of knowledge presented by the teacher. Secondly, data revealed the presence of a process orientation, during which the teacher focuses on the acquisition of skills such as observation, prediction, questioning, discussion, analysis, prediction, analysis, exploration, investigation and experimentation (DES, 1999a). Evidence of this kind of orientation in the classroom is seen where students are engaged in hands-on activities that specifically focus on the development and application of scientific process skills. The students do not have to solve a problem or answer a question in the particular activity. But they are engaged in hands- on activities that support them in developing and applying science skills.

The inquiry orientation referenced by Magnusson et al. (1999) was widened to encompass "confirmation inquiry", "structured inquiry" and "open inquiry", alongside "guided inquiry" which was included in their list of orientations. Confirmation inquiry, adapted from Banchi and Bell (2008), is one that is a "recipe" type approach whereby students are following instructions from their teacher. The students follow the teacher's instructions to engage in hands-on activities while using resources selected by the teacher for them. The teacher decides what steps they should take, what they should

observe and measure. It is a more traditional approach whereby students follow directions to confirm a predetermined “right answer”.

Structured inquiry, based on the work of Banchi and Bell (2008) involves the teacher posing a question or problem to the students, as well as a prescribed procedure for them to use to solve the problem or to answer the question. However, it differs from a confirmation inquiry as students have opportunities to include their own ideas when analysing data themselves and arriving at their own conclusions. Guided inquiry, mentioned by Magnusson et al. (1999), involves the teacher giving the students a question to answer or problem to solve. The students use their own ideas as the basis for planning and carrying out the investigation and the teacher acts as a facilitator or guide, for example supporting them to consider the validity of their approach before they carry out their investigation. It differs from confirmation and structured inquiry as students are given autonomy to select the materials they want and their own procedures for carrying out the inquiry.

In an open inquiry (Cuevas et al., 2005) students propose and pursue their own question or problem. They decide what procedure they will follow to carry out the investigation, including what they will observe, what data they will collect, how to analyse and record their data, and how to present their findings. The entire process is centred on students’ own ideas.

Using the work of Magnusson et al. (1999), in tandem with literature consulted on IBSE, the above framework of analysis was created in the context of data gathered in this study. LS Meeting audio recordings were listened to in order to analyse the manner in which the teachers spoke about their orientations to teaching science before LS, during the process, and at the end of each cycle. Teachers’ individual reflective

logs and the collaboratively designed TLPs were examined for references to the orientations they utilised during LS. The teachers did not explicitly refer to orientations by name, so it was through analysis of their words that their orientations were determined. The “Examples in Practice” listed in Table 4.7 above highlight how each orientation manifested in classroom practice. For example, whenever the teachers referenced scientific skills, this was noted as the process orientation and whenever they referred to situations where the children were told “Here are your materials, figure it out!” as Caroline mentioned in LS2 Meeting 1, such instances were recorded as unstructured exploration.

When differentiating between the different types of inquiry, data were examined to determine the level of teacher-involvement. Confirmation inquiry was associated with situations where the teacher provided the problem and a step-by-step process by which to reach an agreed solution. When the teachers had decided the approach to the inquiry in advance, but the children attempted to analyse their own findings, such as the LS1 research lesson on paper spinners, this was noted as structured inquiry. Guided inquiry was recorded in situations where the children were afforded the opportunity to select their own approach to a given problem, such as when they created their models in the LS2 research lesson. Examples of open inquiry were based on the children determining their own question and approach to investigating it. The Framework for Analysis of Teachers’ Orientations (Table 4.7) was thereby used to evaluate any change in teachers’ orientations as a result of their experience of LS.

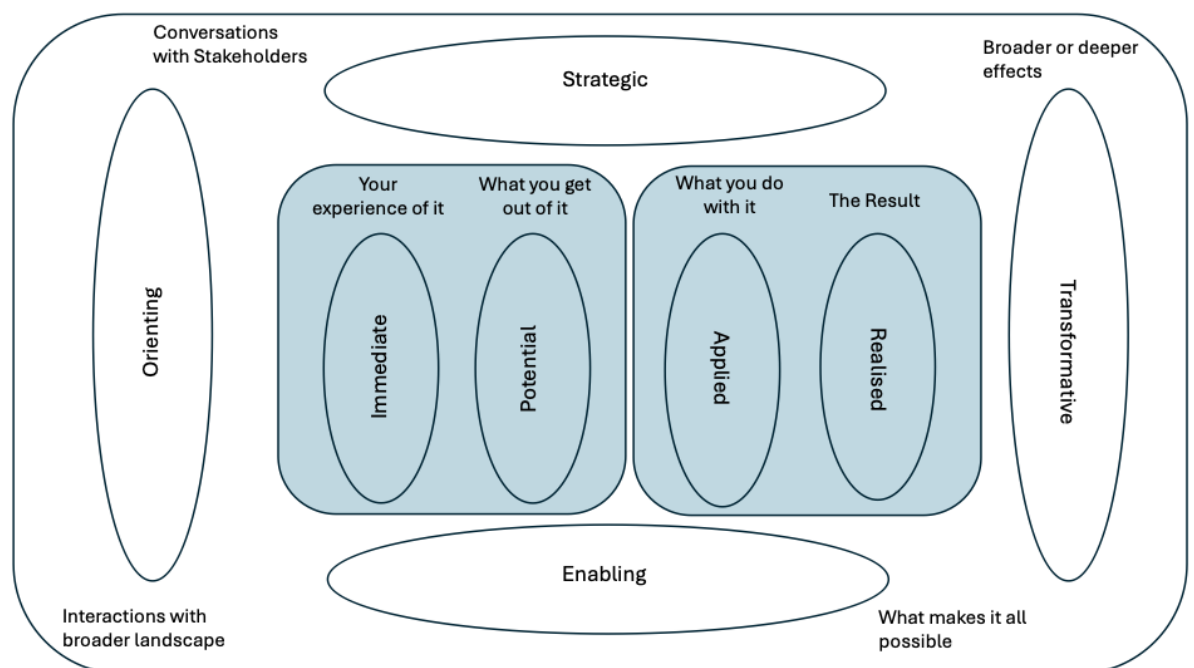
4.7.3 The Value Creation Framework as an Analytical Tool

Wenger-Trayner and Wenger-Trayner (2020) define value creation as a conceptual perspective that “roots social learning in an experience of agency as a person

engages in a social context” (p.243). They created a value creation framework, stating that they were motivated by their finding that “most communities of practice, even successful ones, had difficulty in articulating the value of their learning to stakeholders, and even to themselves” (p.238). The framework is described as a tool for building a logic model from the perspectives of participants, through the collection of structured information. They note that it is not without its weaknesses, given that the SLS is as complex as any human system. They believe that the most they can hope for is a plausible account of the contributions of SLS to changes in the world, a suggestion reinforced by the findings of Guldborg et al. (2021) after their application of the framework to their research. The value creation framework is shown in the figure below, with a more detailed description of its constituent parts thereafter.

Figure 4.1

The Value Creation Framework (Wenger-Trayner & Wenger-Trayner, 2020)



The figure shows the value-creation cycles in a framework, with value creation taking place both within and across cycles (Wenger-Trayner and Wenger-Trayner, 2020). A “cycle” in the work of Wenger-Trayner and Wenger-Trayner is the term used to identify specific types of value, as shown above in Figure 4.1. In this research study, I will avoid using the term “cycle” in relation to value-creation as it is the term I have used to refer to each individual LS process. Rather, I will refer to the various types of value by the labels used in Figure 4.1 above.

Types of Value in the Value Creation Framework

Immediate Value is the value generated by the experience of participating in a SLS, by finding others who understand why a participant cares to make a particular difference and who are willing to engage in mutual uncertainty to make progress. This value “sets the emotional tone and the personal experience of learning” (p.83), with the potential to act as a stimulus for more engaged participation, or lead to disengagement, depending on the participant’s experience. *Potential Value* is the term used when participants engage their uncertainty and pay attention in a way that leads them to take away something that goes beyond their direct experience, and has the potential to make a difference. *Applied Value* occurs when potential value is put into practice outside of the SLS. Wenger-Trayner and Wenger-Trayner (2020) note that applied value can be easy to miss because it can be so integral to simply doing things. *Realised Value* is the difference participants care to make, including any actual achievement, big or small, personal or collective, that further progresses learning. Reflection is identified as a key component of realised value. Realised value can be difficult to perceive because it takes place in the long-term, which may make it challenging to identify in this data set, due to the short-term nature of the study.

Enabling Value is concerned with how the SLS was initiated, how it came into existence and who nurtured the interactions in order to create the conditions for caring to make a difference, for engaging uncertainty and for paying attention (Wenger-Trayner & Wenger-Trayner, 2020). Enabling value is subdivided into internal and external enabling value. Internal enabling value reflects a sense of agency whereby participants feel a sense of ownership over the SLS. In terms of this research study, it included activities such as the collaborative selection of the topic for study, the creation of the TLP including the design of the research lesson, the post-lesson group reflection meeting, and sharing facilitation tasks with participants such as, for example, rotating who was the teacher of the research lesson. Wenger-Trayner and Wenger-Trayner (2020) state that when participants take control of the process “their learning is more likely to be relevant to the difference they want to make” (p.106). My developing role as IKO is also an example of internal enabling value. External enabling value includes outside support which is beneficial to the SLS. Relating to this research, it could include the support of the EKO both to the LS group as a whole during LS1 and specifically to me in the training and guidance I received in order to act independently as IKO during LS2 and LS3. Wenger-Trayner and Wenger-Trayner (2020) note that “one of the difficulties of enabling value is that the more successful it is, the less visible it tends to be” (p.100). This could make it a challenge to identify evidence of enabling value during data analysis.

Strategic Value is described as a key factor in a SLS by Wenger-Trayner and Wenger-Trayner (2020). They also divide strategic value into internal and external categories. Internal strategic value is connected to participants’ articulating their struggles and aspirations as they attempt to make a difference to something they care about. External strategic value includes negotiating with stakeholders and is, according

to Wenger-Trayner and Wenger-Trayner (2020), in their experience, “either overlooked or overemphasised” (p.110). There could be a risk of overlooking external strategic value in this research study, given that it is grounded in an attempt by me as researcher to achieve a personal academic qualification. In this manner, I could be perceived as an internal stakeholder. An understanding of external strategic value could encourage me to be aware of external stakeholders, including the participant pupils, the EKO and the principal of the participant school.

Orienting Value represents an attempt to reach beyond the SLS and its stakeholders, and take into account the broader historical, cultural, and political landscape of other spaces, institutions, practices, relationships, and individuals in which the social learning space exists (Wenger-Trayner & Wenger-Trayner, 2020). The production of internal orienting value is deemed important for learning, given that it embraces other aspects of participants’ lives, and may lead to creative insights, as an idea travels across contexts. External orienting value expands beyond the participants to external audiences. Given the small-scale, short-term nature of this research it is unlikely that such external orienting value will be measured.

Transformative Value is that which goes beyond the goal of making difference, bringing about further transformations, for better or for worse, for example, affecting a boundary, a mindset, identities, an institution, or power relations (Wenger-Trayner & Wenger-Trayner, 2020). Internal transformative value includes personal changes that participants may experience, aside from the initial change they cared to make, as well as changes in how they interact with the world more generally. External transformative value entails something happening within the SLS which causes a transformation outside the learning space. Wenger-Trayner and Wenger-Trayner (2020) describe how “a social learning space does not have to create transformative value to be successful,

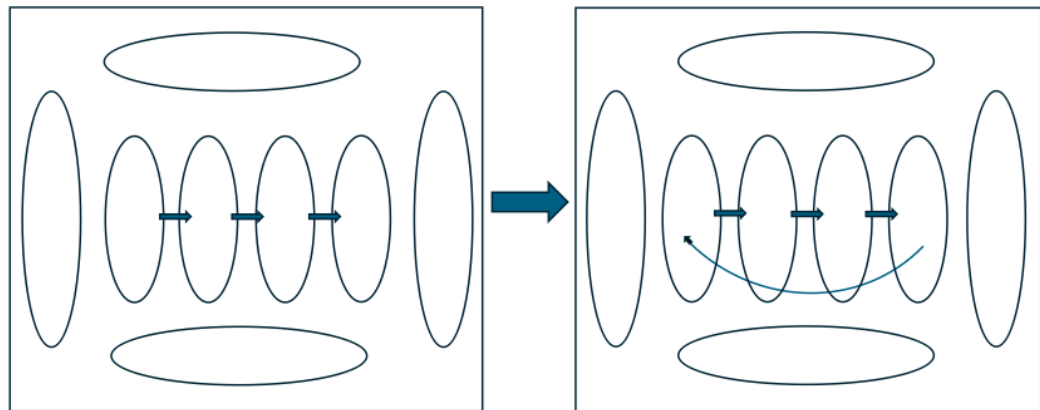
but when it does, it is often its most dramatic outcome” (p.122). This would suggest that the creation of transformative value could be a key indicator of the wider impact of this research study.

Loops and Flows in the Value Creation Framework

Wenger-Trayner and Wenger-Trayner (2020) note that learning needs to *flow* across the value creation framework in order to make a difference, as social learning takes place not just within individual values themselves, but more importantly when value flows across the SLS and gets translated into new forms. They state that “facilitating these flows is also key to fostering, accelerating, and optimising learning in a social space” (p.129). A key characteristic of SLS is that the participants themselves carry the value across the value creation framework through experiencing one type of value, for example, immediate value, and translating it to another, such as potential value. They can share their experience of such flows through giving an account called a *value-creation story* (Wenger-Trayner & Wenger-Trayner, 2020). Value-creation stories are described as an opportunity for spreading learning in a SLS. Stories invite identification with the storyteller, capture the concrete experience and uncertainty involved in practice, and can inspire others to try something similar, or conversely, dissuade them from doing so. In this manner, Wenger-Trayner and Wenger-Trayner (2020) believe that value-creation stories provide an opportunity to create *learning loops*, which occur when participants report back what happened in a learning flow, thus spreading the learning among members. The below diagram (Figure 4.2) illustrates the connection between learning flows and learning loops.

Figure 4.2

A learning flow becomes a learning loop (Wenger-Trayner & Wenger-Trayner, 2020)



A loop is a value flow that returns to its origin, or an earlier point, having become enriched with additional learning along the way (Wenger-Trayner & Wenger-Trayner, 2020). They argue that while any flow is a valuable social learning experience and can make a difference, the presence of loops can accelerate, deepen and widen learning. It is noteworthy that stories about negative value are as important to loop back on, if not more important, as they provide opportunities for reflection.

Wenger-Trayner and Wenger-Trayner (2020) consider both short and long loops as part of a SLS, however, they both play different roles in the process. Short loops can stimulate the flow itself by facilitating the translation from one type of value to another, driving learning forward. They can also create a circular back and forth between values, for example, a good discussion often takes the form of an iterative short loop between immediate value and potential value (Wenger-Trayner & Wenger-

Trayner, 2020). Long loops give participants the opportunity to absorb something more meaningfully by engaging their uncertainty for longer. Identifying the presence of learning loops incorporates accountability into a SLS, by placing emphasis on whether or not a difference has taken place through linking back to the source of the learning. It would seem, therefore, that providing opportunities during LS for participants to share their stories, listening for short loops and analysing data for the presence of long loops could be an important role for me as IKO, to determine if LS does make a difference to those who engage in it.

Effect Data and Contribution Data

Wenger-Trayner and Wenger-Trayner (2020) identify two challenges which complicate the assessment of value creation in social learning spaces. First, it can be difficult to establish that some value was created, which is compounded if the effects of the SLS manifest themselves outside the space itself, and/or with a time delay. The second challenge is to ascertain that the SLS contributed to the value that was created. To address these challenges, the researchers recommend the collection of two types of data: effect data and contribution data (p.190).

Effect data establishes that something of value was achieved through an individual type of value-creation. For example, evidence of effect data relating to immediate value could be collected from recordings of LS meetings, or from participants' reflective journals. Contribution data establishes the role of the SLS itself in achieving a given effect. Wenger-Trayner and Wenger-Trayner (2020) describe how value-creation stories can be sources of contribution data, given that they "reflect the lived logic of generating, recognising, and translating value in order to make a difference" (p.208). They also note that effect data and contribution data are

complementary, and it is “together that they achieve their full capacity to build a robust picture of the value of a social learning space” (p.191). This would imply that, for this research study, it was important to collect data which captured the short loops and flows of value creation, such as LS meeting transcripts, in tandem with the more long-term data gathered from reflective journals and end-of-cycle focus groups. Such an approach was applied and formed the basis for identifying effect and contribution data in the dataset.

Wenger-Trayner and Wenger-Trayner (2020) state that the use of the value-creation framework incorporates the agency of participants into the process of evaluation of a SLS. It is “their stories, as a body of contribution data accounting for effect data, that constitute the logic model” (p.241). The framework supports collaboration between researchers and participants. It allows the participants to become co-researchers, paying attention to the process they have engaged in, and assessing the extent to which the change they aspired to make has occurred, if at all. It has been identified as a promising framework to understand impact in participatory research (Guldberg et al. 2021). To this end, I believe that the value-creation framework is a useful and appropriate tool in the evaluation of LS as a CPL methodology for a group of primary school teachers.

I applied the value-creation framework to my dataset in order to identify effect data and contribution data. The dataset was examined for effect data which established that something of value was created in the research study. I associated effect data with the first research question - measuring the effect of LS on the development of primary teachers’ PCK in science, with a particular focus on teacher orientations, as per the sub-question mentioned earlier. Findings are shared in Chapter 5. The dataset was also examined for contribution data which identified the specific features of LS that were

most effective in supporting the teaching of primary science. Data were analysed for example of flow from one LS cycle to another, and the development of short and long learning loops. Since Wenger-Trayner and Wenger-Trayner (2020) assert that it is when effect data and contribution data come together they build a robust picture of the value of a SLS, the dataset was also examined for interaction between the two types of data and how this impacted the teaching and learning of primary science in this study.

4.8 Trustworthiness

Lincoln and Guba (1985) introduced “trustworthiness” as a term parallel with “rigour” when determining the extent to which one can have confidence in a research study. Whereas rigour is associated with internal validity, external validity, reliability and objectivity, the parallel criteria of trustworthiness are credibility, transferability, dependability and confirmability. Credibility, is concerned with how research findings match reality (Merriam & Tisdell, 2016). The “reality” of this study is based on the teacher participants’ interpretations of reality, as recorded in their reflective logs, observation logs and focus group interview transcripts. For this thesis I used quotes from participants to illustrate their individual perspectives, their multiple realities which corresponded with the epistemological framework outlined in the previous chapter. Triangulation of the multiple sources of data collection ensures the credibility of the study.

Credibility is also addressed through the use of member checks (Merriam & Tisdell, 2016). Some of the participant teachers were asked to examine the researcher’s preliminary findings and analysis to determine if they were an accurate depiction of their interpretations of LS. Merriam and Tisdell (2016) also advocate for adequate time spent on data collection, and an acknowledgement of the researcher’s position. It was

hoped that conducting three cycles of LS generated enough data to address the research questions and that saturation point in terms of developed themes was reached by the end of data collection. I have attempted to make explicit my own worldview and my interpretation of science in this study, and have reflected on my position as insider researcher through the use of a reflective journal.

According to Merriam and Tisdell (2016), dependability refers to the extent to which research findings can be replicated. However, this can be problematic in qualitative research as findings are based on the individual interpretations of participants, which are not static. Merriam and Tisdell (2016) identify the issue of whether the findings are consistent with the data collected as a more important question, in terms of dependability, for qualitative research. The same authors identify triangulation, member checks and acknowledgement of the researcher's position as factors which not only support the credibility of the study, but also its dependability. They also note the presence of an audit trail as a feature of dependability. The audit trail of this study is set out in this methodology chapter, which outlines how the study was conducted, and how the data were analysed. In this manner it would appear that in credibility and dependability have been addressed in the approach to this research study.

Transferability, is the extent to which the findings of one study can be applied to another situation (Merriam & Tisdell, 2016). Again, this is problematic in a qualitative study, as a small purposive sample is selected because the researcher wishes to understand the particular in depth, not to find out what is generally true of the many (Merriam & Tisdell, 2016). This study involves a small purposive sample with whom I wished to explore LS as a methodology of primary CPL. I am aware that the findings are not generalisable. However, the use of "rich, thick description" (Merriam & Tisdell, 2016, p.256) in this study may enable the transferability of the methodology and

findings to other situations. While the findings of this study will not be generalisable, perhaps other researchers may find the methodology utilised here of benefit when planning future research in this area.

4.9 Ethical Considerations

It is necessary for research studies to protect participants from risk of significant harm, both during the research and as a consequence of the research (Morrow & Richards, 1996). In addition to minimising the risk of harm, informed consent and assent, and confidentiality and anonymity are core ethical concepts which arise in research (Department of Children and Youth Affairs, [DCYA], 2012). Prior to the commencement of data collection, an application was made to the university's Research Ethics Committee (REC), seeking approval for this research study in the form of expedited review.

When permission was obtained from the REC to conduct research, letters requesting permission were sent to both the principal and the Board of Management (BOM) of the school (Appendices G and H). On receipt of support for the study from the principal and the BOM, participating teachers were provided with plain language statements and informed consent forms (Appendices I and J). The plain language statements explained what types of data would be collected, where the data would be stored and for what length of time. The statements stated that anonymity could not be guaranteed for participant teachers as people reading the published research could be aware of the name of the school where I work. Participants were advised of their data protection rights. They were assured that participation was voluntary and that they could withdraw from the study at any point with no negative consequences. Participants

were also provided with the name of an independent person from the university's REC that they could discuss the project with, should they have any concerns.

The parents of participating children were also provided with a plain language statement in the form of a letter (Appendix K) which explained the purpose of the research, the potential benefits to taking part and the low level of risk attached to involvement in the research lesson. Parents were informed that while samples of children's work would be collected, no child would not be identified by name in written accounts of the research. Parents were reminded that children could withdraw from the project at any point. Parents were invited to complete an informed consent form prior to the research lesson (Appendix L).

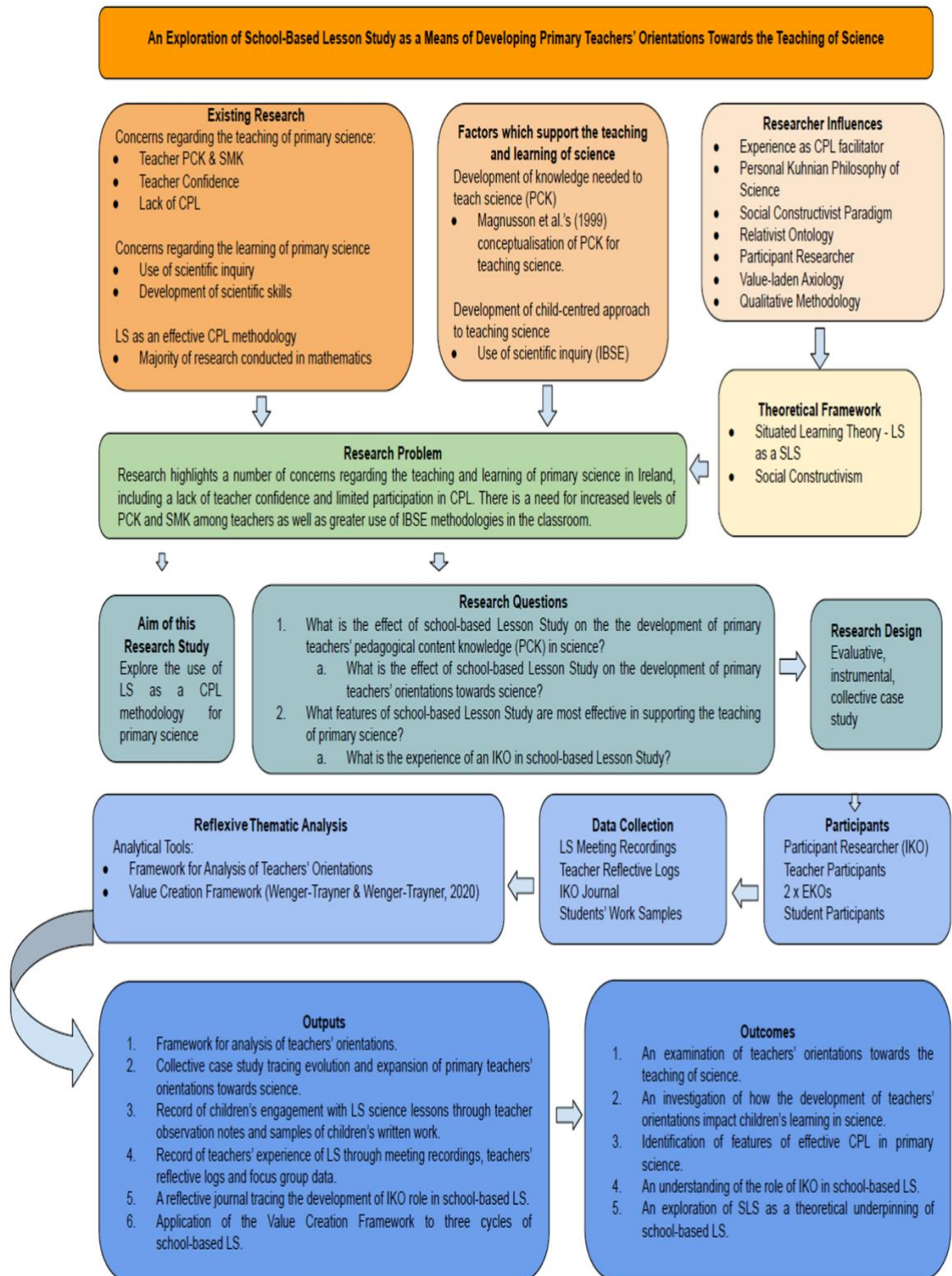
The DCYA (2012) state that, in addition to parental consent, good practice in research also requires the child's agreement to participate, and that this assent should be obtained independently. Participating children were given a letter (Appendix M) which explained the project to them and invited them to participate. A plain language statement (Appendix N) was read aloud to them which explained that their work samples would be examined by the teachers but that I would not include their real names in anything written about the project. Children were informed that they did not have to participate in the lesson. They were then asked to complete an assent form (Appendix O). The *Guidance for developing ethical research projects involving children* (DCYA, 2012) outlines that research should keep with best practice standards of child protection. In order to achieve this, adult participants were made aware of the school's Child Safeguarding Statement and reminded of the obligation to report any disclosure from a child to the school's Designated Liaison Person and Deputy Designated Liaison Person.

4.10 Conceptual Framework associated with this study

The conceptual framework on which this research study is based is shown in Figure 4.3 below. It is a representation of the concepts and ideas that form the basis of this research project, as outlined in both this chapter and the previous one.

Figure 4.3

Conceptual Framework for this study



Ravitch and Riggan (2017) state that a conceptual framework is “an argument about why the topic one wishes to study matters, and why the means proposed to study it are appropriate and rigorous” (p.5). The conceptual framework associated with this study, in Figure 4.3 above, aimed to adhere to their definition. Reference to existing research highlighted areas of concern associated with the teaching and learning of primary science, including lack of teacher PCK and SMK, thus making an argument for the relevance of this research. Consideration of literature led to the identification of factors which can support the teaching and learning of primary science, including the development of teacher PCK, and the use of IBSE approaches in the classroom. The literature review also led to the identification of LS as an effective CPL methodology, although most research was conducted in the area of mathematics.

A conceptual framework should argue convincingly that the research questions are an “outgrowth of the argument for relevance” (Ravitch and Riggan, 2017, p.5). It would seem that the identified research questions were developed from the research problem itself. The first broad question, “What is the effect of school-based Lesson Study on the development of primary teachers’ pedagogical content knowledge (PCK) in science?” is grounded in the identified lack of teacher PCK in primary science. The question connects to the research aim of evaluating the use of school-based LS, as a means to develop PCK. The second research question, “What features of school-based Lesson Study are most effective in supporting the teaching of primary science?” addresses the identified lack of participation by teachers in science CPL, and aims to evaluate school-based LS as an effective CPL methodology. The research design of an evaluative, instrumental, collective case study was selected as a means to gather a variety of data across three LS cycles in order to explore the research questions.

Reflexive thematic analysis was employed in order to address the questions and identify the outputs and outcomes associated with this research study.

4.11 Conclusion

This chapter outlined the research design and methodology of this study. Information on the research site and research participants was included. Details on the various methods of data collection were provided, and the selection of reflexive thematic analysis was described. An outline of the tools of analysis including a Framework for Analysis of Teachers' Orientations, developed from literature reviewed in Chapter 2, and Wenger-Trayner and Wenger-Trayner's Valuation Creation Framework (2020) was presented. The chapter included considerations of how trustworthiness pertains to this study. This section of the research study provided a rationale for the selected methods of data collection. The chapter concluded with an outline of the conceptual framework which guides the overall research process. The following two chapters will present the findings of the data analysis.

**CHAPTER 5: EFFECT OF LESSON STUDY ON THE
DEVELOPMENT OF TEACHERS' PEDAGOGICAL CONTENT
KNOWLEDGE**

5.1 Introduction

The purpose of this study was to investigate the effectiveness of LS as a CPL methodology for the teaching of primary science. Findings were determined in light of the guiding research question and its associated sub-question:

What is the effect of school-based Lesson Study on the development of primary teachers' pedagogical content knowledge (PCK) in science?

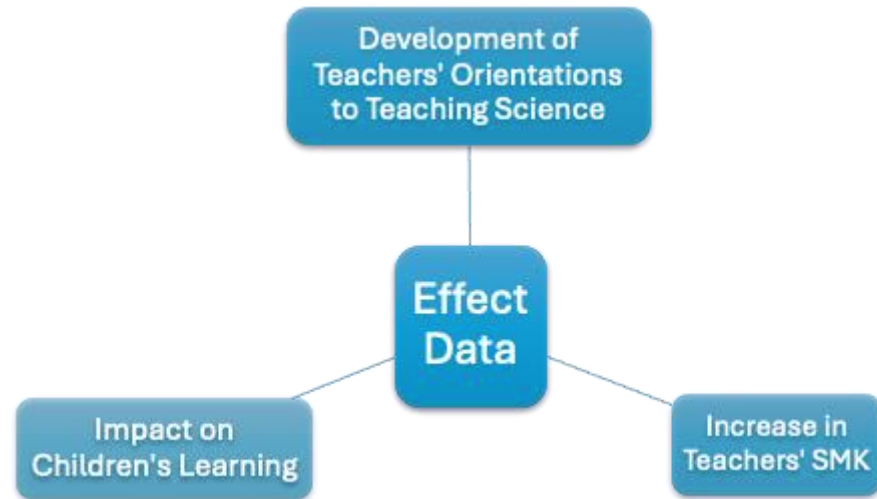
What is the effect of school-based Lesson Study on the development of primary teachers' orientations towards science?

Reflexive thematic analysis was utilised in order to develop themes in a theoretical manner. As data analysis was undertaken it became apparent that participating in LS supported the development of teachers' orientations towards teaching science, an aspect of science PCK identified by Magnusson et al. (1999). In addition, it was evident from the findings that LS also promoted the development of teachers' Subject Matter Knowledge (SMK), one of the three types of content knowledge identified as necessary for teaching by Shulman (1986). Furthermore, the development of both teachers' orientations and SMK for teaching primary science, as a result of LS, culminated in a positive impact on children's learning. Wenger-Trayner and Wenger-Trayner (2020), in their description of SLS, define effect data as that which establish that "something of value was achieved" (p.190). In relation to this study, it would appear that effect data could be characterised in terms of the development of

teacher orientations, SMK and children's learning (see figure below). Each of these three themes will now be individually discussed.

Figure 5.1

Model of Effect Data themes identified in this study



5.2 Development of Teachers' Orientations

Teachers' orientations are defined by Magnusson et al. (1999) as “knowledge and beliefs about the purposes and goals for teaching science at a particular grade level” (p.5). The same researchers ascertain that this component of PCK is significant as it serves as a “conceptual map” that guides teachers' instructional decisions about issues such as teaching objectives, the design of student tasks, the use of resources and assessment of learning. It would appear that teachers' orientations to teaching science, including the beliefs that they hold, influence many other aspects of teaching and learning of the subject in their classrooms.

A framework for analysis, described in the previous chapter, and based on the literature surrounding teachers' orientations to teaching science, including the different

types of scientific inquiry, was utilised. The orientations identified in the data will now be reported with the support of extract samples.

5.2.1 Teachers' Orientations Prior to LS

At the beginning of LS1, the teachers were invited to consider their views of primary science in terms of their “actual” orientations versus their “ideal” orientations (Meeting 1 notes). The thoughts shared by the teachers formed the basis for measuring any change to their orientations as a result of LS. In terms of value creation, as outlined in the previous chapter, this activity on the part of the teachers would appear to correlate with “framing the creation of value” (Wenger-Trayner & Wenger-Trayner, 2020, p.62). Framing the creation of value is identified as a social learning mode, whereby, in an act of agency, participants identify a perspective on what they consider to be of value.

When asked to consider the actual approach to science they were following prior to LS, one of the teachers (unnamed) expressed a wish to “get away from recipe mode”. This indicates an initial orientation of “confirmation inquiry” whereby students follow instructions from their teacher to confirm a predetermined “right answer”. This seems to mirror the finding of Murphy et al. (2020) that there was a tendency for experiments in Irish primary classrooms to be prescriptive, with children following step-by-step instructions from the teacher. The LS teachers expressed some concern that children could be “impatient to work things out” and had a tendency to “give up easily”. The teachers believed that many children “just want the answer” and “will wait for the teacher to give [them] the first letter, [a hint]”. This indicates that the teachers were concerned about falling into the role of imparter of scientific knowledge in a didactic approach. The LS teachers acknowledged that the children were “curious and

inquisitive” however, they did not comment on how these attributes were supported in classroom science lessons prior to LS (LS1, Meeting 1 notes).

Ideally, the teachers’ goals for primary science encompassed placing emphasis on the “development of skills” such as “questioning” and “predicting”, which would indicate an interest in a process orientation to teaching science. They envisaged that children would develop “higher order thinking skills that are cross-curricular and life skills really”. The teachers aimed that their lessons would prepare students for the future through the development of a “suite of 21st century learning skills...considering children who will be moving to undergraduate level”. They highlighted their desire to promote inquiry through the mention of “problem-solving” and “imaginative inquiry” as two of their ideals. This emphasis on scientific inquiry aligns with the key pedagogical practices of the *Science, Technology and Engineering Education Specification* (NCCA, 2024).

Written notes from LS1 Meeting 1 recorded that one of the ideals of science education for the group was the notion that “the children will sit and work something out, and stick with it”. Similarly, NCCA (2024) suggests that teachers can promote the use of scientific inquiry by encouraging children to persevere with their inquiries when they encounter obstacles. This theme also suggests a connection with the scientific philosophy of Imre Lakatos who advocated further investigation when problems arise in a research programme (Larvor, 1998). Lakatos’ belief that research programmes should proceed, even when they encounter problems, could transfer into encouraging children to persevere with investigations and be open to changing their approach when they meet challenges in the classroom.

Teachers identified the natural curiosity of children, their “sense of wonder” and “independent learning” as important during Meeting 1, linking to the curricular aim of using science to “foster the child’s natural curiosity, so encouraging independent inquiry” (DES, 1999a, p.11). In a similar manner, the *Draft Science, Technology and Engineering Education Specification* (NCCA, 2024) aims for children “to explore the world with curiosity and playfulness” (p.6). The teachers also expressed a wish to teach science in a way that meant children were “not handed answers”, or “just accept[ed] the answer” they were given. This could be inferred as a desire to move away from more teacher-centred orientations to primary science such as didactic or confirmation inquiry approaches.

Consideration of the PSC documents after Meeting 1 confirmed a desire to promote more child-centred approaches to science. LS1 Meeting 2 recorded an interest in emphasising “children having autonomy over the learning” and “using children’s ideas as a starting point”. Such comments are in line with the constructivist approach underpinning the PSC (DES, 1999a) whereby it is envisaged that children are involved in the “active construction of their own understanding” (p.3). Likewise, NCCA (2024) advocates facilitating children to use their agency to choose questions and challenges that interest them.

At the conclusion of the introductory process to LS1, the teachers identified long-term goals for the students through the selection of an overall research theme. The teachers decided that “all children [would] have the opportunity to work scientifically” (LS1, TLP). The LS EKO asked the teachers to describe the strategies that they each considered helpful in supporting children to work scientifically during LS1 Meeting 3. This would appear to connect with a “framing event” described by Wenger-Trayner and Wenger-Trayner (2020), choosing areas of focus in the SLS. Some of the teachers

once again emphasised child-centred approaches to teaching science. For example, Darren shared his view that children should be given “open-ended questions...you don’t tell them what to do”. This would align with an open-inquiry approach to teaching science. His opinion was supported by Caroline who agreed that working scientifically involved “letting the children work things out for themselves”. Similarly, Brian advocated a situation whereby the teacher should “try not to control the lesson”. Once again the teachers showed their enthusiasm for shifting away from teacher-directed orientations such as didactic and confirmation inquiry.

Michelle suggested that the classroom environment should encourage “questioning and curiosity” while reminding children “that’s how scientists work - they’re curious about things, they ask questions”. Anna also spoke about encouraging children’s “questioning” and trying “to support children with problem-solving”. This would suggest an interest in applying inquiry-based approaches to scientific learning while also focusing on skills such as questioning. In addition, Michelle mentioned supporting children to develop their scientific skills, in the manner of a process orientation. However, acting as IKO, I proffered the view that it was “important that if we want children to work scientifically we need to teach them the skills – we can’t presume that they naturally have them”. I referred back to previous experience of science CPL where I witnessed a change in children’s ability to “speak more confidently about the [scientific] processes” after a focus on skills development, and how they began to “use words like observe” after “engaging in more science”. I perceived their ability to express themselves using the language of scientific skills as a successful trait of the CPL I participated in. I envisaged that the children participating in this CPL would do likewise.

I, as IKO, furthered my focus on language with a wish that children would develop their language to include “specific terminology” relating to science. Brian concurred with this, asserting his interest in supporting children to “develop the scientific language to describe what is going on in their heads”, as well as an ability to “articulate ...what they’re doing and why they’re doing it” in science lessons. Our emphasis on language development in science lessons correlates with the PSC (DES, 1999) assertion that “language is an integral part of the teaching and learning process” and “contributes to the expansion of the child’s conceptual development” (p.10). It could also be suggested that a focus on language development aligns with the communicating skill of the PSC, again a feature of a process orientation to teaching science. Our focus on scientific language aligns with the *Draft Science, Technology and Engineering Education Specification* (NCCA, 2024), which aims for children to “use and apply science, technology and engineering language in order to communicate, evaluate and reflect on learning experiences” (p.6).

Overall, the teachers’ comments at the outset of LS1 demonstrated how, for them, an ideal approach to primary science incorporated an inquiry-based, problem-solving approach alongside a process orientation focused on the development of children’s scientific skills. They also favoured shifting towards more child-centred approaches to teaching science. An outline will now be provided of the manner in which the teachers’ ideal orientations manifested themselves, alongside other orientations, during the actual LS process. This will provide evidence of the extent to which LS supported the teachers to put their orientations into practice.

5.2.2 Process Orientation

As outlined in Table 4.7 above, evidence of a process orientation in the classroom is where students are engaged in hands-on activities that specifically focus on the development and application of scientific process skills (Magnusson et al., 1999). These could include observation, prediction, questioning, discussion, analysis, prediction, analysis, exploration, investigation and experimentation (DES, 1999).

LS1

The research theme chosen by the teachers for LS1 was that “all children [would] have the opportunity to work scientifically” (LS1, TLP). It highlighted the LS teachers’ interest in the development of children’s scientific skills, as the term “working scientifically” in the PSC (DES, 1999a) outlines how children may engage in scientific inquiry through the development of various component skills, thus modelling how scientists work. This aligns with a “process” orientation to teaching science (Magnusson et al., 1999), whereby students are engaged in hands-on activities that specifically focus on the development and application of scientific process skills. In terms of the PSC (DES, 1999a) these skills include questioning, observing, predicting, investigating and experimenting, estimating and measuring, analysing, recording and communicating.

For Brian and Michelle this was an orientation that they possessed prior to LS. Brian commented in his LS1 Study Phase Reflective Log that he had “always seen my role as enabling the students to expand their skills”. Similarly, Michelle shared how the Study Phase “reaffirmed my belief that developing procedural understanding is of importance to me as a teacher, the development of scientific skills” (LS1, Study Phase Reflective Log). Michelle also revealed that a reading consulted during the LS1 Study

Phase had “challenged” her own view of science. Prior to LS she had “thought there was a sequential order to engaging with scientific skills” and “firmly believed that observation should come first”. However, after reading the Harlen (1993) chapter on “Children’s Ways of Thinking”, Michelle discovered that “in practice process skills are not so separable and that children use the skills in almost any order” which she described as “new learning” and something that she was “happy to incorporate” into her teaching. On the other hand, Anna, Caroline and Darren referred to students' skill development in an aspirational manner at the outset of LS1, in conflict with their actual classroom practice.

The overall broad research theme of supporting all children to work scientifically was narrowed during the Study Phase, when the teachers chose specific topics for investigation. The scientific skill of prediction was identified as a gap in both teaching and learning during initial meetings. This was highlighted by Brian, who noted that in his experience “children find it difficult to predict...I find it difficult to teach” (LS1, Study Phase, Meeting 3). Anna agreed with Brian, commenting that “children struggle with prediction, and we struggle ourselves”. Michelle concurred with their opinions, stating, “it’s hard to get the children away from [concentrating on] was their prediction right, were they right, like a table quiz”. Prediction was selected as the skills focus area for LS1 alongside the scientific content theme of falling objects, which was also identified by the teachers as an area of the PSC (DES, 1999a) they found challenging to teach (LS1, TLP).

The teachers worked collaboratively to design a research lesson to reflect these areas of interest. The lesson plan outlined how the teacher would explain to the children that they were going to “work as scientists” (LS1, TLP) before explaining that they were going to “ask questions, investigate and make predictions, just as scientists do”.

This underlines how the process orientation came to the forefront as the research lesson was introduced to the children in the classroom. An effort was made to teach the children what a prediction is, by explaining “we are going to talk about what we think might happen. We will give a reason for our answers so that it’s not just a wild guess. Scientists call this making a prediction”. This connected to my assertion, as IKO, in Meeting 3 that we needed to explicitly teach the children scientific skills. It also aligns with the *Draft Science, Technology and Engineering Education Specification* (NCCA, 2024), which envisages “drawing children’s attention to the scientific skills they are using and how they are working ‘like a scientist’” (p.21).

Morine-Dersheimer and Kent (1999), in their model of PCK, identified a close relationship between the goals and purposes of teaching and knowledge of assessment. The LS teachers’ points of evaluation were directly connected to their process orientation through their focus on the development of skills such as predicting, observing and analysing. The teachers elected to evaluate if the children could predict how the spinner would fall and give a reason for their thinking. Subsequently they would be assessed on their ability to explain their observations of what happened, and their identification of the role of air resistance in causing the spinner to slow down (LS1 TLP).

During the focus group interview at the end of LS1, teachers were invited to consider the cycle as a whole. Brian believed that “LS facilitated the promotion of scientific skills, which is what it’s all about”, underlining his adherence to a process orientation, as evidenced prior to LS. Darren shared his belief that building a lesson around one skill “was a really interesting way to approach a lesson”, indicating that this was a new approach from him. This would indicate a shift in Darren’s orientations to teaching science as a result of LS1.

LS2

The teachers' interest in advancing a process orientation as part of their science lessons transferred to LS2 which began 19 months after the completion of LS1. In terms of the Value Creation Framework, it would appear to be an example of a flow, or connection, between LS1 and LS2. The teachers decided to retain the same research theme from LS1, that "all children [would] have the opportunity to work scientifically" (LS2 TLP). Brian explained how he liked how the group "chose working scientifically as the broad thing" before they "narrowed it down to prediction" in LS1. He saw LS2 as an opportunity to "do that again this time" with a "different skill" (LS2 Study Phase, Meeting 1). This highlights Brian's commitment to the development of children's scientific skills, once again linking to a process orientation.

The skill of analysing came to the forefront as a process skill for development during LS2 when the teachers focused on the theme of light and shadows. Caroline reflected during Meeting 3 that "the way we're thinking of tasks...it's more about when they've discovered [something], why has that happened?", which led Brian to conclude that "I think it's an analysis kind of lesson". As a result of the teachers' planning meetings, one of the research lesson objectives was that children would "analyse the photos and/or drawings from Lesson 3 (shadows their bodies created outside at different times on a sunny day), noting differences in position and length" (LS2 TLP). Caroline, as the research lesson teacher, invited the children to work in pairs in order to analyse the shadow photos they took on the schoolyard. She posed questions such as "What do you see? Did [the shadows] stay the same? Do you see any differences? Can you think of any reasons for the results you found?" (LS2, Planning Phase, Meeting 5). The style of questioning selected by the LS teachers encouraged the children to carefully examine and analyse the shadows in the photographs they had taken. This contrasted with the

style of questioning utilised in the LS1 research lesson which encouraged the children to predict. For example, in LS1 the children were asked, “What do you think will happen if you drop the spinner and the wings are at the top? Do you have a reason for thinking this?” (TLP). The LS teachers adapted their questions based on the different skills they were emphasising in each research lesson.

In addition to analysing, the teachers elected to focus on the skill of communicating during LS2. During Meeting 4, Brian envisaged that the children would be “working as scientists to communicate an understanding of...how shadows work”. He outlined how they could “communicate through words and through the physical manipulation of the model”. As a result, the LS2 TLP records one of the research lesson objectives as “children will communicate their understanding of the relationship between the shadows formed and the light source”. The teachers discussed how communication could encompass more than oral description. Darren asserted that “by [the children] showing you that they can make the shadows bigger or smaller, they understand that they have to manipulate the distance between the shadow and the light, and the angle”. Brian agreed “that is a form of communication”. Darren continued with his opinion that “if they can communicate that verbally to some degree even better”. It would appear that this interaction emphasised the overall research theme of “all children” working as scientists as Brian and Darren seemed to be cognisant of the varying needs and communication styles of the children in the class.

At the end of LS2 the teachers reflected on the cycle as a whole. The process reaffirmed the importance of developing children’s scientific skills for Brian. He observed that “the single greatest confirmation for me is that science teaching and learning has to be rooted in skills development and not solely in content” (Teaching and Reflective Phase Log). This shows how Brian’s engagement with LS reinforced his

belief that primary science should be a combination of both concept and skills development, reaffirming his process orientation to teaching science, as per LS1.

LS3

LS3 began 7 months after the completion of LS2. Early on in the Study Phase, Brian asked, “Isn’t part of our lesson study that we want to build the scientific skills of observation, analysis and reflection?”, which the other teachers concurred with (LS3, Meeting 2). This indicates that one of the shared goals of LS3 was the promotion of a process orientation to teaching science, continuing its flow from LS1 and LS2. The focus on the promotion of scientific skills continued through to the Planning Phase. One of the research lesson aims was that children would “compare fixed, movable and compound pulley systems in order to analyse the efficacy of the compound pulley” (LS3, TLP). The emphasis on developing the skill of analysing, similar to LS2, links to the process orientation.

By the end of LS3 the teachers had developed an ability to incorporate a process orientation based on an awareness of their students' thinking from earlier investigations. They used the students' own ideas as the basis for developing their skills of analysing. This also points to a desire to apply a constructivist approach to teaching science, whereby the children's own ideas and experiences were factored into the design of the research lesson. For example, during Lesson 3 of the unit plan the children explored movable pulleys where the pulley string is pulled up, before comparing them with fixed pulleys whereby the string is pulled down to lift the object. Caroline described how, during the lesson, two groups “had the moveable pulley and they were pulling up but they obviously knew that pull down is easier, so they wrapped it [up] over the chair and pulled it down over the chair, so they were making it easier for themselves” (LS3,

Planning Phase, Meeting 9). As the research lesson was planned, Michelle asked “could we weave that [the children’s exploration of movable pulleys] into the next lesson?” to which Brian replied, “I was hoping that we could” and that is what transpired.

Given the position of the research lesson at the end of the unit plan, the teachers incorporated this knowledge of the students’ exploration of movable pulleys into the research lesson itself. For “posing the task” it was stated that “the children [would] be invited to reflect upon how they used the chair to improve the functionality of their movable pulley in lesson 3” (LS3, TLP). The children were encouraged to analyse how the positioning of a chair improved the manner in which their movable pulley worked. Earlier lessons in the unit had expanded the teachers’ knowledge of how their students regarded pulleys, thus enabling them to include student ideas in the actual research lesson. The children were invited to actively construct meaning from their experience of the previous lesson, reflecting together on how their idea of using a chair improved the functionality of a movable pulley system by changing the upward force to a downward force, supported by gravity. In contrast, the LS1 research lesson, as a structured inquiry, had a predetermined teacher-directed process for investigating the manner in which paper spinners fell. In a similar manner, the LS2 research lesson, although itself a guided inquiry, used data gathered from its previous lesson - a teacher-directed structured inquiry, as the basis for the creation of a model. The difference in LS3 was that some of the children’s own explorations in earlier lessons were incorporated into the research lesson itself.

While reflecting on what they learned during the LS3 as a whole, the goal of promoting the curriculum skills, a process orientation, was again of clear importance to the group. Brian commented, “I’d rather that I...developed the skills” (LS3 Focus Group). He furthered this by stating “if they didn’t get to do magnetism this year, OK

it's unfortunate but by gosh they got the skills in what they did". This indicates that as a result of LS Brian prioritised the development of scientific skills through deeper engagement with fewer topics. He observed how LS made him "stop thinking about strands and think about skills". Caroline agreed with this when she stated how "all of those skills are being hit when we do it like this" which she viewed as "great". This was reaffirmed by Caroline in her final reflective log when she stated, "through LS, we have come to realise that the skills are the most important aspects to focus on and these are useful for the children across all strands". The teachers contrasted this approach to teaching science with previous practice of skimming superficially over lots of scientific content prior to LS, to the neglect of the application or development of scientific skills. This is of significance given the finding of Murphy et al. (2023) that improvements to both conceptual knowledge and skill development were seen when students were afforded opportunities to use science process skills.

The teachers' comments indicate that the process orientation was of fundamental importance to them at the end of LS3, compounding the similar findings from LS1 and LS2. In terms of progression across the three cycles, it can be seen that the teachers focused solely on prediction in LS1 and continued by focusing on analysing and communicating at the beginning of LS2. However, by the end of LS2 they concluded that their unit plan actually supported the development of a range of scientific skills, including observing, predicting, analysing, experimenting, recording and communicating (LS2, Focus Group). This focus on the inclusion of various skills in the same unit plan continued into LS3.

LS supported the teachers to emphasise a process orientation, through initially focusing on individual skills before expanding to the development of a range of skills in the same unit plans by the end of LS3. This is of significance as the *Science in the*

Primary School (DES, 2012) report found that insufficient attention was given to the development of skills in Irish primary classrooms. Indeed inspectors found that more than half of the classroom teachers in the report were not placing sufficient attention on the development of science skills in their planning. Findings from this study suggest that LS supported the teachers involved to develop their process orientations to teaching science through the emphasis on skills development, which in turn provided the children with opportunities to work scientifically in the classroom.

5.2.3 Inquiry Orientation

Attempts to achieve a balance between the needs of the majority of students who will not become scientists and the minority of students who will pursue science careers have led to an emphasis on teaching science through inquiry (OECD, 2016a). A European Commission report (2007), chaired by Michel Rocard describes how IBSE was traditionally called the “Inductive Approach” or “bottom up” approach to teaching science (p.9). The report describes IBSE approaches as involving observation, experimentation and construction by the child of his/her own knowledge, supported by teacher guidance.

IBSE is thought to promote scientific literacy, and has the potential to improve students’ understanding of science and engagement with science (Capps & Crawford, 2013). Cuevas et al. (2005) outline three approaches to inquiry: student-centred or open, teacher-guided, and teacher-centred or explicit. Banchi and Bell (2008) further subdivide teacher-centred inquiry into confirmation inquiry and structured inquiry. While Murphy et al. (2019) note that there is no universal definition of IBSE, the framework for analysis used in this study offers an interpretation of four different types of scientific inquiry: confirmation, structured, guided and open. This interpretation,

outlined in the methodology chapter, and included in Table 4.7, informs the findings shared below.

Confirmation Inquiry

LS1 reaffirmed the teachers' desire to "get away from recipe mode" in the style of a confirmation inquiry. As she reflected on her experience at the end of LS1, Caroline noted her previous mindset of "let's try this again tomorrow, because I've obviously done something wrong" when things took an unexpected turn during an investigation. In contrast, LS1 gave Caroline the confidence to ask the students "why did you think it happened like that?" She noted how she felt she was "learning along with the kids" as a result of LS1, and felt comfortable doing so. Similarly, Darren voiced a shift in his thinking from approaching scientific investigations with an expected outcome in the style of a confirmation inquiry orientation, to a new orientation whereby "if it doesn't go the way you expected, great, that's just a different line of inquiry that we can follow". This shows a change in Caroline and Darren's approach to inquiry, moving away from a confirmation inquiry orientation as a result of their LS1 experience.

Furthermore, when asked to consider if LS2 had changed their overall approaches to teaching science Caroline was very critical of the school's textbooks which acted as examples of confirmation inquiries, where the only challenge for the students was to "unscramble the sentence to do the method". According to Darren "that's not science" (LS2 Focus Group). Caroline and Darren both described how confirmation inquiries had featured as part of their typical practice prior to engaging in LS1. The above comments suggest that the shift away from such confirmation inquiries, which emerged as a result of LS1 and its focus on structured inquiry and the development of process skills, was further embedded by the end of LS2. Their clear

determination to avoid the confirmation inquiry style of the textbooks available in the school highlights this.

Structured Inquiry

A structured inquiry orientation was evidenced in LS1 through the research lesson on paper spinners. The LS1 TLP (Appendix P) described it “as an introductory teacher-directed inquiry-based lesson, allowing the children to develop their skills of prediction”. It was a structured inquiry given the teacher’s role of steering the children through pre-determined activities in the research lesson. The teachers had decided in advance the procedure which the lesson would follow. To begin with, the children would predict what would happen when they dropped a paper spinner, and give a reason for their suggestion. Subsequently, they would observe how changing the starting height, starting position and size of the spinner would affect the manner in which it fell. Finally, the children would attempt to explain their results, which provided them with an opportunity to analyse the data themselves and arrive at their own conclusions.

The lesson was inspired by a Predict Observe Explain (POE) booklet (Haysom & Bowen, 2010) which the teachers had consulted during the Study Phase. POE is a type of structured inquiry. Students are asked to predict what will happen in an experiment or demonstration, giving a reason why. They then observe what happens and attempt to explain what they observed (Joyce, 2006). The assessment goals also followed the predetermined process of the structured inquiry designed by the teachers. In this manner, a direct link can be established between the teachers’ orientations to teaching in LS1 and their assessment model (Morine-Dershimer & Kent, 1999).

Although the structured inquiry of LS1 meant that the students followed a prescribed procedure, it still afforded the “children the freedom to explore and form

opinions as opposed to feeding them suggestions or predictions” (Caroline, Teaching/Reflective Phase Log, LS1). In contrast, she revealed that before LS1 her tendency was to “stick to the plan, as opposed to allowing the children some degree of control” in her science lessons (Planning Phase Reflective Log, LS1). This represents a shift in her orientation to teaching science as a result of LS1. However, Caroline also shared how she observed a child recording an inaccurate result to match her prediction. This serves to highlight the risk of allowing children to arrive at their own conclusions in a structured inquiry. Furthermore, Anna, acting as observer, commented during the Post-Lesson Reflection Meeting that she found it “really hard not to try and help” when the two children she observed were struggling during the lesson. It could be argued that teacher input is still critical to avoid building inaccurate conceptions of scientific topics. Indeed, Harlen (2018) notes that it is a misinterpretation of IBSE to suggest that children have to discover everything for themselves and should not be given information by the teacher.

On the other hand, Brian saw a conflict between “being organised and structured...and organic conversation” (LS1, Post-Lesson Reflection Meeting). It was his view that “because of the structure you lose the organic nature”. This would suggest that Brian was not in favour of an overly structured, teacher-directed approach to inquiry. That said, Harlen (2012) acknowledges that teachers starting out in IBSE approaches, such as Anna and Caroline, may initially need some structured activities to try with their students, in order to build their own confidence.

Guided Inquiry

Guided inquiry is characterised by the teacher giving the students a problem to solve or a question to answer and affording them the opportunity to select their own

approach to do so. The teacher supports student autonomy during the process while remaining available as a guide to learning. For Michelle and Brian, acting as a guide or facilitator of children's learning was a priority before LS. Brian commented in his LS1 Study Phase Reflective Log that he had always viewed himself as "enabling the students" which would coincide with a guided inquiry orientation. Perhaps his apparent comfort in this role offers a reason for Brian's concern that structured inquiry could stymie organic conversation, as noted above. Guided inquiry was not evident during LS1 itself but it emerged as an orientation during LS2 when the teachers elected to include the children's own ideas as the basis for planning and carrying out investigations. Brian saw opportunities for students to "formulate questions during investigations that might lead the narrative of the lesson down unexpected, challenging but ultimately rich avenues" (LS2 Study Phase Reflective Log). He highlighted a concern that adhering too rigidly to specific curriculum objectives when planning could thwart opportunities for child-led learning based on children's own ideas, reaffirming a belief he held during LS1. Brian's desire to include "children's own ideas" and "child-led learning" points to an interest in guided inquiry orientation.

During the Planning Phase a connection was established between the guided inquiry orientation and the instructional strategy chosen for the research lesson: the creation of a model. The teachers chose to invite the children to create a model that would "recreate the shadows formed at different times of the day" (LS2, TLP). The teachers envisaged how this task would enable the children to "communicate their understanding of the relationship between the shadows formed and the light source" (LS2, TLP). Brian believed the LS2 research lesson would facilitate the children to describe their own thinking and enable them to avail of the key skills that the lesson aimed to support, "namely analysing, working scientifically, elaborating and inferring"

(LS2, Study Phase Reflective Log). This points to an opportunity to simultaneously promote both process and inquiry orientations. The teachers could have chosen to follow a teacher-directed approach through bringing a ready-made model to the classroom with which they could demonstrate the relationship between a light source and the shadows it forms. However, instead Brian described it as “very much a student-led lesson this time where the students are creating shadows and manipulating shadows” (LS2 Planning Phase, Meeting 5). The guided inquiry approach of LS2 emphasised the teachers’ willingness to shift away from teacher-centred approaches to science and instead afford the children more autonomy in the classroom.

The role of the teacher as a guide or facilitator of students’ investigations is a key feature of guided inquiry. The teacher is available to support students, for example, through discussing the approach they have selected for their investigation before they commence, or through practical measures such as the provision of resources. For instance, the LS2 TLP (Appendix Q) records that the teacher would “provide the children with the materials they need[ed]...and encourage them to create the model in pairs”. The teachers also discussed how they would support the children to critically analyse their models, wondering “how are we going to get them to stop moving the light source (representing the sun) and start moving the model (representing the Earth)?” The TLP included guiding questions from the teacher to address this issue: “How accurate is our model to what’s happening in real life? Is the sun really moving across the sky? What do you know about how the Earth travels in space?” In this manner, the lesson supported the children to reach their own conclusions as to the accuracy of the model they created.

Caroline noted that in the guided inquiry approach “the role of teacher was more of a facilitating role and I enjoyed this change”. She viewed it as beneficial that “the

children were able to get involved and excited about what they were discovering as opposed to being told what was going to happen and why” (LS2, Planning Phase Log). This indicates a change from Caroline’s previous teaching style of “Everyone, follow me”, in the manner of confirmation inquiry, prior to LS. Michelle also reflected on the role of the teacher during guided inquiry in the LS2 Post-Reflective Meeting. She commented that “the teacher scaffolding was so important for them”, and observed that Caroline, as the research lesson teacher, “made such a difference” in guiding the children she observed during the lesson. Michelle explained that Caroline had reminded the children “about labelling the shadows with the times” which “they had never even thought of” before she came over. It would appear that the teacher continues to play a key role in supporting children’s learning during guided inquiry, even though the focus is more on children’s autonomy when compared to confirmation inquiry and structured inquiry. García-Carmona et al. (2017) note that some kind of guide or scaffold in IBSE is always of help to participating pupils.

Ultimately Brian highlighted his appreciation of a guided inquiry approach when he declared “this was a wonderful lesson and the quality of the learning was truly impressive since the teacher was a facilitator for exploration” (LS2, Post-Lesson Reflection Meeting). He felt that the children viewed the lessons on light and shadows as more than “this random thing in the middle of the week”, noting that “they were invested in it...you just knew that there was an eagerness to...figure this out!” Caroline supported his assertion through her revelation that “it was something they looked forward to...they were asking me all week, when are we getting to do this?” In contrast, she stated that such levels of student enthusiasm had “never happened before” with her science lessons. Brian and Caroline’s comments echo the work of Ellwood and Abrams (2018) who found that students learning through IBSE approaches experienced positive

academic and motivational gains. Ellwood and Abrams (2018) noted that student motivation and achievement outcomes were elevated when students were given opportunities to act like scientists with the inclusion of critical discourse, debate and social interactions including peer review. They advocated a shift from an IBSE continuum that progresses from teacher-directed to open inquiry to a continuum that focuses on fostering opportunities to more authentically act like scientists. Darren also advocated the guided inquiry orientation promoted during LS2. During the LS2 Focus Group he stated that “a lot of people would enjoy teaching science more if we had lessons like this”. Bernard et al. (2015) also found an increase in the number of Polish secondary science teachers who preferred IBSE methods to traditional methods of teaching after participating in 33 hours of CPL based on IBSE.

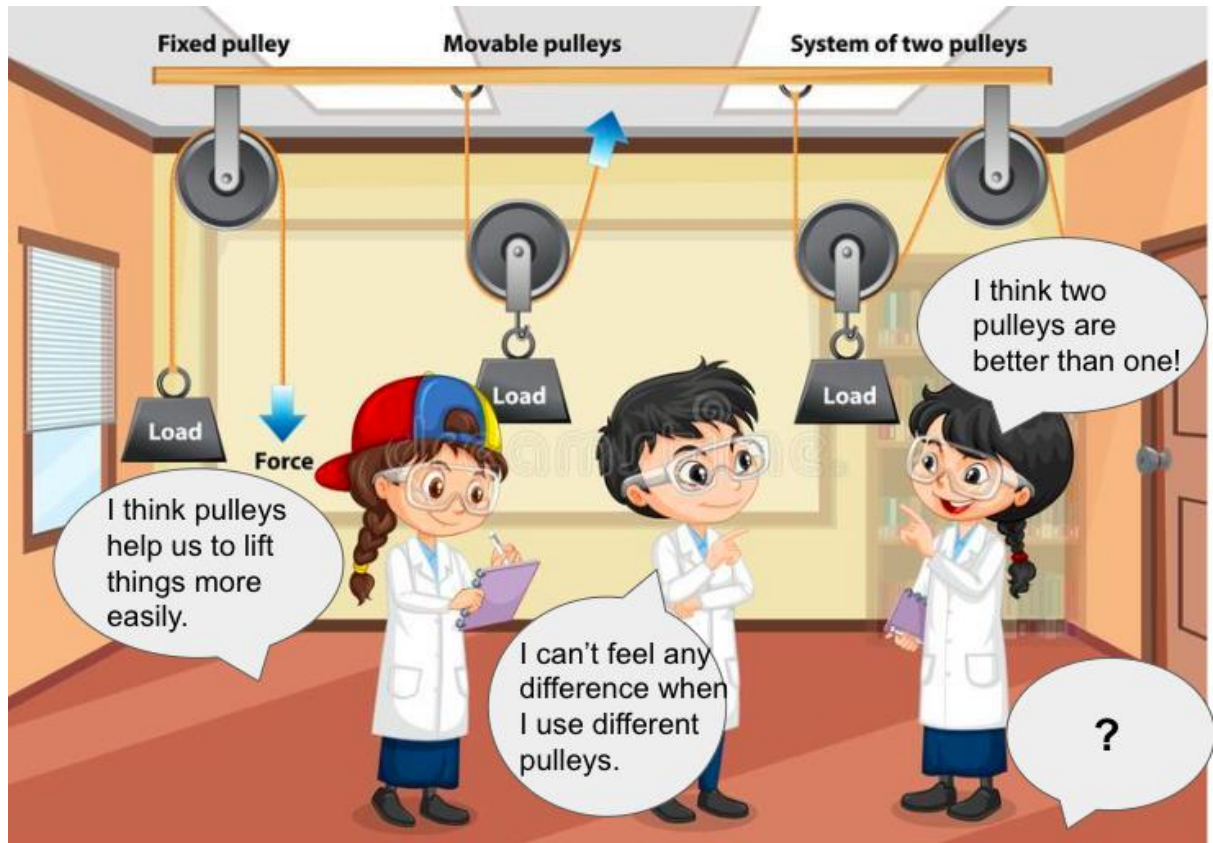
The guided inquiry orientation to teaching science identified in LS2 data re-emerged in LS3 where the focus was on pulleys. One manner of promoting this approach was through the teaching strategies the teachers utilised. In LS1 and LS2 the teachers had consulted premade concept cartoons (Naylor & Keogh, 2001) when exploring the topics of falling objects and light themselves during the Study Phases. They subsequently used them to inform the design of structured inquiries with the children. Naylor and Keogh (2012) describe how they created concept cartoons in 1991 as a strategy to elicit learners’ ideas, challenge their thinking, and support learners in developing their understanding. They list opportunities for argumentation, adjudication, cognitive conflict, formative assessment, development of higher order thinking skills, addressing misconceptions and increased motivation and engagement as some of the benefits of using concept cartoons with students. Naylor and Keogh (2012) assert that concept cartoons support teachers to promote constructivist teaching

approaches, develop pedagogical subject knowledge and make changes to professional practice.

In LS3, the teachers created their own concept cartoon for their final research lesson, a guided inquiry. This is of significance as the varying ideas proffered by the concept cartoon below were based on the teachers' anticipated student responses. They had developed an understanding of the anticipated student responses as a result of the ideas the students had shared in earlier lessons on pulleys (LS3, Planning Phase, Meeting 10). The teachers aimed to use the concept cartoon as the basis of a problem the children would solve through guided inquiry in the research lesson: identifying which pulley system was most efficient for lifting a 1kg weight. The concept cartoon is shown below in Figure 5.2. The aim of the concept cartoon was to support the children in articulating their thinking before comparing three pulley systems (fixed, movable and compound) for their efficiency in lifting a 1kg weight. The concept cartoon shared three ideas "I think pulleys help us to lift things more easily", "I can't feel any difference when I use different pulleys" and "I think two pulleys are better than one!" One blank speech bubble was included so that the children themselves could make their own suggestions, independent of those offered (LS3, Planning Phase, Meeting 6).

Figure 5.2

Concept Cartoon created by the teachers for LS3 Research Lesson (blueringmedia, 2022)



This would indicate that by the end of the LS process the teachers had increased their knowledge of this particular tool for teaching science and developed their confidence sufficiently to design and utilise their own concept cartoon in the classroom. It was included in their guided inquiry approach to compound pulleys by providing the children with ideas which they could then discuss in advance of comparing fixed, movable and compound pulleys. A wider knowledge of concept cartoons, developed during LS1 and LS2, supported the teachers to design their own in LS3. This enhanced their guided inquiry approach to science in the classroom through the inclusion of anticipated student responses, gained from earlier unit lessons, as the content of the

concept cartoon. The children used the concept cartoon as a stimulus for sharing their ideas and as a starting point for comparing the different pulley systems.

The guided inquiry approach was also revealed when the teachers introduced the term “compound pulley”. The teachers explored the children’s understanding of compound words as two words joined together as a stimulus for exploring a system of two pulleys working together. Michelle had suggested that we would “probably have to scaffold them” at that point of the research lesson, by reminding the children that they had made a fixed and a movable pulley, and if a compound pulley has two parts could they figure out “what might the two parts be?” (LS3, Planning Phase, Meeting 9). Subsequently, the children were encouraged to “have a go at creating a system where you have two different pulleys in it” independently. The independent approach to creating the compound pulley system aligned with a guided inquiry approach whereby the children used their own ideas as the basis for planning and carrying out the investigation.

Open Inquiry

An open inquiry orientation, wherein children propose and pursue their own question or problem did not form part of the LS research lessons. However, the orientation was evidenced in the LS1 unit plan designed by the teachers. The follow-up lesson to the research lesson envisaged the children investigating “questions they developed about paper spinners in the previous lesson”. The children had identified these questions at the end of the research lesson. Caroline’s observation notes record that the children she observed wished to “create a spinner out of plastic”, and wanted to investigate what would happen if they changed the wings “into a triangular shape and have them overlapping like a flower”. Although this follow-up lesson was not

observed by the group, it indicated an interest on the teachers' part in expanding from structured inquiry to open inquiry.

Summary of Inquiry Orientations

It can be seen that LS supported some teachers, such as Caroline and Darren, to shift away from confirmation inquiry, as had been their wish at the outset of the process. Instead, they utilised LS to collaboratively design and implement structured inquiries and guided inquiries in the classroom. For other teachers, such as Brian and Michelle, LS confirmed their prior orientations of affording opportunities for child-centred inquiry, such as guided inquiry. At the same time, all teachers agreed that whatever type of inquiry was pursued in the classroom, the role of teacher as guide is of critical importance.

5.2.4 Unstructured Exploration Orientation

Participation in LS1 reinforced Brian's existing unstructured exploration orientation to teaching science. He noted in his Study Phase Reflective log that his desire to give children the "freedom to explore, to question and to wonder" had been "reaffirmed as a result of our group discussions". This was compounded during the Planning Phase when he wrote how LS reaffirmed for him that "in order for science to be absorbing and engaging, enjoyment and wonder are essential". He stated his belief that we should "allow the students to take the lesson down unexpected routes". On the other hand, Caroline's participation in LS1 led her to question her previous approach to teaching science, noting in her Study Phase Reflective Log that her views of teaching science had been "challenged considerably" by LS1. She was critical of how prior to LS her method of teaching science was "based on a very step-by-step approach, with not much freedom for the children to explore and investigate for themselves". This

demonstrates how LS led Caroline to become critical of her reliance on teacher-directed approaches.

Caroline questioned if she “didn’t give enough credit to my younger classes and the ideas they could have produced, had they been given more time and independence to explore and discover?” as a result of LS1. This connects to the findings of Khokhotva (2018) and Samaranayake et al. (2018), whereby teacher participants noted that LS led them to develop an awareness of how their students were more capable than they had given them credit for. Khokhotva (2018) also found that teachers had underestimated the capabilities of lower-achieving pupils in particular. Caroline’s comments suggest that LS1 made her consider the inclusion of more student autonomy in her approaches to teaching science.

This shift toward an unstructured exploration orientation as a result of LS1 transferred to LS2 when Caroline revealed that she had maintained her new approach of “Here are your materials, figure it out” during science lessons in the interim between LS1 and LS2 (LS2, Study Phase, Meeting 1). In contrast, she noted how before LS1 her lessons were characterised by her former approach of “OK here’s how you do the experiment, Step 1: Everyone follow me. Step 2: Everyone follow me”. Once again this represents a shift away from teacher-directed approaches to primary science, as a result of her participation in LS. In terms of value creation, it would indicate that the immediate value Caroline associated with unstructured exploration as a result of LS1 flowed from this experience into her teaching of science outside the intervention.

Caroline believed that an unstructured exploration orientation encouraged the children to be “really invested in trying to get it done”, which she felt “doesn’t happen...for the teacher-led experiments as much” (LS2, Study Phase, Meeting 1). This

orientation influenced Caroline later on in the Study Phase, when considering potential activities for the children. She observed that there were “loads of things that you could let them off to do” (LS2, Study Phase, Meeting 2). She envisaged an approach to science teaching and learning whereby “it’s not the teacher doing all of the teaching”. Similarly, Brian expressed his view that “a great deal of the instruction should centre around firstly ‘playing’ with light” (LS2, Study Phase Log). He asserted that “rich conversations need to be created and this can only be achieved if the students are afforded the autonomy to explore, unencumbered by the teacher’s own understanding of light or hopes for the lessons”. This would suggest that he concurred with Caroline on the importance of unstructured exploration as a means to promote student-led learning.

Caroline’s desire to promote unstructured exploration in the classroom, as a result of LS1, rose to prominence in the LS2 unit plan. She suggested that for the first lesson she “thought it would be nice...to do an unstructured investigation first, where you just let them off with all the materials and the torches, and see what [they] can figure out” (LS2, Planning Phase, Meeting 4). This was reiterated during the later stages of the Planning Phase, as the Research Lesson itself was teased out. Caroline believed that “it’d be interesting to let them off and see what they come up with themselves” (LS2, Planning Phase, Meeting 5). Her interest in unstructured exploration as a result of LS1 transferred into classroom practice during LS2. This also occurred after she herself experienced unstructured exploration of light materials at the end of Meeting 2 with the other teachers, an event which they all agreed was “really important” during the LS2 Focus Group discussion.

Caroline reaffirmed her interest in promoting an unstructured exploration orientation to teaching science in LS3. Her Study Phase Reflective log notes that the group thought “it would be interesting to allow the children to explore the materials themselves when constructing their pulley systems as opposed to being told where everything should go”. She believed that “this would really give the children the opportunity to work as scientists”. Her comments align with the unstructured exploration approach to teaching science through a focus on affording the children freedom to explore for themselves. They also demonstrate a connection between the teachers’ orientations and the instructional strategies they utilised.

The teachers’ desire to facilitate a child-centred unstructured exploration approach to learning, identified during the LS3 Study Phase, was also evident in the lessons they designed during the Planning Phase. While discussing one of the early lessons in the unit plan, Brian commented how the children were given “a lot of freedom” which he thought was “brilliant” (LS3, Meeting 8). Caroline responded that she didn’t “like telling them stuff, because it is fun when they figure it out”. This marks a stark contrast between Caroline’s approach to teaching science prior to LS, as noted earlier in the findings when she described how she previously employed a “Step 1, Everyone follow me. Step 2, Everyone follow me” orientation to teaching science.

Ultimately the importance of the unstructured exploration orientation to the group culminated in this approach having a central role in the final research lesson, which involved the students investigating compound pulleys. It was planned that Brian, as teacher, would say to the class “I’m going to give you two pulleys and I’m going to ask you to see if you could use them to make a compound pulley. I’m not going to tell you what that looks like” (LS3, Meeting 9). This highlights the importance of the unstructured exploration approach to the teachers. They based their final research

lesson on a child-led task, whereby children explored materials independently in order to create a new pulley system. This in turn connected to one of their assessment goals, whereby they aimed to “assess whether children can create a compound pulley independently (no visual aid) or need a diagram for support (LS3 TLP). On the other hand, LS1 assessment goals reflected the structured inquiry design of the lesson, whereby the children analysed the data they gathered following teacher direction. As LS progressed from LS1 to LS3 Caroline and Brian’s efforts to promote more child-centred orientations such as unstructured exploration increased. It would appear that this development took place alongside Caroline’s transition from teacher-directed inquiry to more child-centred guided inquiry. This aligns with Harlen’s view that teachers starting out in active practical learning may need structured activities with their students before they proceed to open-ended inquiry (2012).

5.2.5 Summary of the Development of Teacher Orientations

Before the commencement of LS the teachers described their ideal orientations to teaching primary science as incorporating a culture of problem-solving, independent learning, imaginative inquiry and perseverance, alongside the development of scientific skills. Their actual classroom practice prior to LS was varied, with Brian and Michelle already viewing themselves as facilitators of skills development and child-led exploration. LS confirmed these approaches to the teaching and learning of primary science as preferable to them.

In contrast, Darren and Caroline followed a more recipe-style, confirmation inquiry approach prior to LS. Their experiences of LS appeared to have led to a shift in mindset towards more child-centred inquiry. In LS1 this manifested in a structured inquiry, whereby the teacher directed the process of dropping paper spinners but the

children analysed their own observations of what happened when they dropped the spinners. In LS2 child-centred inquiry progressed further to afford the children more autonomy through unstructured exploration of creating shadows with torches early in the unit plan, and the creation of a model through guided inquiry, to explore shadows created outside on a sunny day in the research lesson.

As part of providing the children with more agency through unstructured exploration and guided inquiry orientations, the teachers observed progression in their ability to persevere in the face of challenges. Whereas they suggested the children were “impatient to work things out” before LS (LS1, Meeting 1 notes), they shifted to displaying an eagerness and persistence to “figure out how it was done” for themselves by the end of LS3 (Focus Group).

The process orientation, whereby students are engaged in hands-on activities that support them in developing and applying science skills, was prevalent across all three LS cycles. The process orientation evolved from LS1 to LS3. It began with a focus on specific science skills in LS1 (predicting) and LS2 (analysing and communicating). However, by the end of LS2 the teachers had expanded their process orientation from focus on individual skills to the development of numerous scientific skills simultaneously. This method of applying a process orientation whereby several skills were emphasised together continued in LS3.

Overall, it would appear from the data that LS contributed to the development of the teachers’ preferred orientations to teaching science: process, unstructured exploration, and inquiry-based approaches such as structured and guided inquiry. In terms of the Value Creation Framework it would seem that a learning loop (Wenger-Trayner & Wenger-Trayner, 2020) was created by LS. The teachers identified their

preferred orientations at the beginning of LS, developed them through the process and gained an understanding of how to implement their ideals when teaching science. Through reflecting on the LS process they were afforded the opportunity to confirm their adherence to their preferred orientations, thus completing the learning loop. Findings suggest that teachers can have multiple orientations towards teaching science, as stated by Magnusson et al. (1999), and that these multiple orientations can co-exist and develop simultaneously. The process was deemed very positive by all of the participant teachers. Indeed Caroline encapsulated her experience by stating she felt it had “definitely made me think about how I teach science in the best possible way”. (LS3, Focus Group).

5.3 Development of Teachers’ Subject Matter Knowledge

Murphy et al. (2023), as part of a systematic literature review of learning in primary science education, note that there are concerns regarding teachers not having sufficient science conceptual knowledge to effectively implement curricula or to address children’s naive scientific conceptions. Indeed, one of their recommendations is that “longitudinal professional learning opportunities to support teachers in developing their science content and pedagogical knowledge must be made available” (p.10). Data gathered during the current research study highlights the positive effect LS had on the development of the teachers’ content knowledge or Subject Matter Knowledge (SMK), as outlined below.

5.3.1 LS1

The scientific concepts chosen for each LS cycle reflected areas of the curriculum that the teachers lacked confidence in teaching, due to self-identified

deficiencies in SMK. Brian described how “as the teacher, the single entity in the room, there is often the presumption of knowing seer”, suggesting that he felt he was perceived as the source of scientific knowledge in the classroom. In contrast, he felt “the reality is often very different” (LS1 Study Phase Reflective Log). Similarly, Anna observed that LS1 gave her “an opportunity to re-evaluate my knowledge and understanding of [science]”. It would appear that LS1 led Brian and Anna to consider their own SMK in relation to science.

The theme of falling objects, selected for LS1, was identified by the teachers as an area of the curriculum they found challenging to teach (LS1 TLP). The TLP (Appendix P) reports how “we would like to develop our own scientific content knowledge in this area of the curriculum”. The teachers observed that “shortcomings” in their own SMK of gravity and falling objects made it a “challenge to support student learning and answer children’s questions on this theme”. For example, during LS1 Meeting 3, Brian shared how he “still couldn’t explain how gravity works...couldn’t answer the children’s questions...[didn’t] have good scientific knowledge on this [topic]”. Michelle concurred that gravity is a “difficult topic”. At the end of Meeting 3, it was agreed that the teachers would research gravity themselves online, in advance of Meeting 4, in an effort to develop their own SMK.

Despite this research, Brian restated at Meeting 4 “how little [he] knew” and that “if [he] had to teach about gravity tomorrow [he] couldn’t explain what it is”. Similarly, Michelle noted how, after researching online, some “things were throwing [her]”. For example, she stated that she understood how objects fall at the same speed in a vacuum, but “that’s not Earth so that’s a problem for me”. Anna shared that the Study Phase challenged her to “address any hang-ups or uncertainties” she had with regard to gravity (LS1 Study Phase Log), although she did not specify what they were.

Michelle recorded in her personal Teacher Participant log after the meeting that “the concept of gravity appears to be challenging for all of us”. She questioned if “this lack of confidence/doubts about our own conceptual understanding make this a daunting topic to cover?” The LS1 TLP, reflecting the views of the group as a whole, confirmed that “we supplemented our initial study materials with additional explainer videos from YouTube but still felt that our conceptual knowledge was lacking which made us reluctant to pursue [gravity] for our research lesson”. It is evident that, despite spending time researching gravity during the Study Phase, the LS teachers still perceived gaps in their own SMK, which made them hesitant to teach about gravity in the research lesson.

At any rate, consideration of the PSC (DES, 1999a) during the LS1 Study Phase led the teachers to become aware that the term “gravity” is only included in the learning objectives for 5th and 6th classes.⁷ The TLP noted that since “our focus is on 3rd class⁸ we are choosing to investigate falling objects as per the 3rd and 4th class guidelines”. The teachers believed “this also enables us to avoid a concept where we lack confidence”. Subsequently they “decided to switch [the] focus to air resistance as we feel more confident about this rather than gravity, also it may be more appropriate for 3rd class”. This highlights a link between developing teachers’ SMK and their ability to support children’s learning in the classroom. It could be inferred that if teachers do not have the requisite SMK themselves on particular science topics it is very challenging for them to teach them in the classroom, which could lead to avoidance, as in this case.

⁷ The final two years of primary school in Ireland, generally children aged between 11 and 13 years old.

⁸ The fifth year of primary school in Ireland, comprised of children who are, on average, 9 years old.

As part of their focus on air resistance (a frictional force that opposes the movement of an object through the air), the LS teachers included some of the PSC (DES, 1999a) learning objectives for forces at 3rd and 4th class level in the TLP. They aimed for the children to “explore how some moving objects may be slowed down” and to “investigate falling objects”. This developed into the research lesson whereby the children dropped paper spinners in various positions, predicting what would happen, observing what did happen and attempting to analyse and explain what they observed. One of the research lesson objectives was that “children would recognise that air causes the paper spinner to slow down as it falls” (LS1, TLP), connecting to the scientific concept of air resistance. This aligned with one of the assessment objectives whereby the teachers would determine “whether or not the children can interpret that air is a slowing down force” (LS1, TLP). They developed a research lesson with clear learning objectives and assessment objectives based on the topic of air resistance which they had earlier identified as a theme they were confident to teach.

Prior to the mock lesson, the LS teachers followed the structured inquiry of the research lesson themselves. This happened on an individual basis due to the Covid-19 lockdown restrictions. Brian reflected on the impact of trying out the paper spinner activities himself, and observed that when he tried the activities for himself the “learning and the acquisition of skills seemed to be more easily achieved” (Planning Phase Reflective Log, LS1). Experiencing the structured inquiry for himself gave Brian an insight into how the paper spinners would fall on each occasion, thus connecting to his own SMK of falling objects and air resistance in advance of the lesson. It also supported him to gain an understanding of how the students would experience the approach designed by the teachers. He believed conducting the inquiry himself allowed

him to “actually focus on the enjoyment, the wonder and the discovery elements of the teaching and learning” which he deemed “very helpful”.

However, he also shared his view that “it would have been easier if we had sat around a table and made them together” (LS1, Planning Phase Reflective Log). He believed such collaboration “would have led to more discussion about the size, shape, nature and design of the spinners” whereby the teachers could “have made lots of prototypes and this would have been much better before trialling the lesson with other teachers”. It is clear that Brian found it beneficial both in terms of his own learning and his preparedness for the classroom to have engaged with the research lesson activities himself in advance. At the same time, he felt Covid-19 restrictions negatively impacted his experience, by enforcing solitary rather than collaborative exploration of the paper spinners.

Unfortunately, LS1 Post-Lesson Reflection Meeting notes record that as the research lesson was “too long”, there was “no time to go into analysis of air as a slowing down force”. However, Caroline did observe how “a few of [the children] mentioned air in their predictions”. She described how one child predicted “the air is going to catch [the paper spinner]” and how since she was an observing teacher she “was dying to ask [the child to explain] but didn’t”. Caroline concluded the child “did have knowledge of what was happening” in terms of air resistance slowing the spinner down as it fell. Overall, it would appear that the teachers’ believed they did not sufficiently develop their SMK of gravity to have confidence in teaching this topic at a 5th and 6th class level. However, they were comfortable to focus on falling objects and air resistance, as per 3rd and 4th class objectives. Their own understandings of the role of air in slowing down the paper spinners were included as lesson aims, however the lesson was too long for this aspect to be explored with all children, aside from those who mentioned air

themselves in the earlier stages of the lesson. Further discussion of the impact of LS on children's learning will take place in the final section of this chapter.

5.3.2 LS2

The theme of light and shadows was selected for LS2 based on the teachers' desire to improve their own SMK, in a similar manner to LS1. Caroline revealed at the first meeting that she "wasn't overly sure of the topic" and although she had covered the topic with the class prior to LS2, she felt she "didn't have enough information to give [the students]". Brian concurred that he too perceived light as a "difficult concept", revealing that "light travelling from the sun to Earth and all that, I don't know how to explain that". During Meeting 2, the teachers discussed what they had discovered while studying light themselves. Caroline shared how she had "no idea" prior to LS that "colour is light being reflected as opposed to absorbed". This would indicate that the LS Study Phase led to an increase in her SMK with regard to light in general.

Data from LS2 demonstrated the importance of the teachers experiencing an unstructured exploration orientation for themselves as a means to develop their own SMK in advance of teaching the children about light and shadows. The teachers examined the school's light resources as a group at the end of Meeting 2, in what they described as a "play session". Brian and Michelle explored shining light through a coloured filter, finding that only the colour of the lens itself passed through. They also discovered that when they layered two filters of the same colour, the light that passed through was a deeper shade than one filter alone. Caroline asked them to mix colours and they discovered that the light created was a combination of the two, for example when they layered blue and red filters the light which passed through onto the wall was purple. The resulting comments of "wow!" and "that's cool" indicated a novel

experience for the teachers, an increase in their conceptual understanding of the passage of light through colour filters, as a result of the LS2 Study Phase.

Darren and Caroline examined the light produced by different sources such as torches and phones. Afterwards, Darren, with his background as a science graduate, explained to the rest of the group how the torch bulb was surrounded by a reflective surface, like a mirror, which caused the light to disperse. He demonstrated how, through making a hole in a paper cup, and shining the torch through it, it was possible to concentrate the light from the torch. Michelle later informed Darren, “that thing you did with the cup, I would have never known that, to focus the light”. Similarly, Caroline informed Darren how he had “looked at the torches, and [said] there’s a mirror there. And I was like, there’s a mirror there?! I had no idea” (LS2, Planning Phase, Meeting 5).

The LS2 TLP noted that the aim of the “play session” was “to enhance our own understanding and simulate what the children might discover”. As a result, the teachers “were able to pre-empt the questions the children might ask”. It also enabled them “to bolster [their] own confidence and test out materials prior to discussing the lesson goals and targets” they hoped to achieve in the classroom. It is clear that developing their own SMK through the LS “play sessions” was beneficial to the teachers in terms of their own understanding of light and shadows, their understanding of students’ preconceptions, and their ability to design relevant classroom activities.

During the LS2 Study Phase the teachers also consulted online educational videos on light and shadows (Smithsonian Science Education Center 2020a; 2020b; 2020c; 2020d; 2020e). The videos appeared to support the group with instructional strategies for teaching the topic due to their “practical nature” (Brian, LS2, Meeting 3).

On the other hand, conversations around their content also appeared to increase the SMK of some teachers. For example, Caroline shared how she “hadn’t copped” that moving the torch (representing the Sun) was not an accurate representation of what happens in reality, “until Brian said it” (LS2, Meeting 3). She then expanded this development of her own understanding into an idea for classroom practice, suggesting “it’d be nice to even have that as say a puzzle for the kids...it’d be nice to kind of say, well, you know, is the torch moving? Is that accurate? Is that the Sun? Does the Sun move?” Ultimately, the final research lesson activity involved “encouraging the children to relate what they’ve seen to everyday life - the Sun isn’t moving, we are!” (LS2 TLP). This indicates that Caroline’s increased understanding of the Earth’s rotation around the Sun, and the subsequent variation in shadows created at different times of the day, transferred into an opportunity for student learning as part of the research lesson.

In a similar manner to Caroline, Brian, having watched the Smithsonian Science Education Center videos, commented how “you know how your shadow goes from long to really short to long again? It makes sense but I didn’t know that” (LS2, Study Phase, Meeting 3). This indicates a development in Brian’s conception of shadows as a result of the LS2 Study Phase. In keeping with that theme, Caroline then suggested that it would be “cool” to compare the shadows created by the Sun “at different times of day”. This eventually developed into Lesson 3 of the unit plan, where Caroline gave a diagram of the back of the school to each pair of children, who then took photographs from the same position at given intervals, recording both where the Sun appeared in the sky and the corresponding shadows created by their bodies. The teachers were then able to assess the children’s conceptual understanding of the shortening of shadows from morning towards noon and, conversely, their lengthening afterwards towards evening.

Their findings will be outlined in the following section on children's learning. It would appear that the Study Phase resources expanded some of the teachers' own knowledge of shadows, such as Brian. They then utilised this increased understanding as the basis for some of the investigations they planned for the children.

Brian later commented in LS2 that "it's difficult to navigate their inquiries when you don't know the underlying concepts" (Meeting 5), in response to Caroline's revelation that when she had taught light previously she "didn't understand it" which meant she "wasn't sure how much [the children] had actually learned from it". This connects to the finding of Murphy and Smith (2012) that a very high percentage of pre-service teachers revealed inaccurate understandings of forces and electricity, with many holding similar inaccurate conceptions to children.

The teachers believed that developing their own SMK during the Study Phase had a positive impact on their knowledge of instructional strategies for light and on their ability to promote a culture of exploration for their students. While reflecting on LS2 Brian commented that "it was great to be able to 'play' with the resources" as this supported the teachers to "understand which resources were superfluous and which resources might actually offer an authentic exploration of the topic" (Planning Phase Reflective Log). Darren noted that the Study Phase was "really important" and that it "definitely informed a lot of things that we ended up planning" (Focus Group Interview). Brian and Darren's comments show that through exploring resources pertaining to light themselves during the LS2 Study Phase, they widened their knowledge of how to teach light in the classroom. This would appear to correlate with Khokhotva (2018), who found that participation in LS led to an increase in teacher knowledge of new strategies and methods of teaching.

5.3.3 LS3

In a similar manner to LS2, there was a direct connection between the teachers' experience of unstructured exploration of pulleys and an advancement in their own SMK in LS3. Indeed one of the reasons the teachers chose to focus on pulleys was due to their own lack of SMK. The LS teachers recorded this issue in the LS3 TLP, citing that "a direct consequence of lack of confidence in our own knowledge of pulleys impacts on our ability to teach the concept". Indeed the TLP states that the teachers were "actively avoiding the topic" prior to LS3. Brian revealed that he was "intrigued" by pulleys because he "wouldn't know an awful lot about them" (LS3, Meeting 3) which Caroline and Michelle agreed with. As the teachers initially explored making pulleys themselves during the Study Phase (Meeting 3) it was obvious that they lacked the conceptual knowledge to do so. For example, Michelle asked "what do we need for our pulley?", to which Caroline responded "I don't know" (LS3, Meeting 3). While Brian struggled to set up the school's sole example of a pulley (a three-sheath system) he observed that "this wasn't as successful as I thought it was going to be". Brian summarised the group's collective lack of knowledge of pulleys as a "real problem" (LS3, Meeting 3).

The teachers finished LS3 Meeting 3 without any increase in their own understanding of pulleys. Michelle commented that "[she] felt leaving [Meeting 3] that [she] hadn't a clue about pulleys" (LS3, Meeting 4). Subsequently, the teachers spent time researching pulleys themselves in advance of Meeting 4, which itself was another "play session". Michelle noted that before the meeting she "felt [she] had to do some study on [her] own", and had found a Discover Primary Science (n.d.) webpage Caroline had uploaded to the shared folder "very helpful". Michelle described how it showed examples of fixed and movable pulleys and concluded that there was "probably

a lot in this [Discover Primary Science page] that we possibly will use”. Subsequently the page was consulted as the group created fixed pulleys firstly by using a rolling pin and then using a commercial pulley.

Caroline reflected on the rolling pin pulley activity by stating “when we started it with the two chairs on the ground, it wasn’t really feeling much of a difference. Then when we moved [the rolling pin pulley system] on top of the table, that was brilliant” (LS3, Meeting 4). The LS teachers concurred that the rolling pin activity would make a “good intro lesson”, in other words a suitable first lesson in the unit plan. Caroline believed that would be “a nice handy one because it was literally just over the rolling pin and back, and there wasn’t too much fiddling about with it”. She felt such an introductory lesson could be used as a stimulus for the children to “figure it out, like we did, with the pulleys and everything else after that”. It was agreed that for the second lesson the “real” fixed pulley would be introduced since it was “kind of the same thing: the rolling pin is fixed, that little [commercial] pulley is fixed, and gravity is helping you” (Researcher, LS3 Meeting 4). It would appear that the development of the teachers’ own SMK in relation to pulleys transferred into the style of unit plan they designed for the children.

Following the creation of fixed pulley systems, the teachers advanced to setting up a movable pulley, guided by the same Discover Primary Science (n.d.) page. They concluded their explorations by making a compound pulley system consisting of a fixed pulley and a movable pulley. These activities converted into the final two lessons of the unit plan, once again linking an increase in teacher SMK with their ability to plan appropriate classroom activities for the students. Caroline believed it would be “nice to have the movable one on its own first where you have to pull up and then to put the two of them together it would be like - wow that is so much easier”. This corresponded to

the reaction of “wow” when the teachers first created a compound system, confirming “what I kept reading, the more pulleys you have the more impact that has on the [less] force you need” (Michelle, LS3, Meeting 4). At the end of Meeting 4 Michelle commented how “I feel like I have a much, much better grasp of this now than two weeks ago”, to which Brian replied “Oh my God, infinitely better”. Their exchange underlines the progression in their SMK of pulleys as a result of the LS3 Study Phase.

The LS teachers used the insights gained during their own exploratory “play sessions” with pulleys in the LS3 Study Phase to guide the design of their lesson unit during the Planning Phase. Brian recalled how the group “watched videos, played with virtual manipulatives, examined pictures, found working examples in the local environment, created and played with pulleys”. He described these activities as “enormously helpful since the focus was a playful learning experience for us as teachers” (Study Phase Reflective Log). Directly after investigating pulleys themselves, they agreed on the content of the unit plan based on what they had “personally learned” (Caroline, LS3 Meeting 4). They aimed for students “to understand that pulleys help us to lift things and that you can have different types of pulleys, like fixed and movable. But then if you combine them together into a compound, that actually that one is the best of all for lifting”. (Michelle, Study Phase, Meeting 4). The teachers utilised the conceptual knowledge of pulleys they developed in the Study Phase to design the unit plan they would present to the students.

The teachers’ expectation that experiencing an exploratory approach to learning about pulleys themselves would support them to understand their students’ thinking was borne out during the early lessons of the unit plan. After the introductory lesson on pulleys, Brian observed that “it was so interesting that they had similar gaps in their knowledge that we had” (Planning phase, Meeting 8). This underlines the importance

of affording teachers the chance to engage with scientific topics themselves, in order to develop their own SMK before teaching a topic to their students. In addition to developing their own knowledge, they are also better prepared to “predict the types of questions/responses” their students may have, as noted by Caroline in her LS3 Study Phase Reflective Log.

It could be argued that it is challenging for teachers to promote their desired approach to teaching science if they are lacking the conceptual knowledge themselves to do so. A link was established between the development of teachers’ SMK through their own inquiry-based approach during the LS Study Phases and a knowledgeable expectation of what students might experience during the lessons. Caroline believed that LS had been “a learning curve” for her, and “it would be for the kids also” (LS3, Planning Phase, Meeting 5). Michelle observed that since “we did it now ourselves, we kind of will know what to expect” during the student lessons (Planning Phase, Meeting 5). This suggests a connection between teachers’ conceptual understanding of science topics and their ability to support children’s learning in the classroom. Similarly, Smith (2014) found that when teachers experienced the same content, methods and activities that their pupils were expected to learn in schools it enabled them to face problems they might face when teaching the content to the children in their classrooms. Smith (2014) also observed a “decisive improvement in teachers’ science content knowledge in all questions where there could be improvement” (p.477) at the end of the intervention. It would appear that the development of teachers’ SMK is crucial to supporting children’s learning in the classroom.

Overall, it would appear that engagement with LS as a CPL methodology afforded the teachers opportunities to develop their own SMK in relation to the topics of falling objects, light and shadows and pulleys. The characteristics of LS, with its

Study and Planning Phases, supported the teachers to take part in self-titled “play sessions” whereby they trialled the activities that the students undertook in the research lessons. This increased the teachers’ own SMK and gave them a set of realistic expectations of what might happen in the classroom, as well as a deeper understanding of how to design appropriate theme-based lessons. The development of SMK as an example of effect data, captured one of the overall effects of LS on participating teachers. Furthermore, when the teachers’ increased SMK was combined with their developing orientations towards teaching science, as outlined in the previous section, there was an impact on children’s learning. This will be the focus of the next section of findings below.

5.4 The Impact of LS on Children’s Learning

Wenger-Trayner and Wenger-Trayner (2020) observe that effect data capture the overall effects of a project in terms of its impact on team members and other stakeholders. The previous two sections focused on the team members, the LS teachers and the impact of the CPL on the development of both their orientations to teaching science and their SMK. The final section in this chapter focuses on the impact of LS on the children who participated in both the unit plans and research lessons, given their role as key stakeholders in the process.

5.4.1 LS1

Teachers’ observation records enhanced evaluation of how the research lesson supported the children to engage in prediction and explore falling objects such as paper spinners. The PSC *Science Teacher Guidelines* (DES, 1999b) state that “patterns that have been identified in observations or in investigations can form the basis for a prediction. Pupils make predictions to forecast what might happen in certain

circumstances” (p.19). Furthermore, the PSC outlines how the predictions of younger children (in infant classes and in first and second classes)⁹ will be prompted by the teacher, whereas older children (from third to sixth classes)¹⁰ pupils’ predictions should be based on previous experience or observations (DES, 1999b). Caroline recorded how a child she observed predicted the paper spinner would “glide” to the ground when dropped with its wings at the top. Caroline believed that the use of the word “glide” was “a very good description” since it suggested that “she thought it would move slowly to the ground and not just drop” (LS1, Observation Log). However, no reason for the child’s prediction was recorded so it would appear that she needed further support with developing this skill. Brian’s observation records state that the children he observed “struggled enormously to answer the why question”. The children appeared to find it challenging to ground their predictions in a rational basis. At the same time, their difficulties with giving reasons for predictions could be viewed as progression in their ability to predict. As one of the EKO’s commented at the LS1 Post-Reflection meeting, the child who struggled to give a reason didn’t “make a wild guess, he didn’t have the experience so he couldn’t give a reason why” which she described as “fantastic”. On this basis, shifting from guessing to predicting was viewed as progress in itself. The ability to give a reason for a prediction was viewed as a further advancement in knowledge, which some of the children had not yet acquired.

Darren’s experience prior to LS of children’s reluctance to predict “in case they’re wrong”, (LS1, Meeting 3) and Michelle’s assertion at the same meeting that children can tend to focus on whether their predictions are “right” were borne out in the

⁹ Junior Infants, Senior Infants, First Class and Second Class are the first four years of school in Ireland, generally comprised of children between the ages of 5 and 8 years old.

¹⁰ Third Class, Fourth Class, Fifth Class and Sixth Class are the fifth, sixth, seventh and eighth years of primary school in Ireland, generally comprised of children between the ages of 9 and 12.

research lesson. Anna described at the Post-Lesson Reflective Meeting how the girls she observed “both struggled to predict” at the start of the lesson with “lots of rubbing out” as they were “unsure of what to write” on their record sheet. She inferred that “maybe [they] didn’t want to give an answer in case it wasn’t right”. Caroline recorded how the child she observed predicted that the spinner would not spin at all when it was turned upside down and dropped with its wings at the bottom. Although Caroline stated that the child “watched” as the spinner did “right itself as it got closer to the floor and spun”, she “still wrote that the spinner did not spin at all”. In a similar manner to Anna, Caroline deduced that the child “wanted her prediction to be right”. This would suggest that these children required further support with predicting, in order to shift from focusing on prediction as a means of getting the “right answer”.



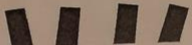
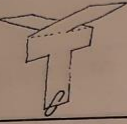
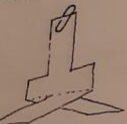
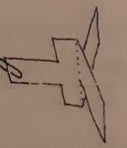
At the same time, the child predicted for the next activity (spinner turned on its side) that it would “spin a little at the end” which Caroline viewed as “interesting, considering her previous prediction”. Caroline inferred that although the child had recorded the spinner did not spin previously when it had, “she may have observed differently and used this knowledge to help her next prediction”. Caroline’s inference suggested that the child was using previous experience to assist with her predictions as the lesson progressed.

The children’s LS1 worksheets also enabled the teachers to evaluate how the lesson they planned and taught supported the children’s learning. In addition, they are an example of how the teachers’ orientations manifested in classroom practice. It is noteworthy that, when asked to predict what would happen during the second and third spinner drops, three children recorded on their worksheets that the spinner would spin “because last time it happened” (Figure 5.3 below). This showed a progression in some children’s ability to predict, and ground their predictions in observations. It therefore

would appear that the teachers' promotion of a process orientation had a positive impact on these children's understanding of prediction.

Figure 5.3

LSI Children's Record Sheet

Spinner Starting Point:	What I think will happen when I drop it: 	My reason for thinking this: WHY?  
Wings are at the top 	I think it will slowly fall down.	because here are wings on it
Wings are at the bottom 	I think it will spin	because last time it happind.
Spinner is turned on its side 	I think it will just drop down	because it will be on its side

“Because last time it happened” indicating child’s use of previous observations to predict what might happen next.

Darren noted in the Post-Lesson Reflection Meeting that he witnessed children who were reluctant to predict at first but then noticed that when “it twirled twice [already] they decided right, I think it’s going to twirl again. And they predicted based on what they had seen”. He also described a child who the first time “thought [the spinner] would fly because it had wings, second time [she predicted] it will fall to the ground instead because it’s the wrong way round, third time [she] predicted that it’s going to twirl”. He believed that for the final prediction the child “used her evidence”

which he found “very interesting”. Darren’s assessment of the students’ learning shows progression in some of the children’s prediction skills as a result of the LS lesson - their predictions were not wild guesses, they were grounded in observation, demonstrated in what they had seen “last time” in Figure 5.1 above. Caroline also observed progression in children’s ability to predict as the lesson progressed, in how they could relate their predictions to previous spinner drops, as noted above. This finding compares favourably with that of Murphy et al. (2011) that many older Irish primary students associated making a prediction with being similar to a guess. It suggests that by explicitly focusing on prediction and providing repeated opportunities for children to predict they can develop the ability to predict based on observation and/or experience, thereby disassociating predicting from guessing. Kruit et al. (2018) state that while both implicit and explicit instruction facilitate the acquisition of science inquiry skills, only explicit instruction had a positive effect on students’ abilities to apply these skills to new and unfamiliar topics.

The teachers described prediction as being difficult for both teachers and learners at the outset of LS1. Data suggest that it was still a challenge for some children after the research lesson. For example, Brian noted in the Post-Lesson Reflective meeting how he witnessed one child writing in a prediction after he observed what happened when he dropped the spinner. Just as the teachers benefitted from spending time during the Study Phase and Planning Phase building their own knowledge of prediction, it would seem that some of the students themselves required more engagement with lessons focusing on this skill. The research lesson indicated that it is necessary for teachers to spend time explicitly teaching scientific skills in order for a process orientation to transfer successfully into student learning. At the same time the science EKO commented at the Post-Lesson Reflection that when the overall theme of

working scientifically with its “main aim” of getting the children to practise their scientific skills was considered, the LS1 research lesson achieved this.

The research theme of encouraging “all children to work like scientists” with its focus on scientific skills, and prediction in particular for LS1, was dominant in the research lesson itself. Michelle, who taught the lesson, commented at the Post-Lesson Reflective meeting that she “[didn’t] think I ever mentioned working like scientists so much in my life, our overall theme was on my mind constantly which kept me focused”. Brian also noticed how she “continuously went back to it about the whole idea of predicting, and no prediction is right or wrong” and deduced that the children “certainly seemed to get that” (LS1 Focus Group). Furthermore he believed that “small one lesson...did have a huge impact, in terms of building their ability to predict and to be okay with their prediction”. Again, this would indicate that the research lesson did achieve its aim of developing the children’s ability to predict, in the manner of a process orientation to teaching science.

5.4.2 LS2

Caroline’s increase in SMK enabled her to support the children in her class in the earlier stages of the unit plan, before the research lesson. She reported how one child compared the light from a torch with the light from a phone and shared how the light from the torch could “spread” more than the phone. Caroline asked him to try and explain why this was the case, and as he examined the torch he asked her “are those mirrors in there?”, which she was able to confirm after Darren’s explanation during the teachers’ “play session”. The child subsequently concluded that “the light would be reflecting off the mirrors” in the torch. Caroline’s increased SMK of light, as a result

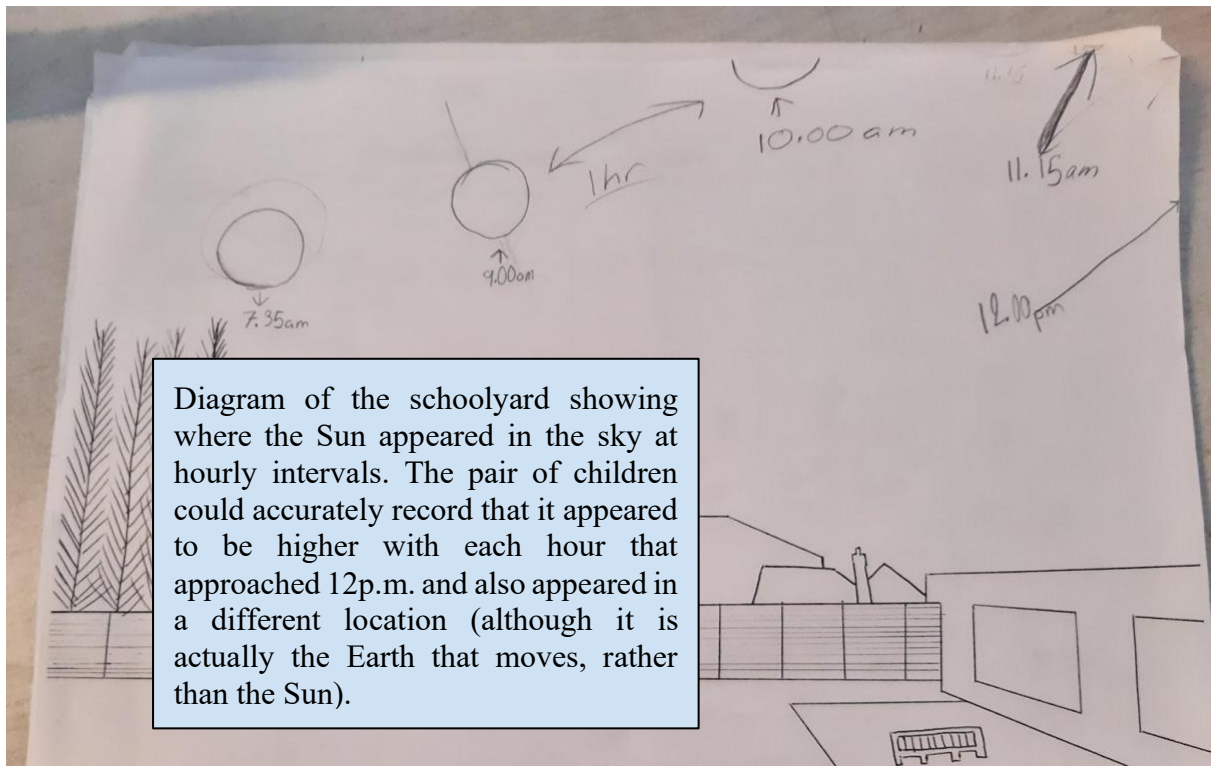
of the LS2 Study Phase, had a direct impact on her ability to support the child's learning in the classroom.

Structured inquiry formed the basis of some of the introductory lessons on light and shadows in the LS2 unit plan, in that the teachers decided in advance what procedure the children would follow. It was agreed that for Lesson 3 the children would “work as scientists to observe what happens to their shadow at different intervals on a sunny day”. As part of this exercise, they recorded where the Sun appeared to be in the sky at various times of the day on a diagram (shown below) and simultaneously recorded observations about the shadows created by their bodies at the selected times on an accompanying record sheet (also below). Samples of children's worksheets from LS2 facilitated the teachers' evaluation of how Lesson 3 had supported children's learning and also provided evidence of how the structured inquiry they pursued impacted on classroom practice.

The below diagram (Figure 5.4) shows how two children were able to record with accuracy where the sun appeared in the sky, based on their observations during the morning.

Figure 5.4

Diagram showing observations of the Sun made during LS2 Lesson 3



Caroline drew the above diagram of the schoolyard, showing a blank sky, and provided each pair with a copy. She took a photo of the Sun's position at 7.35a.m. one morning which she then showed the children on the interactive whiteboard and they copied the Sun's position onto their diagrams and recorded the time. The children went out to the schoolyard at 9a.m., 10a.m., 11.15a.m., 12p.m., 1p.m. and 2p.m. on the same day and each pair took photos from the same position using a tablet. They then recorded where the Sun appeared to be in the sky on their diagrams, as shown above. The pair of children, whose work is in Figure 5.4 above, accurately recorded where they observed the Sun, showing a development in their understanding of how the position of the Sun appeared different at different times of day. It would be scientifically inaccurate to suggest that the Sun moves across the sky, when it is actually the Earth which is in

rotation. The different shadow lengths created at different times of day are related to the Earth's rotation on its axis. The structured inquiry approach to Lesson 3 (LS2) was applied, whereby the LS teachers decided in advance the approach Caroline would take, through providing the diagram and bringing the children to the yard at pre-decided intervals to take photos of the sky and their accompanying shadows. This provided the children in the class with an opportunity to develop their recording skills.

The teachers also designed a record sheet for the children to write a description of their shadow observations to supplement the photographs they took on the yard. Having this decided and organised in advance also indicated a structured inquiry orientation whereby the teachers had decided the times the children would make observations, as well as the titles of two of the columns: shadows/positions and length. The remaining columns were left blank for each pair to decide their own criteria, which showed a measure of student autonomy. The children were invited to include their own ideas, following the teachers' pre-determined structure of data collection.

The children's record sheets below provide evidence of the extent to which the children were able to record accurate observations with regard to the appearance of their shadows. Accurate representation of results would have indicated that the shadows were longer early in the morning, shortening towards 12p.m. at which time they should have been at their shortest, as the Sun would have appeared to be at its highest point in the sky (although it is really the Earth which rotates), before the shadows lengthened again towards the evening. This correct pattern was not always recorded fully by the children as will now be outlined with reference to the record sheets.

Figure 5.5

Student record of shadow observations made during LS2 Lesson 3

	Position/changes	Length	Brightness of the Area
9.00am	straight forward from me and it very clear	the shadow is very long and pretty skinny	The light is
10.00am	the shadow was angling a little and from straight forward	long as 9:00 (roughly)	
11.15am	The position is a little angled that not as much as 10:00	the shadow is probably a little shorter than 10:00	
12.00pm	The position of the shadow was going a 45° angle and it was very clear My shadow was directly on the side from me its on the right of me and a little behind me.	The length was pretty longer than 11:00am not by much though its like the length of 2:00pm the shadow length is probably about two arms wide across	

The child's record of the shadows accurately describes their changing positions from "forward from me" at 9 a.m. to "on the right of me and a little behind me" at 2p.m.

Length recordings from 9a.m. to 12p.m. are accurate as they note shortening shadows.

Inaccurate representation of afternoon shadows, suggesting that 12p.m. was the longest when it should be the shortest given that the Sun appears at its highest point in the sky at noon.

Figure 5.5 demonstrates the recorded observations of the children identified by the class teacher (Caroline) as higher achievers. It reveals both accurate and inaccurate conceptions regarding shadows. They successfully recorded how the shadows appeared to move during the day, from "straight forward from me" at 9a.m. to "a little behind me" by 2p.m. Allen (2010) notes how during the course of a sunny day if one were to record the position of the Sun in the sky every couple of hours then an arc-like motion would be observed. Similarly, accurate length recordings were accurately recorded from 9a.m. to 11.15a.m. given that the children noted how the shadow had shortened by late morning. However, the lengths recorded for the afternoon were inaccurate,

suggesting that the shadow at noon was longer than the one created at 2p.m. It is curious that the 12p.m. and 1p.m. records both refer to the 2p.m. shadow as their reference for length. This would suggest that those boxes were filled retrospectively at the end of the day since had they been filled at the time the photo was taken the students would not have had the 2p.m. shadow as a reference point. At any rate, regardless of the time of recording, the observations reveal inaccurate conceptions of the length of shadows created from 12p.m. onwards.

Figure 5.6

Student record of shadow observations made during LS2 Lesson 3

	Position/changes	Length	Width
9.00am	shadow	Long	
10.00am	shadow shadow	short	
11.15am	shadow	short	
12.00pm	shadow	short	Big
	shadow	long	Bigh
2.00pm	shadow	long	Big

Accurate record of the changes to shadow length, albeit lacking detail.

Shadow position not recorded at any time.

On the other hand, Figure 5.6 above, completed by the children identified as lower achievers, correctly records how the shadow lengths would have started long, shortened up to noon before increasing in length again in the afternoon. At the same

time, it must be acknowledged that these single word answers lack further detail. Similarly, the children only recorded that there was a shadow each time, rather than describing its position as per Figure 5.3 above. Perhaps if the teachers had chosen that the children would measure the length of the various shadows, as part of their structured inquiry, this would have supported each of the children above to provide more accurate results. In a similar manner to LS1, when the children had opportunities to record their own findings, some wrote inaccurate accounts and others lacked detail. Caroline described how, through the record sheets, the children “were definitely analysing more than they would have done previously...but I do think there's a lot of scaffolding and prompting needed for that for most of them” (LS2, Focus Group). The inaccuracies and lack of detail shown above on the record sheets do indeed suggest, as observed by the LS teachers, that teacher guidance is still crucial to the development of accurate scientific conceptions.

The teachers elected to retain a structured inquiry orientation in LS2, similar to LS1, combining a teacher-directed procedure with opportunities for students to record their own findings and share their own ideas as part of their responses. In terms of this activity, had they used a confirmation inquiry approach, described by Caroline and Darren as their approach before LS, Caroline could have presented the children with a completed diagram showing the position of the sun in the sky at the selected times, as well as a record sheet with pre-determined shadow lengths and positions. The children could have then observed the Sun’s position in real time as well as the shadows created, thus confirming the “right answer” provided to them by the teacher. In contrast, the structured inquiry approach allowed them to present their own findings in the diagram, giving the children autonomy while also affording the teachers an awareness of their conceptual understanding of the tasks.

The written journal accounts of some children corroborated the conceptual knowledge of light and shadows they had demonstrated when creating their models during the live research lesson. Figure 5.7 below, providing an example of the work of higher achievers, shows how one of the children drew an accurate diagram of his model, with a shadow in front of his Lego character correctly corresponding to the position of the torch he drew. He elaborated on the shared class conclusions by adding in his own comments. For example, he noted it was “more accurate” to move the whiteboard representing the Earth, rather than the torch representing the Sun (the correct scientific explanation since the Earth orbits the Sun). Along with the other children, he recorded how the shadows could be longer or shorter but he added that this was “depending on where the Earth has spun away from the Sun” (correctly identifying that the shadow’s length is due to the tilt of the Earth’s axis, relative to the Sun). The guided inquiry orientation afforded this child the freedom to share his own ideas in his responses by giving him the autonomy to do so. I had commented during the Post-Lesson Reflective Meeting that I had “really liked” how Caroline had given the children the “freedom” to write their own investigation reports where possible. Teacher-centred approaches to this lesson, such as didactic or even confirmation inquiry would not have included space for student voice. A structured inquiry orientation to this lesson would have allowed the child’s own ideas to come forward during analysis, but he would have followed instructions to create his model, rather than independently developing it, as per guided inquiry.

Figure 5.7

Science Journal Record of LS2 Research Lesson

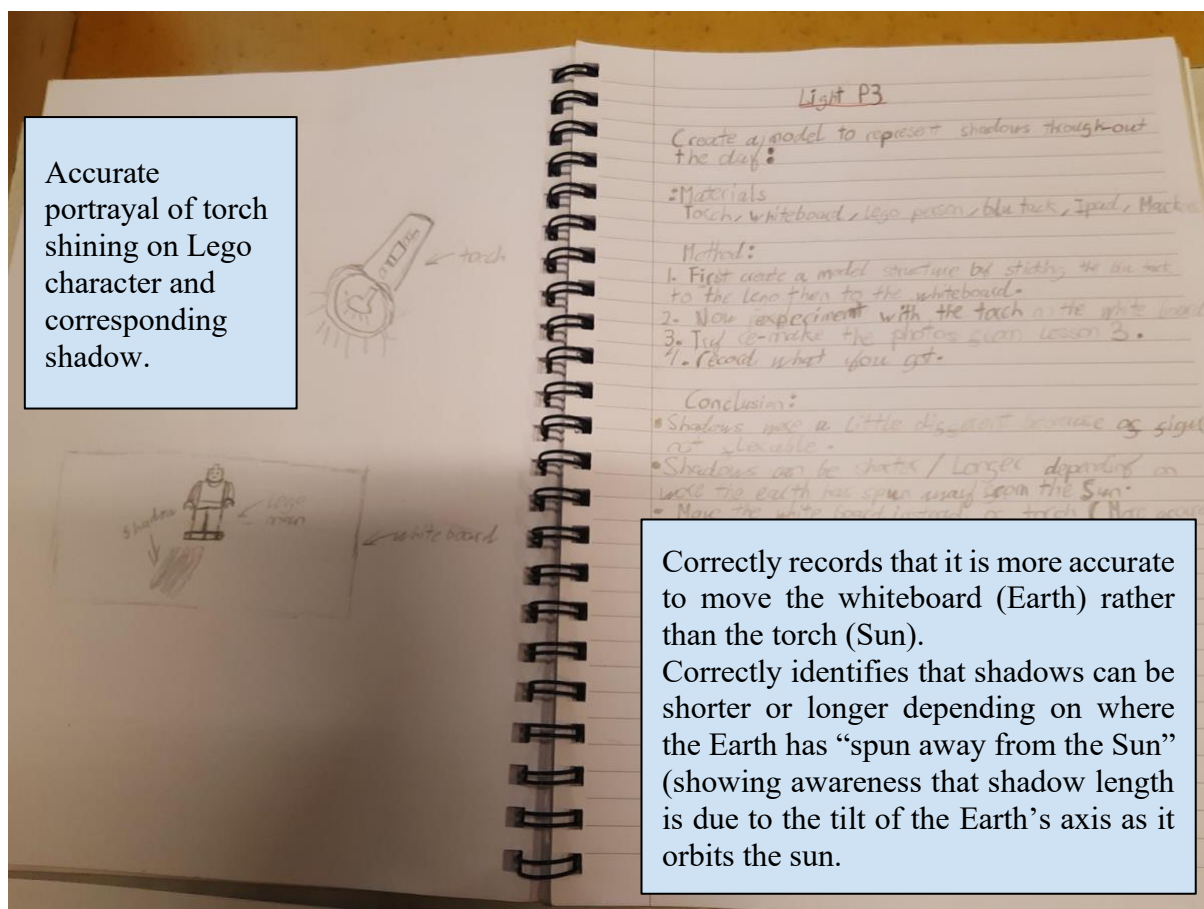
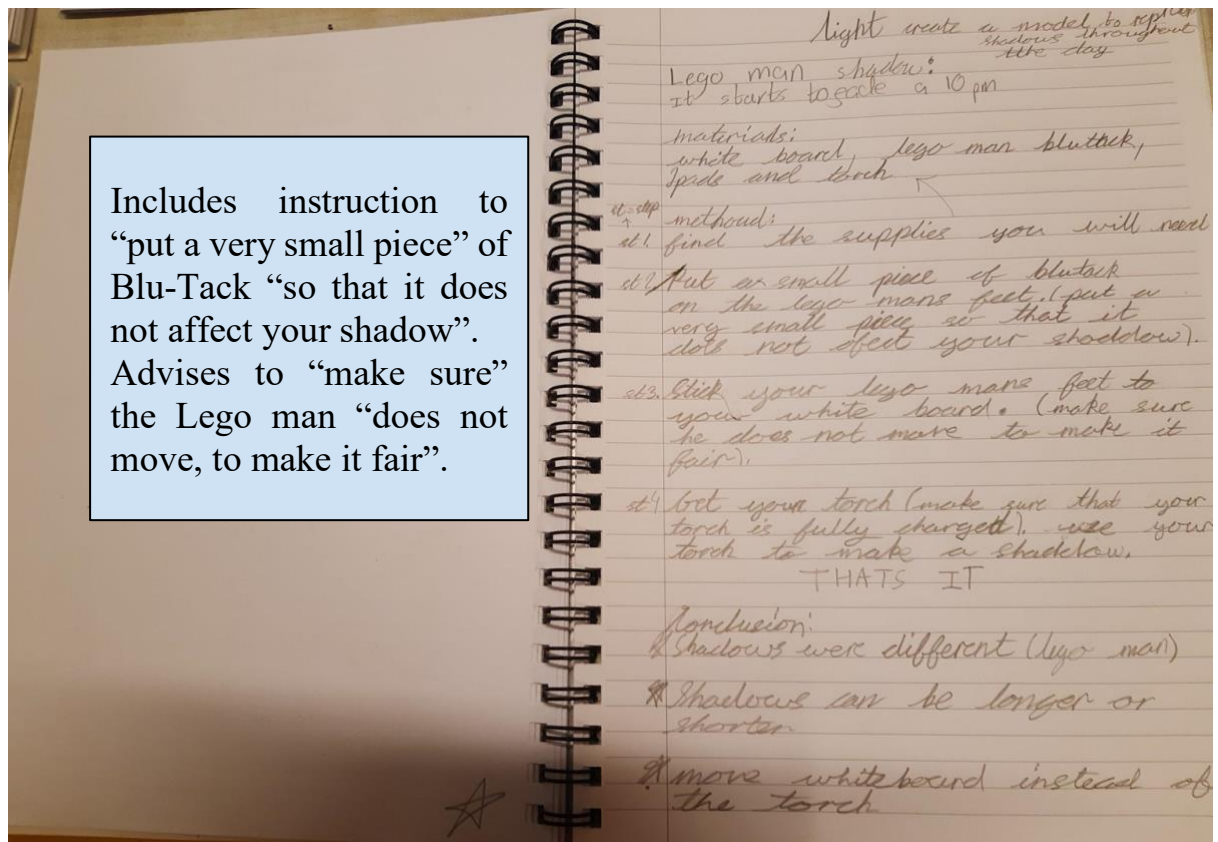


Figure 5.8 below, as an example of work produced by children identified as average achievers, does not show a diagram of the model as the child did not draw one. This child copied the shared class conclusions, with no additional personal reflections as per the sample of work in Figure 5.7 above. However, she showed deep consideration of how to plan the creation of the model in her written work. She added notes to her method such as “put a very small piece [of Blu-tack on the Lego character] so that it does not affect your shadow”, and “make sure he does not move to make it fair”. These personal notes link to the guided inquiry orientation, whereby the students are given autonomy to plan and carry out an investigation themselves. Her comments also

indicate a wider understanding of the need for fair testing in science investigations which Darren later observed was a feature of LS2, “how many times they mentioned it has to be a fair test”, which he perceived as “in terms of working as scientists, big box ticked” (Focus Group).

Figure 5.8

Science Journal Record of LS2 Research Lesson



Includes instruction to “put a very small piece” of Blu-Tack “so that it does not affect your shadow”. Advises to “make sure” the Lego man “does not move, to make it fair”.

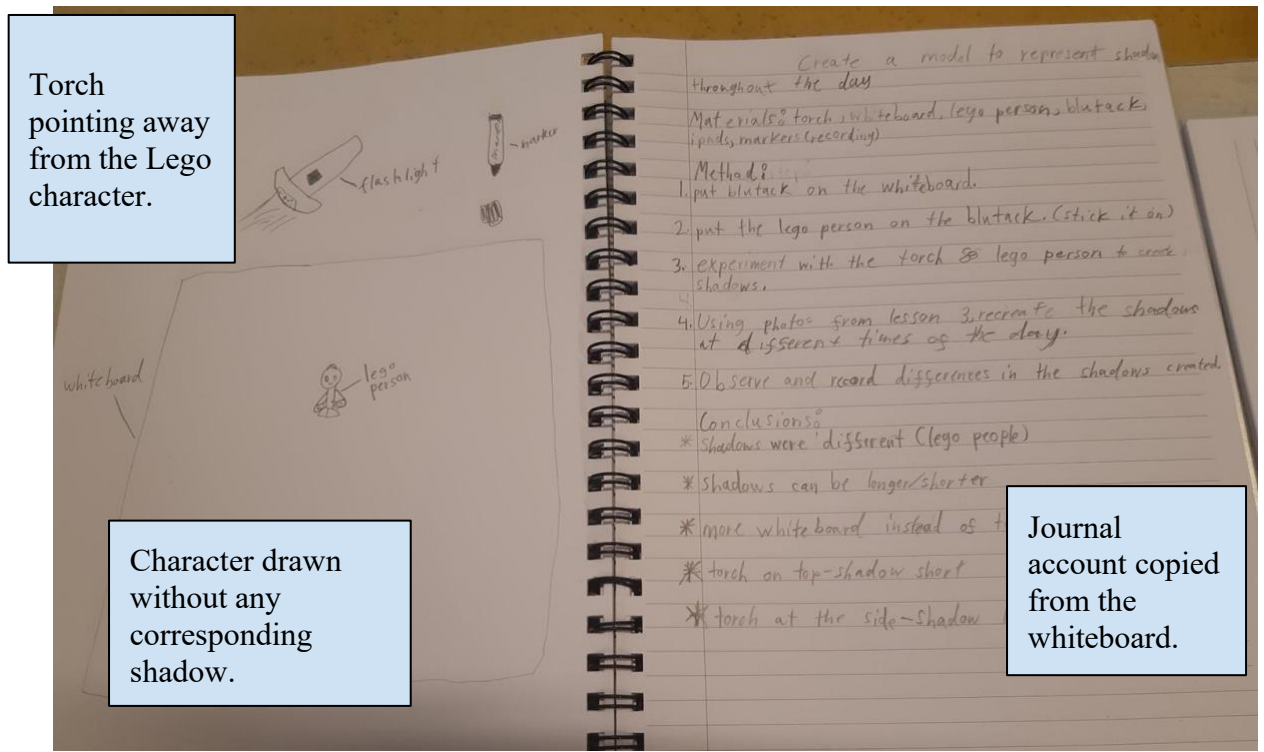
Caroline stated that prior to LS she felt that she could not “give [the students] the autonomy to go and write [their] own method” whereas LS2 enabled her to apply a student-centred guided inquiry approach in the classroom. Similarly, after engaging a group of junior high school Taiwanese students in IBSE approaches to science, Chang and Mao (1999) recommended that instruction should provide opportunities for students to think independently. Caroline believed the guided inquiry orientation

applied during LS2 compared favourably with the didactic approach she employed before. She observed how prior to LS her emphasis was on covering content in a rushed manner, “trying to get one science lesson done a week, each lesson...on a different topic”. This led to a situation whereby she felt “stretched to the max”, and relied on telling the children “to write exactly what I'm writing on the board” as otherwise lessons were “taking too long”. This would indicate a shift in the manner in which she supported children to communicate their own scientific understandings as a result of LS.

The inclusion of multiple means of communication in the LS2 research lesson facilitated both student learning and the teachers’ ability to evaluate their conceptual understanding of light and shadows. Michelle remarked that it was through “what [the students] were doing” (creating a model to demonstrate how shadows are made) that she determined they had some conceptual knowledge of the Earth orbiting the Sun. For example, one of the children she observed, who was identified as having lower ability, copied her journal account from the board (see Figure 5.9 below) with no independent observations. The child’s diagram did not show any shadow beside the character, and the torch was not pointed in the direction of the character, indicating an inaccurate conception of light and shadows.

Figure 5.9

Science Journal Record of LS2 Research Lesson



In this case, if we as the LS team had solely relied on the child's journal response, we would not have been aware that she had some knowledge of the concept. Had we employed a didactic approach where the students were invited to regurgitate a discussion on light and shadows, it is unlikely that this student would have succeeded, based on her lack of oral or independent written response. However, since Michelle had watched how she "took the board and the torch and recreated it herself by moving the board...[Michelle] knew that even though she was quiet, she did have some understanding that it's the Earth that's moving". In this instance, giving the student the autonomy to create the model herself enabled her to communicate her understanding of light and shadows in a way that a didactic approach would not have, given her inaccurate written account in her science journal. Focus on demonstration as a means

of communicating student responses gave this child an opportunity to successfully showcase what she had learned, which was at odds with her written response.

As the teachers reflected on the research lesson itself during the LS2 Post-Lesson Reflection meeting, the skills of analysing and communicating were considered as per the Planning Phase. Brian believed that the children were “very articulate in their thinking”, that they could “elaborate on what's going on inside their head[s]” which he deemed “very important”. The group agreed that “there was a difference in what was achieved” between individual children, but expressed the belief that “each child made at least some progression”. Moreover, it became apparent that the teachers viewed the development of all scientific skills as an integral part of LS2. Brian regarded “the amount of scientific skills that were done in a series of lessons” to be “amazing”. Caroline noted progression in the children’s comprehension of scientific skills and their use of words such as “observe, record”. She believed that “they actually understood” what the skills entailed, whereas she didn’t “think they had understood that before [LS]”. This highlights the positive impact that the teachers’ focus on a process orientation to science had on children’s learning during LS2.

5.4.3 LS3

The children’s record sheets highlighted the extent to which the teachers’ guided inquiry orientation transferred into the development of the children’s conceptual knowledge of pulleys. The progression of the two children identified as having average ability was evident from their reflection sheets below.

Figure 5.10

Child's Reflection Sheet LS3

Pulleys		
15.3.23 What I think I know	22.3.23 What I've found out	28.3.23 What I now know about pulleys
<p>To pull stuff</p> <ul style="list-style-type: none"> • You are this on blinds, wells and more things. • Circular shape • has a string 	<ul style="list-style-type: none"> • A pulley helps you to carry heavy stuff up. • It's easier to use a pulley instead of 	<ul style="list-style-type: none"> • It is easier to use a compound pulley because it has two pulleys. • It is easier
<p>After Lesson 1: Refers to pulleys on “blinds” and “wells”. Describes its “circular shape” and how it has “string”.</p>	<p>Lesson 2: Notes a pulley “helps to carry heavy stuff up”. Inaccurate description that “the string doesn’t move” in a fixed pulley.</p>	<p>After Research Lesson: Accurate description that “it is easier to use a compound pulley because it has two pulleys”.</p>

Figure 5.11

Child's Reflection Sheet LS3

15.3.23 Pulleys

What I think I know	What I've found out	What I now know about pulleys
<p>I know a pulley pulls up and down blinds, heavy boxes, ships and wells. I think I know a pulley works like a spring balance.</p>	<p>A pulley helps you lift heavy objects up a stairs, ladders, etc. A pulley is a mechanism with a pulley and string threaded</p>	<p>I know there is 3 types of pulleys. pulleys are used more than you think. Compound pulleys includes using a fixed pulley and a</p>
<p>After Lesson 1: "I know a pulley pulls up and down heavy boxes, ships and well. I think I know a pulley works like a spring balance".</p>	<p>Lesson 2: "A pulley helps you lift heavy objects up a stairs, ladder etc. A pulley is a mechanism with a pulley and string threaded through".</p>	<p>After Research Lesson: I know there [are] 3 types of pulley. Pulleys are used more than you think. Compound pulleys include using a fixed pulley and a moveable pulley.</p>

As indicated in Figures 5.10 and 5.11 the children's records both included technical terms such as "fixed" and "compound". One child showed progression from describing how pulleys "pull stuff" in the first section to writing "it is easier to use a compound pulley because it has two pulleys" at the end of the unit (Figure 5.10). Similarly, the other child, identified as an average achiever, commenced the unit with the knowledge that "a pulley pulls up and down blinds, heavy boxes, ships and wells" and finished by stating "there are three types of pulleys. Pulleys are used more than you think. Compound pulleys include using a fixed pulley and a movable pulley" (Figure 5.11). Their recordings indicate that the combination of two orientations which the

teachers employed in LS3, guided inquiry and unstructured exploration, enabled them to support the development of children’s conceptual knowledge of pulleys. Similar progression was noted in the reflection sheets of the children identified as being of higher ability, an example of which is Figure 5.12 below.

Figure 5.12

Child’s Reflection Sheet LS3

Pulleys		
15.3.23	22.3.23	22.3.23
What I think I know	What I’ve found out	What I now know about pulleys
<p>I think it's used to pull something up and down.</p> <p>I think it's used for wells, blinds, fishing, flags and cranes</p> <p>I think it can be used for rock climbing</p>	<p>Using Pulleys is easier than using your hand.</p> <p>There is different types of Pulleys</p> <p>A fixed pulley doesn't move</p>	<p>There are different types of pulleys (fixed, movable, compound)</p> <p>A compound pulley is a fixed and movable pulley put together</p>
<p>After Lesson 1: I think it's used to pull something up and down. I think it's used for wells, blinds, fishing, flags and cranes. I think it can be used for rock climbing.</p>	<p>Lesson 2: Using pulleys is easier than using your hand. There [are] different types of pulleys. A fixed pulley doesn't move.</p>	<p>After Research Lesson: There are different types of pulleys (fixed, movable, compound). A compound pulley is a fixed and movable pulley put together. A compound pulley is easier than a fixed and movable pulley because it has them both together.</p>

It is clear that the child’s conceptual knowledge of pulleys increased across the unit plan devised by the LS teachers. The first entry included an understanding of how pulleys “pull something up and down”, and gave examples from the world around us such as “wells, blinds, fishing, flags and cranes”, demonstrating some conceptual knowledge after Lesson 1. However, as the unit progressed, more technical information

was recorded on the sheet such as “a fixed pulley doesn’t move”. Ultimately the final entry, at the end of the research lesson, indicates the depth of conceptual knowledge this child attained as a result of the unit plan. Reference was made to “fixed, movable and compound” pulleys, as well as an understanding of the components of a compound pulley, combined with an appreciation that compound pulleys make things “easier” to lift. This indicates that the teachers’ orientations to teaching about pulleys, which included child-centred approaches such as guided inquiry and unstructured exploration, had a positive impact on children’s learning.

In a similar finding to LS2, the role of the teacher was identified as a crucial component of guided inquiry in LS3. Michelle noted “just how much scaffolding the children of lower ability need...we can’t let them off really because they need us” (LS3, Post-Lesson Reflection Meeting). The two children she observed during the LS3 research lesson, who were identified as having lower ability, “they just stood back...they were given jobs by the other children”. When asked to draw a fixed and a movable pulley, one child copied the examples on the board and the other child drew two fixed pulleys. (Michelle, LS3, Post-Lesson Reflection Meeting). This indicates that the two children needed further teacher support to develop their understanding of pulleys, when compared to their peers, as indicated by the work samples of the children above.

Furthermore, Michelle shared at the Post-Lesson Reflective Meeting that although she was in an observer role and supposed to be “the eyes and ears, not the hands and the mouth” she decided she was “going to scaffold” at one point during the research lesson because the children she was assigned to observe were in need of support. Michelle explained that she assisted them with holding the compound pulley and asked them “what are you going to do with that bit?” She further described her

actions as not “telling them, but just kind of helping”. Michelle related her experience to “observing the lower ability children in LS2 and it just screamed at me that they need so much help from us”. The role of the teacher acting as guide, as a component of a guided inquiry orientation to teaching science, would appear to be particularly important. With regard to LS, it reinforces the challenges faced by observing teachers, such as Anna observing the paper spinners in LS1, and Michelle herself in LS2. It would appear that as teachers they naturally wished to engage with the children and guide them when they faced challenges, which was at odds with their LS observer role.

The individual reflection sheets of the two children identified by Caroline as of lower ability, whom Michelle described scaffolding above, provide further evidence of their thinking in relation to pulleys:

Figure 5.13

Child's Reflection Sheet LS3

Pulleys

What I think I know	What I've found out	What I now know about pulleys
Grab two chairs and two tables to put the chairs on then you need 4 partners to help with it after		I know that you'll have to grab two pulleys for this pulley called compound and the compound pulley has a fixable and

After Lesson 1: "Grab two chairs and two tables to put the chairs on, then you need 4 partners to help with it after". Representing incomplete instructions on how to set up a fixed pulley. No indication of understanding the function of pulleys or where they might be seen in the environment.

After Research Lesson: I know that you'll have to grab two pulleys for this pulley called compound (accurate) and the compound pulley has a fixable and... (inaccurate).

This child (Figure 5.13) did not mention the word “pulley” when asked to record what he thought he knew about them after Lesson 1, and rather gave incomplete instructions on how they set up a fixed pulley. He wrote “Grab two chairs, and two tables to put the chairs on. Then you need 4 partners to help with it after”. This was an accurate description of what happened in a practical sense, but it did not indicate any conceptual understanding of pulleys. Although the child’s second reflection was missing, his final one states “I know that you’ll have to grab two pulleys for this pulley called compound” (Figure 5.13). This indicates that although he stood back during group-work, his knowledge of pulleys did increase as a result of the set of lessons designed by the LS teachers.

Figure 5.14

Child's Reflection Sheet LS3

Pulleys		
15.3.23 What I think I know	22.3.23 What I've found out	What I now know about pulleys
<p>pulleys are for lifting up and down. I think its kinda like a spring balance. I know</p>	<p>I found out that pulleys they can lift very heavy items. They are also used for boats, farms.</p>	<p>pulleys are useful for lifting heavy things pulleys are for lifting up down for even small</p>
<p>After Lesson 1: Pulleys are for lifting up and down. I think it kinda looks like a spring balance. I know it's found in a well. I know it's used in farms.</p>	<p>Lesson 2: I found out that pulleys they can lift very heavy items. They are also used for boats, farms.</p>	<p>After the Research Lesson: Pulleys are useful for lifting heavy things. Pulleys are for ? up down for example small for pulling the blind.</p>

This child progressed from “pulleys are for lifting up and down” to “pulleys are useful for lifting heavy things” (Figure 5.14). The phrase “useful for lifting heavy things” suggests the child had some understanding of the function of pulleys by the end of the unit. However, there was no reference to specific terms such as “fixed”, “movable” or “compound”. This would appear to correlate with Brian’s assertion that “at the end of Lesson Four it was evident that some students were still unsure of certain parts of how pulleys worked” (Brian, LS3, Planning/Teaching/Reflecting Log). It would seem that although the teachers’ orientations to teaching about pulleys in a guided inquiry manner led to progression in many children’s conceptual understanding

of the topic, as evidenced in the work samples above, some children still needed further consolidation of their knowledge of pulleys at the end of the unit plan.

A guided inquiry orientation facilitated a problem-solving approach to science. The teachers elected to challenge the children to use their own ideas as the basis for planning and trialling compound pulley systems. It also allowed the children to develop their skills of perseverance, one of the ideals of primary science identified by the LS teachers at the start of LS1. Caroline described how on several occasions she had asked the children “how’s it going? And they were like, oh not very well. And then one of them would just say, oh we’ll just try something else” (LS3, Focus Group Interview). Caroline commented how she “loved that it was so persistent...they wanted to do it, they wanted to figure out how it was done”. This connects to the “problem-solving and applying” element of the *Draft Science, Technology and Engineering Education Specification* (NCCA, 2024) which aims for children to “persevere” (p.7). Furthermore, the notion that the children would “just try something else” upon reaching a stumbling block echoes the philosophy of Imre Lakatos who advocated that research programmes should proceed even when they encounter problems. The trait of perseverance in the face of problems, evidenced among the students, links their experience of guided inquiry in LS3, to some of the philosophies of science itself.

The emphasis on building perseverance amongst the students in a process of self-discovery was also identified by Brian as a positive result of the lessons designed through LS3. It could be argued that affording the students more autonomy through guided inquiry and unstructured exploration, when compared to the structured inquiry of LS1 for example, encouraged the children “to be persistent...to keep going...to fail a little bit” (Focus Group Interview). He viewed this as something the teachers “did really well” and described it as a “great skill”. It could be suggested that this

development of the ability to continue on in the face of challenges connects positively to the “life skills” the teachers wished to encourage at the outset of LS. Caroline and Brian’s comments at the end of LS3 shows that LS enabled the teachers to facilitate their aim that children “would sit and work something out, and stick with it”, also envisaged as an ideal of science teaching at the beginning of LS1. This links to the Nature of Science and the idea that science incorporates “human imagination and creativity” as part of problem-solving (Lederman, 2007). It would seem that the orientations chosen by the teachers in LS3, including guided inquiry and unstructured exploration, facilitated the students to work like scientists, as per their overall research theme. When compared to LS1 and its emphasis on structured inquiry, a shift can be seen towards more student autonomy in LS2 and LS3, with the inclusion of guided inquiry orientations to teaching science.

5.4.4 Summary

Overall, the children’s work samples confirm how the various approaches to teaching science selected by the teachers positively impacted the children’s learning across each cycle. The children were supported to develop their conceptual knowledge of falling objects, light and shadows, and pulleys, aided by the increased SMK their teachers possessed as a result of the LS Study Phases. They were afforded opportunities to develop their science process skills, in line with the teachers’ focus on promoting a process orientation. At times this took place through explicit focus on a particular skill, for example prediction in LS1. In LS2 and LS3 the process orientation integrated with the structured inquiries and guided inquiries proffered, offering time to observe, explore, record, analyse and communicate. Some children utilised the autonomy they received during guided inquiry to share their own ideas in personalised records of the investigations. However, for some children this was too great a challenge, and called

into question the suitability of child-centred inquiry for all children. In the end, it became apparent that for all children, regardless of ability, the teacher played a crucial role in guiding and supporting them in their science investigations, whatever the approach selected by the teacher.

5.5 Conclusion

This chapter aimed to outline the effects of LS on both participating teachers and the children they taught as part of the process. It can be seen that the teachers were able to reflect on their orientations, or knowledge and beliefs about the purposes and goals of teaching science. This is significant since Magnusson et al. (1999) assert that teachers' orientations guide their instructional decisions about issues such as teaching objectives, the design of student tasks, the use of resources and assessment of learning. For some teachers, their existing orientations were confirmed by participation in LS whereas for others their orientations were challenged and shifted as a result of participation in the CPL. Data highlight the importance of a process orientation, focused on the development of scientific skills to the teachers. They also wished to promote inquiry in the classroom, initially utilising more teacher-centred structured inquiry in LS1 and early lessons of LS2 before transitioning to more child-centred guided inquiry for the research lessons of both LS2 and LS3. This desire to include child-centred approaches to teaching science also incorporated an unstructured exploration orientation.

It became clear that in order to best support the teaching and learning of science through the orientations they selected, it was imperative that the teachers possessed the necessary science conceptual knowledge to do so. They utilised each LS cycle to increase their SMK of the selected topics, most especially during the Study Phase and

in particular the “play sessions”. Not only did this aid them in the design of appropriate unit plans regarding falling objects, light and shadows and pulleys, it also enabled them to anticipate with accuracy the preconceptions the students would possess.

Overall, the impact of LS on teachers is only one side of the effect data gathered here. It was also crucial to determine its impact on the student stakeholders. It would appear that the development of teachers’ orientations and increased SMK had a positive influence on the learning of science during the unit plans and research lessons. Data gathered showed most children developed their conceptual knowledge of falling objects, light and shadows, and pulleys, albeit to varying degrees. It would seem that the LS lessons allowed for skills development, which the teachers noted as an explicit aim of all three cycles. The children experienced a variety of teacher-centred structured inquiry and more child-centred guided inquiry and unstructured exploration. This led the teachers to conclude that regardless of ability, all children require guidance from the teacher, no matter if a child-centred approach is selected.

This chapter outlined the effect of LS on teachers’ orientations and SMK for teaching science, and the subsequent impact on children’s learning. The following chapter extends from the effect data described here to identify the specific features of LS as a CPL methodology which supported the teaching of primary science, also known as contribution data (Wenger-Trayner & Wenger-Trayner, 2020).

CHAPTER 6: FEATURES OF LESSON STUDY THAT SUPPORT THE TEACHING OF PRIMARY SCIENCE

6.1 Introduction

The previous chapter demonstrated the effects of LS: supporting teachers to develop their orientations to teaching primary science, increasing their SMK, and the subsequent positive impact on children's learning. This chapter draws on the data set in order to identify the features of LS that supported these findings, in other words, the contribution data (Wenger-Trayner & Wenger-Trayner, 2020). Contribution data are defined as data which establish the role of the social learning space in achieving a given effect. Wenger-Trayner and Wenger-Trayner (2020) note that participants find value in a SLS to the extent that their participation is seen as leading to a difference that matters. Participant agency is at the heart of learning. The same authors observe that the practice of evaluation often hands agency to outside forces, whereas "using the value creation framework allows the process of evaluating to honour the agency of participants" (p.189). The views of participants themselves are key to the evaluation process. Therefore this chapter is based on the second research question:

What features of school-based Lesson Study are most effective in supporting the teaching of primary science?

As this study includes a novel exploration of my role as IKO, this led to the inclusion of the following sub-question?

What is the experience of an IKO in school-based LS?

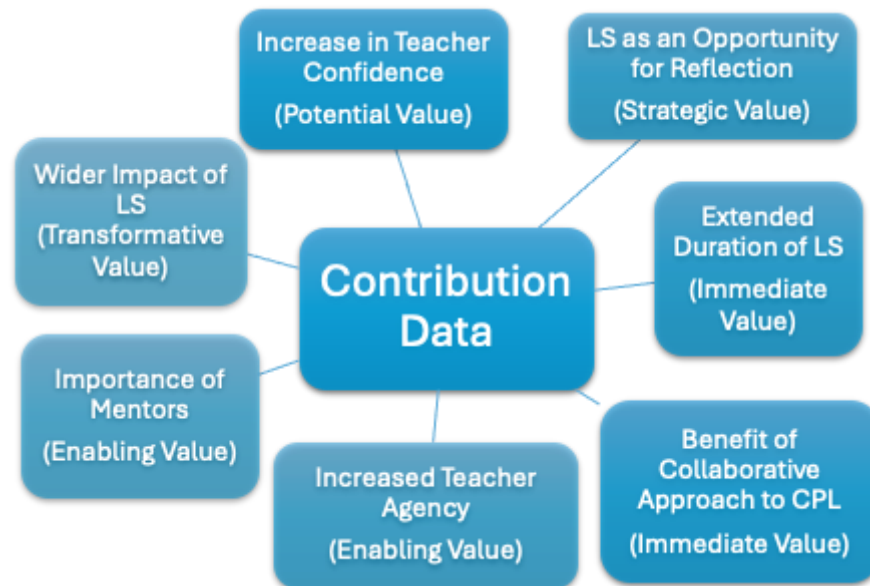
In a similar manner to the analysis conducted on effect data in the previous chapter, reflexive thematic analysis was utilised in order to develop themes in a

theoretical manner. Themes were determined from contribution data that provide plausible claims that these effects of LS are linked to the intervention itself. Wenger-Trayner and Wenger-Trayner (2020) describe how both effect and contribution data are informative, but “it is together that they achieve their full capacity to build a robust picture of the value of a social learning space” (p.191). As a result, an attempt will be made to integrate the contribution data of this chapter with the effect data identified in the previous chapter. In other words, how the features of LS noted as valuable by the participants impacted on teachers’ orientations, the development of teachers’ SMK and children’s learning.

Analysis of data highlighted a number of developed themes with regard to the aspects of LS which participants identified as valuable. These included the benefit of a collaborative approach to CPL, the development of teachers’ confidence, the duration of the LS process, the opportunity for reflection, a sense of agency attached to this CPL model, the benefit of mentors and the wider impact of LS beyond the intervention itself. The themes are illustrated in the figure below.

Figure 6.1

Model of Contribution Data themes identified in this study



Each of these themes will now be outlined in greater detail, with reference to the Value Creation Framework (Wenger-Trayner & Wenger-Trayner, 2020), and with connections to the effect data identified in the previous chapter.

6.2 Teacher Collaboration as a Feature of CPL (Immediate Value)

The benefits of a collaborative approach to CPL, and the importance of being part of a group permeated the data collected across the three LS cycles. In terms of social learning theory and the value creation framework, collaboration appears to correspond to immediate value. This is where value lies in the experience of being in a particular space, or a particular moment together, regardless of whether or not it leads to something else (Wenger-Trayner & Wenger-Trayner, 2020). Data on the collaborative aspect of LS provide examples of contribution data - how this feature of LS added to the overall effects identified in the previous chapter.

6.2.1 Collaborative Sharing of Ideas and Vulnerabilities

The teachers appeared to benefit from the group discussions during the introductory stages of LS1. I noted in my LS1 Study Phase log that “there seemed to be a real sense of community within the group”. The style of group conversation led the teachers to discover that they were not alone in having doubts about their abilities to teach science effectively. Anna observed that “it was comforting to realise that many teachers struggle with similar issues or insecurities that I may have” (LS1, Study Phase Log). Similarly, Brian noted that “the sharing of ideas...might even have allowed for an honesty around vulnerabilities”. He believed that when speaking together as a group the teachers could be “open about what fears and/or concerns they may have” (LS1, Study Phase Log). It would seem that the collaborative atmosphere supported the teachers to share aspects of science teaching that they regarded as challenging, which for some was a “comfort”, as identified by Anna above. Similarly, Ní Shúilleabháin et al. (2024) found that “having the opportunity and trust to question one’s own practice and pedagogical practices within Lesson Study affords instances to colleagues to support one another” (p.11).

Brian also found value in the “collective introspection” of LS, contrasting this favourably with “classroom practice, where most of one’s experience is individual and not informed by discussion or reflection other than self-reflection”. He described how the group atmosphere enabled the teachers “to dig quite deeply into our own anxieties over science...in a supportive and encouraging way”, which he deemed “helpful”. Indeed LS1 Meeting 3 notes highlight how the collective sharing of areas of the curriculum which the teachers found challenging to teach led to the identification of the theme of the LS1 research lesson. When the EKO with expertise in LS invited the teachers to identify topics they perceived difficult to teach Brian and Michelle

mentioned “gravity”. Brian and Claire also referenced scientific skills, “prediction” in particular. Caroline subsequently combined these areas, suggesting that “exploring gravity and forces [would be] a good one for prediction”. These topics were ultimately pursued by the teachers in LS1, resulting in the development of teachers’ process and structured inquiry orientations, as well as having a positive impact on children’s understanding of falling objects and prediction, as identified in the previous chapter. In a similar manner, Brian, Caroline and Michelle collectively shared their lack of knowledge with regard to pulleys at the beginning of LS3 (LS3 Meeting 3 notes). Their group conversation was the catalyst for the development of their own SMK in relation to pulleys, and the promotion of both guided inquiry and unstructured exploration orientations. It culminated in lessons which were effective in increasing the children’s understanding of pulleys. The teachers’ collaborative sharing of vulnerabilities during LS was ultimately beneficial to both the teachers themselves and the children who participated in the LS lessons. This highlights a link between teacher collaboration through LS and a positive impact on the teaching and learning of science, connecting the contribution data of this chapter with the effect data of the last chapter. It would seem that there was an inherent value in finding others who understood and even shared similar challenges to the teaching and learning of primary science.

At the beginning of LS1, the teachers were concerned after reading Lewis & Tsuchida (1998) that they were “good at self-reflection but less able to reflect together” in the manner of Japanese LS (Meeting 2). However, Brian observed at the end of the LS1 Study Phase that further reflection on the article brought forth the notion that “the creation of open conversations with colleagues is an important aspect of effective science teaching”. Furthermore he believed he needed “to re-evaluate what might be perceived as criticism and value the strength and support that is yielded from purposeful

conversation”. Likewise, Darren noted a positive in hearing different ideas from his colleagues. During the LS1 focus group, he described how LS incorporated “[trying] out an idea and then other people kind of either agree or disagree with you...or they bring their own perspective on it”. This would indicate that Darren valued the discussion element of LS. Darren viewed it as “really interesting” to see “the thought processes of your colleagues”. Similarly, Caroline mentioned how “it was really nice to get other teachers’ opinions” during the LS process. Their comments align with Wenger’s (1998) description of communities of practice as being a joint enterprise, wherein not “everybody believes the same things or agrees with everything” but in that meaning is “communally negotiated” (p.72). This would indicate that these teachers relished the opportunity to discuss ideas with the other teachers as part of LS, whether they were in agreement or not.

In addition, it was noted that having the LS group participate in the Research Lesson altogether was a positive experience for the class teacher. Caroline felt it was “nice to know that there are other people in the room who have witnessed some of the things that are going on in the class” (LS2, Post-Lesson Reflection Meeting). Her words echo the view of Anna at the end of LS1, who saw it as a benefit of LS that “you’re not isolated” and appreciated the opportunity to “see how other teachers work, and how they think” (LS1, Focus Group). In a similar manner, Smith (2014) found that CPL can play an important role in “the breakdown of teacher isolation” (p.481). Brian and Caroline referenced the importance of the teachers’ private “WhatsApp group” at the end of LS3. Caroline described it as an “informal way” to engage in “general chit chat about pulleys which was really nice” outside of the organised meetings (LS3, Focus Group). It would appear that the creation of a LS community was a positive aspect of the process, countering the usual solitary experience of the teacher in the classroom.

It seems that the collaborative aspect of LS held an immediate value for some participants and was a motivating factor for their continued involvement in LS2. Caroline stated that she “really wanted to be involved” and that she loved “getting into a group and talking science”. She believed that the nature of the LS group supported her to discover that either “everybody else doesn’t know as much as I think they know...or they can kind of help you” (LS2, Focus Group Interview). This was reiterated by Brian, at the same meeting, when he commented that “it’s a lovely group of people...you feel like you can say things...try things out and didn’t feel as though it was a disaster that you didn’t know [all the answers]”. Brian reiterated this point at the end of LS3 when he stated “teaching is very lonely when you’re trying to figure things out on your own and just three people sitting around chatting about how to do it...was actually great”. Caroline also noted the importance of shared interest to LS when she commented “we’ve been working towards a small goal and I suppose the small group of people who are all interested in it has been helpful” (Caroline, LS3, Focus Group). The words of Brian and Caroline emphasise the value they attached to the collaborative aspect of LS. It supported them to work together on a shared vision of how they wanted to teach particular science topics, enabled them to feel comfortable enough to share their vulnerabilities and ask each other for support and provided opportunities to discuss ideas with colleagues who shared their interest in primary science. Caroline’s comment regarding the “small group of people” was also highlighted by Anna as a beneficial feature of LS1. She opined that the “small group allowed for meetings to be efficient and relevant at all times” which suggests that she believed the size of the LS group contributed to the success of LS1.

6.2.2 Collaborative Planning

As the research theme was identified and LS1 progressed, collaborative planning was identified as beneficial to the teachers' experience of LS. Caroline mentioned that she "enjoyed coming together as a group to discuss findings and opinions and it felt a lot more productive than doing this independently" (LS1, Study Phase Log). She "was grateful to hear the experiences and thoughts" of the teachers who had previously taught at senior level, something she had not experienced prior to LS. Caroline commented that "everyone was happy to question, suggest and compromise and through that I think we came up with the best lesson that we could have" (LS1, Planning Phase Log). Given the group's initial concerns regarding how well they would take criticism from each other, it is interesting to note that Caroline believed they were "happy" to "question, suggest and compromise" as LS1 progressed. The word "compromise" in particular suggests that the LS teachers were able to manage differing opinions effectively to the satisfaction of all. Brian also referenced how "we were able to ask questions of one another and question the approach that we were taking" (LS1, Planning Phase Reflective Log). Michelle too observed that "consensus" in the group was "very important" (LS1, Study Phase, Log). While the lack of audio data for LS1 meetings makes it impossible to provide a tangible example of such consensus and compromise, it would appear that the LS teachers shared and debated ideas as part of their collaboration, and they viewed their questioning of each other as a positive aspect of their experience.

Data show that this debating of ideas came to the forefront later in the process when designing the LS3 unit plan lesson based on the efficacy of fixed pulleys. Michelle voiced a concern that the lesson could be too short, and that perhaps the children could test different types of string on the pulley as an extension activity. Brian

disagreed saying “sorry, is that going to complicate the concept if you introduce [something else?]”. Caroline suggested that the group “could keep [that idea] on the back burner” but preferred to “send them along the route of making sure, do [the investigation] several times”, which was then agreed. Although there was disagreement, through discussion the teachers arrived at consensus in their approach. This appears to align with “navigating fault lines” in LS (Ní Shúilleabháin et al., 2024, p.9), where teachers communicate differences of opinions and utilise this to build on ideas for lessons.

The positive impact of collaborative planning was also noted throughout LS2. From the outset, Brian, building on his experience of LS1, described collaboration as central to the LS process. He asserted that LS1 was “based solidly around the idea that our community approach to sharing ideas and our sincere willingness to plot a navigable route through a topic and a lesson is not only sufficient but possibly exemplary practice” (LS2, Study Phase Log). This approach was again applied during LS2. The collective knowledge gained through the teachers’ “play sessions” and examination of resources such as the Smithsonian videos (Smithsonian Science Education Center, 2020a; 2020b; 2020c; 2020d; 2020e) concept cartoons (Naylor & Keogh, 2001) and the PSC (DES, 1999a) supported them to collaboratively design a unit plan based on the topic of light and shadows.

Collective discussion formed the basis of the unit plan. Michelle asked Caroline, who as class teacher was responsible for teaching the lessons leading to the research lesson, whether she needed “to go outside in the very beginning?” (LS2 Meeting 3), as per the Smithsonian videos. Caroline retorted that she felt “an indoor lesson” would be “an interesting way to introduce shadows” through investigating light’s relationship with materials. This resulted in the children exploring opaque, translucent and

transparent materials. In terms of Lesson 2 of the unit plan, Michelle wondered if the teachers could incorporate some of the play session activities. Brian concurred, suggesting that the children could test “the strength of the shadow” which Michelle connected to “that concept cartoon that we talked about last week: when I change the distance between light and an object, what will happen to the shadow?” This is what the children explored in the second lesson of the unit plan in advance of “heading more towards the Sun” (Michelle, LS2, Meeting 3).

Collaboration was key to the wording of the LS2 TLP. For example, the following exchange during Meeting 3 highlights how the goal of Lesson 3 was developed:

Brian: Children would work as scientists to explore...

Michelle: To observe?

Brian: To observe how their shadows...

Michelle: To observe what happens to their shadows on a sunny day?

Brian: At different intervals throughout a sunny day, how about that?

Michelle and Caroline: Yes

The above conversation underlines how the teachers latched onto each other’s suggestions as they attempted to articulate the lesson goal. They collectively developed the aim of the lesson through modifying and strengthening each other’s ideas until they reached consensus. In terms of the Value Creation Framework the interaction above appears to be an example of a “short loop” (Wenger-Trayner & Wenger-Trayner, 2020), which through collective discussion propelled the learning forward.

The same approach was applied when the teachers became “stuck” (LS2, Meeting 4) in attempting to articulate the lesson goal and task for the research lesson itself, which involved the children creating a model to represent the shortening and

lengthening of their shadows. Darren wondered if the goal was to “analyse the relationship between shadows and light?” which Caroline agreed with. Brian then asked if the children were “working as scientists to communicate an understanding?” Darren combined this with his earlier suggestion to compose the version which the group settled on: children will communicate their understanding of the relationship between the shadows formed [by their models] and the light source (LS2, TLP). It is evident that collaboration was crucial to the development of the lesson goals.

The teachers’ own appreciation for a collaborative approach was present once more at the end of LS2, when they agreed that “none of us would ever come up with that unit individually” (Focus Group). Such statements underline the importance of collaborative planning to the LS process - it was through the collective efforts of the group that the TLP emerged as it did. In addition, Brian believed “the chatting that we did was far more powerful than any of the reading” (LS2, Focus Group Interview). This indicates that he perceived the group conversations as the most worthwhile aspect of the planning process. It seems that the teachers felt that the collaborative approach to planning during LS had a significant impact on the set of lessons produced for the classroom.

Brian believed in the benefit of teacher collaboration before LS, but his experience confirmed its importance. Although he “was positively disposed towards it” before LS, he noted that “it is only when a willing group of teachers come together in a sincere and enthusiastic manner, that one comes to appreciate and value it” (LS2, Planning Phase Log). He described how LS encompassed “fruitful and systematic planning...generated by mutually respected individuals who were planning, not alone for what it would do to benefit the students, but equally what it might do to enhance our own teaching and understanding of science” (LS2, Planning Phase Log). While

Brian came to LS with a positive attitude towards collaboration among teachers, his experience of LS confirmed his belief that it is of benefit for both the teaching and learning of primary science. Connecting to the Value Creation Framework (Wenger-Trayner & Wenger-Trayner, 2020) this would seem to be an example of a “long loop” where his experience of LS substantiated his initial view. Brian’s comments connect collaboration with the overall effects of LS identified in the previous chapter: the development of teachers’ orientations and SMK, and a positive impact on student learning.

6.2.3 Individual Roles within the Collaborative Process

I, as IKO, observed how each individual teacher’s role was key to the LS1 Planning Phase. I volunteered to act as teacher of the mock lesson on paper spinners, and in advance I “put a lot of effort into preparing adequately” as I felt a sense of responsibility to the group. I noted that I perceived that the mock lesson was “all on me” (LS1, Planning Phase Reflective Log), since I was the “face” of the lesson in my role as teacher. However, after the mock lesson took place I recorded that “I [saw] how important everyone’s role was” in it. For example, “the observers took detailed notes which are of great benefit to the group as we reflect on what adjustments we will make going forward”. These included something as simple as a suggestion to “colour one of the [spinner’s] wings to help check the direction” in which it spun to the ground (Caroline, Mock Lesson Observations). I noted how it was “good to have everyone’s input on the children’s worksheet”, such as when Caroline added coloured icons which made it more attractive and “I wouldn’t have thought of”. While the teachers had spoken of how they valued the collaborative aspect of LS during the Study Phase, the mock lesson highlighted how cooperation was also a key factor during the Planning Phase. The individual roles each group member assumed had an influence on the design

of the subsequent research lesson for the students, highlighting how teacher collaboration had an impact on children's learning in the classroom.

The live research lesson also underlined the importance of collaboration to LS. I noted how in advance of teaching it, I felt it would be "intimidating" to teach in front of four observing teachers and two EKO's. However, in reality I observed how "everyone was busy with their own observation job and that they weren't really watching me at all" (LS1, Teaching and Reflective Phase Log). This led me to acknowledge the "importance of each role to the Lesson Study process; teacher, observer, EKO". I concluded that "each task was critical to the process and it would not have worked in the same way if anyone's contribution was missing". I suggested that "it was almost easier to be the teacher" since I could "just get up and perform the lesson". My words underline the importance of each role to the LS process.

While I facilitated the lesson, it was "up to observing teachers to really determine how the children were interacting with it", through having to "concentrate on what they were saying and document it". For example, Brian shared how prior to the research lesson he believed that children's difficulty with prediction was "not an unwillingness to predict but rather a sincere challenge to consider 'in the abstract' what might happen and why it might happen" (LS1, Teaching and Reflective Log). He then revealed how "as one of the observers, this challenge was confirmed to me throughout the lesson...the two students earnestly tried to consider what might happen but could not articulate why this might be the case". LS afforded him the opportunity to carefully watch students during the research lesson and share his observations with the group. In this manner, while I facilitated the lesson in my role as teacher, the observing teachers collaborated with me, making an invaluable contribution to our ability to evaluate how the lesson impacted children's learning. Once again, during the LS2 Post Lesson

Reflection Meeting I observed how I heard a “eureka moment” when the children Brian was observing shared their understanding of light and shadows. He replied that he “hoped [he] was writing that down!” which I confirmed he was. In this manner it was teacher observations, in combination with the children’s worksheets, which enabled us to determine the impact of the lessons on children’s learning, as outlined in the previous chapter. It would seem that collaboration, as an attribute of LS, had a positive effect on both the teaching and learning of science in this instance.

Anna described how it was “really interesting to listen to all the opinions and experience of the research lesson” at the Post-Lesson Reflective Meeting (LS1, Teaching and Reflective Log). She determined that it was “a lovely way to finish off the Lesson Plan process, finishing it as a whole group just as how it began in March”. Analysis of the importance of each LS teacher’s contribution to the research lesson itself and its evaluation highlights how the collaborative aspect of LS extended beyond the Study Phase and Planning Phase, becoming a feature of utmost importance to the Teaching and Reflective Phases also. It is evident that teacher collaboration was a key feature of each stage of the LS process.

6.2.4 The Importance of Collaboration Amongst Colleagues

Dooley et al. (2014) noted that LS can be “particularly beneficial when enacted by a community of educators working in their own setting...where colleagues are mutually engaged in the shared enterprise of developing mathematical proficiency in their learners” (p.123). Although their suggestions relate to mathematics and not science, the sentiment of working collaboratively with colleagues was also identified by the LS teachers in this study as a positive aspect of the process. Some of the teachers felt that familiarity with each other through being colleagues was a significant feature

of the LS. For example, Brian commented that “the fact that we are colleagues with a shared respect for one another is obviously hugely significant. It is easier to be vulnerable with people for whom you have great respect” (LS1, Study Phase Log). Similarly, Caroline said that due to “the fact that I knew everybody in the group...I never felt judgement ever at any point from anybody in the group for, I suppose, not knowing or doing or saying”. Indeed she felt that LS1 had given her a “group that you know you could turn to if you needed a bit of, I don’t know, a bit of assistance in some sort of lesson like that” (LS1, Focus Group). The collaborative nature of LS provided her with colleagues she felt she could turn to for support when teaching science outside of LS if she was unsure of something.

This sentiment continued right through to LS3 whereby Brian commented that he wouldn’t have felt “enthusiasm” to “go off and do pulleys on [his] own”, whereas the LS group gave him the confidence that if there was “stuff that [he was] not sure of [he had] somebody else to ask” (Meeting 3). The teachers’ comments indicate that familiarity with each other as colleagues supported them to work collaboratively during the LS process. Desimone et al. (2002) also found that “collective participation of groups of teachers from the same school...as opposed to the participation of individual teachers from many schools” (p.83) was a key feature of effective professional learning. Data here equally identifies the value teachers associated with school-based LS. as the teachers worked together to both design and evaluate the research lesson.

6.2.5 Overall Significance of Collaboration

Wenger-Trayner and Wenger-Trayner (2020) attribute a significance to immediate value, in that it sets the emotional tone and the personal experience of learning, whether positive or negative. The above comments from all participants

highlight the positive immediate effect collaboration had on their experience of LS. Indeed, Brian's final reflective log indicated an emotional response to having participated in the LS process. He described how "the completion of this cycle of LS evoked mixed emotions. Gratitude for what has been achieved, respect for the incredible efforts of the students and the LS group, and a little disappointment that it was all over" (LS3, Study/Planning/Reflective Phase log). This highlights a positive immediate value attached to having been part of the SLS created by LS as a CPL methodology.

Overall, it would appear that the collaborative nature of LS as a method of CPL was identified as an immediate value by the participants, in terms of sharing ideas and vulnerabilities, and the mutual creation of resources, such as the TLP. It is noteworthy that the teachers themselves identified specific aspects of LS, including familiarity with their colleagues and the size of the group as significant factors in the success of the collaborative approach. Their words correlate with the findings of Smith (2014) who noted that participants "stressed the importance of professional development providing opportunities for teachers to collaborate with each other, share ideas and participate in pedagogical discussions" (p.481). Similarly, Murphy et al. (2015) found "a particularly positive aspect" of their CPD model was the "strong emphasis placed on collaboration" among teachers (p.12). It would seem that this research study emphasises the importance of collaboration among teachers as a significant feature of LS.

6.3 Extended Duration of the LS Cycle (Immediate Value)

The extended duration of each LS cycle was identified as a positive attribute by group members. Similar to the collaborative approach, this feature appears to be an indicator of the immediate value of participating in the LS group. An appreciation for

the time spent engaging with LS was evident from the earliest phases of the project. After the introductory Study Phase in LS1, Brian mentioned that “the longevity of the process is important” since “the speed at which classrooms and schools operate can seem daunting and overwhelming”. On the other hand, he viewed LS as taking “a more measured approach, there is time to breathe and this is very important” (LS1, Study Phase Log). This would seem to suggest that Brian found participating in extended CPL beneficial. Darling-Hammond et al. (2017) identify CPL of longer duration as one of the six key features of effective professional development.

At the end of LS2, the teachers chatted about the LS process, and considered whether each phase was worthy of inclusion. Caroline believed that the Study Phase was of crucial importance because it allowed the teachers to choose the topic for study together, which she felt caused them to be “motivated to do it properly” (LS2, Focus Group). She reiterated her belief that the Study Phase in particular was critical to the overall LS experience for both teachers and students at the end of LS3. She asserted that although the Study Phase (which consisted of four meetings according to the data) was longer in LS3, “we couldn’t have done those lessons if...we’d only half done it. We wouldn’t have gotten the same responses from the kids” (Focus Group). This indicates a link between the teachers engaging in an in-depth Study Phase and a subsequent positive effect on children’s learning. Caroline believed that the time taken to study pulleys during the Study Phase was “so worth it”. Similarly, I, as IKO, noted how “time consuming” that stage could be and participants could perceive “you are getting nowhere”, whereas “in actual fact everything else comes together quite quickly after a rich Study Phase” (LS3, Study Phase Reflective Log). It would appear that, like Brian, Caroline and I also attached value to the longevity of the LS process, and in particular the importance of not rushing the Study Phase.

It seems that the length of time taken to plan the research lesson was viewed as beneficial to the process. Caroline commented that “one of the main ideas” LS1 left her with was that “even seemingly short science lessons can offer such a wealth of opportunities and learning when you study and think through each step” (LS1, Planning Phase Log). Brian also shared her view, stating that “the time we dedicated to the planning was very important. It cannot be achieved in one or two sessions” (LS1, Planning Phase Log). For example, data indicate the Planning Phase of LS3 comprised six meetings. Similarly, Darren noted how “interesting” it was to bear witness to “how many times the lesson itself evolved and changed”. He acknowledged that “it was a long process” but balanced this by describing the duration as “really beneficial” (LS1, Focus Group Interview). Brian contrasted the long duration of the Study and Planning phases with the relatively short duration of the Teaching and Reflective phases. He wondered if “maybe it does go quicker because you’ve done the donkey work to begin with?” (LS2, Focus Group Interview). It would seem that most of the teachers believed that each LS phase had its place, and viewed the longer duration of the LS cycle as a benefit of this form of CPL, which led to a richer experience for those involved. Ding et al. (2024) also observe how the “careful lesson planning and deep reflections [involved in LS] require significant time” (p.95). The comments of the teachers above would appear to align with this sentiment.

At the same time, one of the teachers sounded a note of caution with regard to the length of LS. While Anna “thought the whole concept of LS [was] really good...because it’s such a slow and collaborative and detailed process”, she “[didn’t] know how achievable it would be”. She questioned “would it be viable really?”, taking into account “time, life, course curriculum” and other constraints (Anna, LS1, Focus Group). This correlates to the finding of Khokhotva (2018) that time is a barrier to the

implementation of LS. She reported that the majority of teachers in her study found the lack of time to integrate LS into the school routine a challenge. They could not allot time to LS during the school day so the meetings were held after work in their personal time. This was seen as a disadvantage. Indeed as I reflected on the LS1 Planning Phase I noted in my reflective log how “it just seemed to be so much work, so many hours of preparation for one lesson”. Similarly, Caroline identified the length of time it takes to engage in a LS cycle as a potential challenge to teacher participation. She believed that teachers “can’t afford to be spending hours after school, you know, meeting with teachers and all of that”. She asserted that “it would have to be done as a Croke Park¹¹ initiative” while believing that “if people realised how worthwhile [LS] was” they “would be happy” to do so. (LS3, Focus Group). Caroline’s view suggests that, just as Khokhotva’s research participants found it a challenge to participate in LS outside school hours, a similar barrier could block the expansion of LS in Ireland, unless it is incorporated into additional activities such as Croke Park hours.

Overall, the duration of LS gave the teachers time to engage with the process in-depth, which they considered a positive. Lengthy Study and Planning Phases afforded them the opportunities to steadily build up their SMK of paper spinners, light and shadows and pulleys. Furthermore, LS allowed them to take the time to develop their orientations to teaching science. It supported them to explore structured inquiry, guided inquiry, unstructured exploration and process orientations, as outlined in the previous chapter. Spending sufficient time planning the lessons resulted in effective TLPs which in turn had a positive impact on children’s learning as described in Chapter 4. However, some participants in this study cautioned that committing to the lengthy

¹¹ The Croke Park Agreement provides for an additional 36 hours per school year for Irish primary teachers, outside of tuition time. School management may use the time for activities such as staff meetings, CPL, pre and post school supervision.

process of LS may be a challenge for some teachers, similar to Khokhotva (2018). In terms of value, this would appear to connect the assertion of Wenger-Trayner and Wenger-Trayner (2020), whereby immediate value can be a stimulus for more engaged participation or cause disengagement. It would seem that the long duration of LS was favourable for some participants but not others, thus making time a potential barrier to teacher engagement with LS. On the whole, it would appear that the duration of LS could be perceived as a strength of the process, but also a challenge to its success.

6.4 Increased Teacher Confidence (Potential Value)

Wenger-Trayner and Wenger-Trayner (2020) believe that potential value is created due to a meaningful experience in a SLS. It occurs when participants in a SLS can take away something that goes beyond their direct experience in the space itself. It is called potential value because “it has yet to prove useful in practice” although they say that is not to diminish the value (p.88). Wenger-Trayner and Wenger-Trayner (2020) identify increased confidence as an indicator of potential value. All teachers noted an increase in their confidence to teach science during LS1. This increase was mentioned throughout the process, from the initial stages to the focus group interview at the end of the cycle. After the introductory phase Brian stated that he had “really enjoyed the LS and [had] grown in confidence as we have developed the process further” (LS1, Study Phase Reflective Log). Later on, while reflecting on the live research lesson, Anna referenced her increased confidence saying that “LS has had a positive impact where I feel that I would be more confident in teaching science”. In contrast she noted that “prior to this LS, science would have been a subject which I would have struggled with in terms of my own knowledge and ability” (LS1, Teaching/Reflective Phase Log). Anna’s comments indicate that participation in LS, and the development of her own SMK as a result, was responsible for her increased

confidence in teaching science. Once again, this links the contribution data of this chapter with the effect data of the last, the two culminating to highlight the value of LS as a social learning space.

Similar to Anna, at the end of LS1, Caroline summed up her experience by declaring that she felt she had “gotten so much out of it” and that she benefitted from a “confidence boost, above anything else” (Focus Group Interview). Brian commented that LS1 “demystified that whole sense of you needed to know things and you need to be an expert” while still maintaining the “quality of the lesson” and being able to “support the expertise the children will bring to it...and the learning [they] gained from it”. Anna retorted that she would “agree with Brian”, admitting that she “wouldn’t be as daunted by the process of teaching science” after LS1. Contrary to this, before LS she perceived that science lessons “always had to be a bit more complex”, whereas LS1 introduced her to the notion that she could “simplify it” which led her to feel “more confident” in teaching science. It is evident that the teachers related their increased confidence to teach science with their experience of LS1.

When data from LS2 were examined, it became apparent, that once again, teacher confidence was a key theme. Caroline explained that she had stayed part of the LS group as she found LS1 “so helpful” since her “confidence in teaching science [was] not that high” before the process (LS2 Focus Group). She suggested light as the theme for Cycle 2, based on her own lack of confidence in her ability to teach the topic effectively. At the first meeting, Caroline gave a rationale for this, while reflecting on a recent lesson. She stated, “I felt my lesson was very higgledy piggledy...I don’t know how many of their questions were actually answered...I didn’t feel that I had done my best teaching that particular day” (Caroline, LS2, Meeting 1). In contrast, at the end of LS2 she proclaimed that she “felt so much more confident teaching. And that was

having the same class, the same topic. And say a couple of weeks in the difference”. This indicates that LS2 had a positive impact on Caroline’s confidence to teach about light whereby she “felt really good teaching” the topic by the end of it (Focus Group Interview), connected to her increased SMK as a result of LS, like Anna above. In addition, Caroline also referenced how her experience of LS1 had given her “a little bit more confidence that I would be able to teach a lesson and have people watch me” in LS2. She based this on the fact that she had “had seen one [LS cycle] the whole way through, and I had watched you teach the lesson”. Not only had LS given her greater confidence in her ability to teach about light and shadows, it had also increased her confidence to teach a lesson in front of her peers.

Data from LS3 demonstrated a reduction in references to teacher confidence, when compared to LS1 and LS2. The positive impact of earlier LS cycles on participants’ confidence was identified by Brian during the final meeting when asked to compare the three cycles. He believed that “there was a greater confidence I think starting this [final] cycle” since the teachers were “building on what [they] had done already” (LS3, Focus Group). This would suggest that the development of teachers’ orientations and SMK, and the subsequent positive effect on children’s learning in LS1 and LS2 supported the teachers to commence LS3 with greater confidence in themselves. This reiterates a connection between increased teacher confidence as an example of contribution data and the effect data described in the previous chapter.

Ultimately, LS was favourably compared with concurrent CPL. Brian mentioned the “implementation of the Primary Language Curriculum” and referenced the various in-service days, webinars and “all the things we’ve had over four years”. The introduction of the new Primary Language Curriculum (DES, 2019), covering both Irish and English, included 8 whole-staff webinars to support teachers with its

implementation, in addition to a number of whole-staff in-service training days. Brian opined that “if you went around the staff and polled the staff and say who feels more confident now, I would hazard a guess very few”. On the other hand, he suggested that “if you asked those of us here and those who did LS previously how much more confident you feel, I’d say there would be a big difference” (LS3, Focus Group). This highlights how LS was noted as a contributing factor to the increase in participants’ confidence to teach science by the end of the intervention.

6.5 LS as an Opportunity for Reflection (Strategic Value)

Wenger-Trayner and Wenger-Trayner (2020) describe how a “key factor in the potential to make a difference is the strategic clarity that animates the learning of a social space” (p.106). They describe how strategic value includes “conversations among members about their learning imperatives as well as the conversations with outside stakeholders to fit the learning in a bigger picture of what matters to whom” (p.106). They note how the strategic value of a SLS can be indicated through frequent moments of reflection on the difference participants care to make and how their SLS can help them achieve it.

6.5.1 Reflection as a Gateway to Developing Teachers’ Orientations to Science

The difference participants cared to make in this research study, the “gap” perceived in the teaching and learning of science at the beginning of LS1, was in developing children’s scientific skills, providing opportunities for inquiry, and nurturing the ability to persevere when a task becomes challenging. Once the teachers had reflected on their ideals for the teaching and learning of primary science, they then embarked on their attempts to bring their ideals to fruition in the classroom through LS. A connection can be made between these gaps and the orientations subsequently

developed by the teachers as a result of LS and discussed in the previous chapter. Their wish to emphasise children's scientific skills manifested in the promotion of a process orientation. They developed their knowledge of IBSE through implementing both structured and guided inquiry in the unit plans and research lessons. The first step to developing their orientations was to reflect at the outset of LS1 on the changes they cared to make.

The teachers' initiation into LS involved becoming familiar with the LS process itself. At the very beginning of LS1, the teachers were provided with an introductory reading (Lewis & Tsuchida, 1998) which gave them an insight into how LS operates in Japan. They shared their thoughts and reflections on the reading during Meeting 2. It was noted that "in Japan they appear to go for depth above breadth", in terms of scientific content. On the other hand, the LS teachers perceived that in Ireland "we are the opposite...racing to tick boxes and cover areas" of the PSC. They contended that "the Japanese approach is looking at the broad goals, whereas we look at objectives which are nitty gritty and specific...we don't focus on the broader goals as much as we should here". It would appear that the teachers favoured the Japanese style, through the use of the phrase "as much as we should". As a result the question was asked, "Could we choose something broad from our initial conversation, for example, perseverance, as our research goal before refining it?" Gaining an understanding of the LS process in Japan, through reflecting on the work of Lewis and Tsuchida (1998), appeared to have an influence on the style of research theme selected by the teachers. When afforded the opportunity to make their own selection of focus, they decided to choose "something broad" in the style of the Japanese approach to LS. The group's initial conversations about what research theme to select, including an identification of what style of overall goal mattered to them, link to the strategic value of LS.

Following on from reading the article, the teachers examined the PSC as part of their refinement of the research theme. Consideration of curriculum documents culminated in a decision to “focus on the skills as they link everything together”, as the “long-term goal right now” (LS1, Meeting 2). Meeting notes record how the teachers’ phrasing progressed from discussing “development of scientific skills” to “development of the working scientifically skills”, in line with the PSC (DES, 1999a). The conversation again turned to discussing a desire to support “children working as scientists”. Ultimately this was refined to an agreed research theme that remained consistent throughout each LS cycle: that “all children would have the opportunity to work scientifically” (LS1, LS2, LS3 TLP). In my role as IKO, I informed them during LS1 Meeting 3 that “we as teachers must want to pursue this research theme. It must matter for us”. Anna determined that a focus on children “working scientifically will lead us where we want them to get”. The selection of the research theme was built on consideration of the difference the teachers cared to make to the teaching and learning of science in their school: the provision of opportunities for children to work scientifically. In other words, there was a strategic value attached to the research theme which pervaded each LS cycle. Data from Chapter 4 indicates that the teachers were indeed successful in the pursuit of this goal: they developed their orientations which in turn had a positive impact on children’s learning.

6.5.2 Reflection on the PSC

Data also show that LS led the teachers to question the curriculum, and reflect on their engagement with it. Some of the teachers alluded to a previous habit of rushing through topics from an overloaded curriculum before LS. For example, at the end of the LS1 Study Phase, Caroline described how her experience of LS made her “feel that

I have allowed the idea of a ticked box on a Cuntas Míosúil¹² to dictate the time I am willing to spend on each of the numerous science topics in our curriculum”. In other words, pressure to cover the content of her monthly plan, influenced the time she spent on scientific themes. She characterised her science teaching prior to LS as “racing through topics in order that most children will have a vague idea of many topics, as opposed to all children having a firm grasp of a few”. Her words indicate that she believed she was not teaching scientific content correctly before LS, since it resulted in most children having a “vague idea” of many topics as opposed to “a firm grasp” of a few. Caroline’s experience of LS led her to “wonder if our curriculum is doing us justice as we are tied to trying to get everything done but are surely compromising learning as very little has time to be done well”. Her words indicate that LS led her to consider the curriculum in a critical manner for the first time.

Similarly, Brian perceived that “we’re trying to do too much [in the PSC], and we’re doing an awful lot badly”. He observed that LS “showed me that doing one concept really well is far, far better than this thing of trying to do 100 different [things]” (LS2, Post-Lesson Reflection Meeting). Likewise, I noted how the LS2 Planning Phase “confirmed my belief that it is better to cover less material in-depth, rather than trying to cover lots of content superficially”. I believed that “giving the children a chance to explore a topic in depth allows them to really work as scientists – who surely do not jump from topic to topic in reality” (LS2, Planning Phase Log). Brian asserted that he “would much rather see somebody do that [LS2] light lesson for a whole month, and look at the amount of learning, the amount of language that they had, the amount of interaction that went on, as opposed to this thing of, we’ve tried to do light, we better

¹² A Cuntas Míosúil is an individual teacher’s written record of the work covered with students over the course of one month in Irish primary schools.

move on”. In his personal reflection at the end of LS2, Brian shared how he felt the “need to abandon my preoccupation with strands and strand units and I need to teach with a view to allowing the students to spend plenty of time with a topic”. His use of the word “need” implies that he perceived such a change in approach as of fundamental importance, which would be “far better for the students and...a greater use of time” (LS2, Teaching/Reflective Log). Brian’s words imply that LS enabled him to critically reflect on his use of the PSC (DES, 1999a) and suggest that he wished to spend greater time on individual topics as a result, which he perceived as necessary to improve the students’ experience of science in his classroom.

Like Caroline and Brian, Darren noted how “something like [LS] does really show the shortcomings of the curriculum, we’re overburdened”. Reflecting on our introductory reading (Lewis & Tsuchida, 1998) also led me to consider the contrast between “our loaded curriculum” and the “frugal curriculum” of Japan. However, I contemplated the potential shortcomings of a curriculum with reduced content, and wondered “would we embrace such a curriculum here or would the limited content be intimidating?” (LS1, Study Phase Reflective Log). It could be argued that curricula should strike a balance in terms of content which is neither too prescriptive nor too sparse.

LS appeared to encourage some of the teachers to look at the PSC with a more critical eye, while reflecting on their own teaching of science before the project. It would seem that LS brought about a shift in mindset, from skimming over many scientific topics prior to LS, in an effort to cover the content of what they perceived to be an overloaded PSC, to prioritising less scientific content but exploring that selected content in greater depth. The teachers perceived that this was more beneficial to the children’s experience of science, highlighted by Brian’s observation of the “amount of

learning” that occurred as a result of the approach taken to teaching light in LS2. It would appear that the teachers’ learning imperatives changed as they reflected on how best to use the curriculum, through their engagement with LS. This is another example of the strategic value of this CPL methodology, as evidenced in this study.

6.5.3 LS as an Opportunity for Collaborative Reflection and Self-Reflection

Participation in LS seemed to afford one of the teachers, in particular, an opportunity to consider the importance of reflection in his approach to teaching science. After completing the Study Phase of LS1, Brian commented that “perhaps teaching science effectively is about building in periods of reflection...I would hope that my approach to science might be improved in this way” (Study Phase Log). Later on, he described how reflection was built into the LS1 Planning Phase and how this was “critical” since “reflection was not criticism” but rather led to “honesty and support for one another” which was “really helpful” (LS1, Planning Phase Log). Opportunities for reflection were again mentioned by Brian during LS2, when considering how the Planning Phase may have impacted his view of the overall goal of science teaching. He observed how LS encouraged “a more robust and open minded self-reflection when planning and setting goals” (LS2, Study Phase Log). He noted how “the reflective sharing of ideas forces you to challenge some of the things that you are doing, which may not be wrong but certainly may need to be edited” (LS2, Planning Phase Log). It can be seen that Brian viewed the moments of self-reflection and collaborative reflection LS afforded him as beneficial to his approach to teaching science. This would suggest a connection between reflection and the development of teachers’ orientations, one of the effects of LS noted in the previous chapter. Similarly, Murphy et al. (2015) found opportunities for teacher self-reflection and group reflection were a “very important feature” (p.13) of their two-year science CPL programme.

Brian also considered the flow of learning which started in LS1, continued into LS2 and culminated in LS3. He believed that “each cycle of LS was feeding into the next one” and “the ever increasing circles allowed for a reverberation of learning”. His words align with the idea of flows and loops across the LS cycles, associated with learning in a SLS, as per the Value Creation Framework. Brian asserted that “the rich discussions and reflections from [LS1 & LS2] directly influenc[ed] how we directed our attention, scaled back our conversation and honed our collective enthusiasm”. In this manner, he felt that the group’s experiences of LS1 and LS2 enabled them to “eliminate the unnecessary or superfluous content and look directly at what might work for our school context” which was “crucial” (LS3, Study Phase Reflective Log). He perceived that the group’s experience of LS1 and LS2 contributed positively to the manner in which they could focus on a suitable approach to meet the particular needs of their own school environment in LS3. Brian’s words would appear to concur with those of the STEM Education Review Group (2016). They assert that CPL activities which are “sustained, contextual, and require participation and reflection are more likely to translate into good classroom practice” (p.36). It would seem that Brian’s comments are in line with literature that advocates localised CPL of longer duration that includes opportunities for reflection as a means of enhancing the experience of both teachers themselves and children in the classroom.

While just one teacher specifically mentioned reflection, when combined with other teachers’ consideration of their orientations to science, as outlined in the previous chapter, it would seem that LS provided all participating teachers with an opportunity to reflect on their approach to teaching science. Nilsson (2008) noted that reflection on teaching experiences is a critical aspect of the development of PCK for student teachers. She found that engaging science student-teachers in projects with a focus on reflection

on their own teaching of science supported them to make “insightful shifts in their thinking about their orientation toward science teaching and learning” (p.1297). This study would also suggest that reflection on teaching experiences is central to the development of orientations to teaching science as an aspect of PCK for in-service teachers.

6.6 Teacher Agency (Enabling Value)

Enabling value has been described as key to the sustainability of value creation (Wenger-Trayner & Wenger-Trayner, 2020). They identify participants taking initiative and the sharing of leadership and facilitation tasks as indicators of internal enabling value. Lewis and Tsuchida (1998) describe how in LS the teachers themselves are the agents for change. The findings of this study concur with this suggestion.

6.6.1 Agency within LS

LS enabled the teachers to identify perceived gaps in the teaching and learning of science in their school and plan three unit plans and targeted research lessons specific to those gaps. It empowered them to identify change and attempt to address it themselves. This feature of LS appeared to be novel for the teachers. They were more accustomed to attempting to implement change developed by others external to their context. For example, notes from LS1 Meeting 2 record that “taking ownership of a problem in our school, not something that is dictated to us from outside, is attractive”. I observed that “working together to discuss our gap, discussing our ideal students in terms of science...was very refreshing as we never get a chance to do this” (LS1, Study Phase Log). I noted how ordinarily our focus “tends to be on curriculum, inspectors etc., not the big picture of what we are trying to do as educators in the longer term”. Affording the teachers an opportunity to lead their own learning was identified as an

advantage of LS. In terms of value creation, giving teachers ownership over the LS process is an example of internal enabling value (Wenger-Trayner & Wenger-Trayner, 2020). They suggest that when participants take control of the process, their learning is more likely to be relevant to the difference that they want to make. It would appear that the autonomous style of LS, whereby the teachers identified the gap they perceived in the teaching and learning of science and subsequently tried to address it, was a valuable aspect of the intervention.

It was interesting to note that some of the teachers began to refer to the research lesson as “our lesson” during the LS1 Planning Phase, and that this continued in later phases of the project. Even in a practical sense, I observed how the teachers took ownership of the design of the children’s worksheet and “appeared to have more confidence in sharing their own thoughts and expertise” with regard to that since “we are familiar with our children and know the level of language they use” (IKO Journal). Caroline described how she “really enjoyed watching our lesson come to life and felt the accumulation of all phases had finally come together” (LS1, Teaching/Reflective Phase Log). As IKO, I noted how collaboratively working on the TLP made the process feel like “our project as opposed to my project” (LS1, Planning Phase Log), which I identified as an “advantage” of the Planning Phase. Similarly, Brian revealed how invested he was in LS1 when sharing how the “build-up and anticipation before the lesson was matched only by the joy of actually putting the whole plan in action”. He admitted how he “was surprised by how nervous [he] felt, given how prepared we were to implement what had taken several months” (LS1, Teaching/Reflective Phase Log). By the end of LS1 it was apparent that the teachers valued the experience of watching something they had chosen to address themselves come to fruition in a CPL environment. Indeed, Lewis et al. (2012) note how “well-designed lesson study

provides opportunities for teachers to experience agency as they choose the topic to work on... and human connection as they work on ‘our’ lesson for ‘our’ students” (p.373). It would seem that such features of “well-designed” LS, which are also examples of internal enabling value, were present in this research study.

This sense of teacher agency continued into LS2, whereby the EKO’s did not attend any meetings, but were available to support the group if needed. I noted in my LS2 Study Phase Log that it was “exciting to take ownership of the project ourselves” and looked forward to seeing “if we [could] pull it off!”. Brian revealed the impact the teachers’ experience in LS1 had on their approach to LS2. He stated that there “was a greater feeling of ownership of the lesson since the group had an overwhelmingly positive experience during the first cycle”. Furthermore, LS1 empowered the group to adapt their approach to the second research lesson. Brian shared his view that the first cycle “imbued us all with a desire to revisit the areas of the lesson that had been identified previously as positive but in need of refinement”. He gave the example of how the LS1 research lesson on paper spinners was too “ambitious in its content”, whereas for LS2, “there was a feeling that it might be more prudent to plan a lesson that explored a concept deeply without trying to overly anticipate every possible part of the topic”. Brian felt that this “deep analysis...might prove more beneficial for the students and indeed more manageable for the teacher” (LS2, Study Phase Log). Critiquing their own approach to LS1 emboldened the teachers to make what they perceived as necessary adaptations to their approach to the LS2 research lesson. Wenger-Trayner and Wenger-Trayner (2020) list conducting after-action reviews to reflect on an activity and its design as an example of internal enabling value. In this case, it would appear that the post-lesson reflection at the end of LS1 had a direct impact on the inclusion of less content in the LS2 research lesson. The teachers were informed by their review of

LS1 to make what they perceived to be necessary adaptations to the length of the next research lesson.

The final conversation of LS2 reflected how this sense of teacher ownership was identified as an attribute of LS. Caroline revealed how she felt the group “wanted to get four good lessons” that they “chose together”. In contrast, she believed that if the lessons had been selected in advance and presented to the group of teachers it would not “have been as motivating for us”. She also explained how, as teacher of the research lesson, she wanted “to do the lesson justice” since “we all created this...so much work has been put into it”. This would suggest that she felt a sense of responsibility to the group when teaching the lesson that had been collaboratively designed. She described how LS “was a real group, a real team effort”, to which Brian countered “whereas a lot of things are forced on us”. (LS2, Focus Group). This sentiment remained when participants were asked why they elected to be part of the final LS cycle. Brian commented that “we’ve invested a lot in it now, and you kind of feel I’d hate to stop now when we’ve put so much into it” (LS3, Meeting 1, Study Phase). Once again, it became apparent that the teachers identified the autonomous style of LS as a benefit of this approach to CPL. Brian’s comment that he would “hate to stop now” links with Wenger-Trayner and Wenger-Trayner’s (2020) description of internal enabling value as a sign that the space is creating enough value for participants that they identify with it and want to sustain it.

6.6.2 Agency as a feature of CPL

Engagement with LS as a CPL methodology led Brian and Caroline to reflect, at the end of LS1, on what CPL should involve. Brian suggested that “maybe the problem is that CPL is...structured incorrectly, in that it's trying to, to give teachers stuff

as opposed to saying to teachers, you have to kind of discover stuff for yourself, a little bit”. His words indicate a preference for more teacher autonomy in CPL activities. He followed this by asserting that “if LS did nothing else...it's kind of self-discovery a bit, that actually you have the resources, you have the abilities, you just need to kind of put it into practice”. Ultimately, he felt he “could go in and teach that lesson or a subsequent lesson armed with a lot of skills and a new mindset”. He concluded “that’s what CPL should be” and “LS can really contribute to that” (LS1, Focus Group Interview). Similarly, Caroline observed that LS was “so much better than any CPL I’ve done to date since it’s kind of the ‘teach a man to fish’ thing isn’t it?” (LS1, Focus Group Interview). Smith (2014) also found teachers to be critical of traditional types of CPL whereby they were “overloaded with information” (p.480). Brian and Caroline’s comments suggest that they felt empowered by acting as agents of change for their own CPL through their experience of LS, as opposed to being passive recipients of information in more traditional methods of CPL.

Consideration of what CPL should consist of was also referenced at the end of LS2 by Brian, and it was clear that he advocated a LS approach. He asserted that “there’s always this talk about investment. I’d say, stop investing in books and resources and actually invest in giving teachers time to do what we did” (Focus Group Interview). Moreover, by the end of LS3 Brian linked LS to “our School Self-Evaluation”¹³ since it forced the teachers to consider “what’s critical in our school? Or what’s critical in my teaching situation?” As a result he felt teachers could “use lesson study to really hone in on that...focus in on something really specific, do it really, really

¹³ School Self-Evaluation is a process of collaborative, internal school reflection, review and planning for improvement which was formally introduced to Irish schools in 2012.

well, and then actually other things will benefit from it” (LS3, Focus Group). Brian contrasted the autonomous nature of LS with other types of CPL whereby “in-service is exactly the same as it was when I started my teaching career...someone comes in and talks, they go through slides and they talk you through an entire day and you’re switched off by 11.00 because you think, my head can’t take this in”. Whereas he believed “you need to do something like [LS] in order to engage teachers and get them actually changing practice. Because it’s not going to work otherwise”. Such comments highlight the value Brian placed on teachers themselves being actively involved in their own CPL, as opposed to having change dictated to them.

It would seem that LS gave the teachers a chance to take ownership of their own professional development, through identifying and pursuing a gap in the teaching and learning of science, particular to their own school. This feature of LS was attractive to them, and led Brian and Caroline to consider how teacher agency could be a feature of effective CPL. Agency connects with internal enabling value identified as part of the Value Creation Framework (Wenger-Trayner & Wenger-Trayner, 2020). The teachers’ comments suggest that LS enabled them to become “agents for change”, as per Lewis and Tsuchida (1998), and that they welcomed such an active role in their own CPL. Indeed, it would appear that the choices they made were the catalyst for the overall effects of LS identified in Chapter 4 - the development in their orientations and SMK which ultimately had a positive impact on children’s learning in the classroom.

6.7 The Importance of Mentoring (Enabling Value)

Appleton (2008) and Hanuscin (2013) found the support of a mentor benefitted both preservice and in-service primary teachers to develop their PCK to teach science. In terms of value creation, mentorship appears to correlate with external enabling value

in the case of the EKO and internal enabling value in my case, acting as IKO. Data shows that both external and internal mentorship were valuable aspects of the LS process.

6.7.1 The Role of EKOs

The mentorship of the KOs in LS1 had a positive impact on the participants, particularly in the early phases. The EKO with expertise in LS guided the group through a discussion on what topic might lend itself to the development of prediction skills, which resulted in the selection of gravity and falling objects as the scientific content of the research lesson. The EKO with expertise in science sourced suitable readings on both gravity and prediction for the teachers to consider during the study phase. Having an EKO with experience in LS itself, as well as an EKO with expertise in the topic to be studied, in this case primary science education, would appear to align with the definition of LS KO proffered by Takahashi and McDougal (2016). They state that KOs should have both extensive knowledge of the LS topic and extensive expertise of LS itself.

Some of the teachers acknowledged how the expertise of the EKOs was beneficial to the group. Anna described how “the group meeting with the two (EKOs) was an excellent introduction to LS. It provided clarity and guidance to the process ahead in a pragmatic way” (LS1, Study Phase Log). Indeed, Anna furthered this point by suggesting that “without this [meeting] it would have been a very daunting process where commitment levels may have subsided”. Similarly, Caroline commented that “it was great to have the assistance of the KOs in order to lead us in the right direction” (LS1, Study Phase Log). I stated that I would strongly recommend [having EKOs] for a LS cycle with new participants” and how I believed we “benefitted as a group” from

having “one with expertise in the area of LS and the other with expertise in the area of science education” (LS1, Study Phase Log). During the LS1 Planning Phase, Caroline referenced the role of the KO through stating “it was nice to have...someone who was conscious and vocal of the true research goal”. (Planning Phase Log). I wrote in my own LS1 Study Phase reflective log that “there is no way that I, as IKO, would have been able to steer us through the initial weeks”. It is evident that the EKO’s were particularly important to the LS process during its introductory phases. This aligns with Takahashi and MacDougal (2016) who identify KO’s as a fundamental component of LS, providing additional support and contributing periodically, most notably at the end of the process but also at earlier stages, such as the Planning Phase.

However, by the end of the Study Phase the teachers shifted to conduct some meetings without the EKO’s present. I observed how “the conversation felt a little freer, as in, people were more willing to share opinions without fear of being wrong in front of an expert” (LS1, Study Phase Log). At the same time, I noted how the “downside is that if there was a question we wanted answered we had no one to ask!” I was in a position to put such questions to the EKO’s at a follow-up meeting. I regarded it as “important” to have “a mixture of both types of meeting – some with KO input and some just for participants”. After the Planning Phase of LS1, references to the KO’s lessened, whereas the sense of teachers taking ownership of the project, as in the previous point, increased. It could be inferred that the mentorship of the EKO’s was critical to the initial phases of the LS, as found by Khokhotva (2018), and that perhaps the teachers were less reliant on the mentors as they took ownership of the TLP themselves and their own sense of agency increased.

At the same time, I noted in my LS1 Planning Phase Reflective Log that “at times I found the Planning Phase very challenging – trying to think of everything while

wearing three hats – IKO, teacher participant and researcher can be overwhelming”. I grounded my own difficulties in “my own inexperience of LS”, suggesting that it could “have been more beneficial to me personally, and therefore to the other participants, had I been a participant in a LS prior to this”. In this manner, it could be suggested that in the early stages of LS1, although I labelled myself an IKO, in reality perhaps I was more a LS “facilitator”, a term used by Lewis (2016) to describe those who lead LS without experience of the process as participant teachers. Initially, I felt that “perhaps it was almost my duty as internal KO to lead the way” in teaching the mock lesson (remotely with other teacher colleagues in the role of students due to Covid-19 school closure). Indeed “selfishly” I wanted “to tick as many boxes as possible in the LS process as part of my research, to get a sense of what the different roles feel like” (LS1, Planning Phase Reflective Log). It would seem that it would have been preferable to have experienced LS solely as a teacher participant before embarking on the role of IKO.

During the Planning Phase the group switched to a mixture of meetings with the EKO's present and meetings on their own. While Anna described this as a “great balance”, I recorded that “there were times when I felt that I wasted the group’s time, led them down the garden path during meetings where the external KO's were absent”. Subsequently, I wrote how “the light bulb moment seemed to come after a meeting with the external KO's (on my own)”, during which they “kept emphasising the broad research goal” of giving all children the opportunity to work as scientists. I perceived how as a result of that meeting, the importance of the research goal “finally clicked with me” and “I seemed to be able to lead the group through the TLP effectively”. Notwithstanding this progress, when we had decided on the research lesson activities, we invited the EKO's to meet us again, “for guidance on the sections of the TLP that we

weren't sure of" (Researcher, LS1, Planning Phase Log). It would appear that while mentions of the EKO were reduced in the data pertaining to the teacher participants after the LS1 Study Phase, their assistance was still key to the remainder of LS1, particularly in their support of my developing role of IKO.

6.7.2 The Role of IKOs

Data from LS2, where the EKO were not part of the process, showed that the teachers turned to Darren, who is a science graduate, as their science IKO, particularly when they wanted to check or develop their SMK. It was included in the TLP that the group "benefitted from a group member's background in science in order to better understand certain concepts". Brian also emphasised the importance of Darren's background in science to the group at the end of LS2 when he stated "it was great having a knowledgeable other that did know [the scientific concepts]. I found that really helpful" (Focus Group). He also felt that familiarity with Darren, acting as science IKO, was a bonus, sharing how "knowing the knowledgeable other is helpful since it is easier to ask questions, probe and be wrong". (LS2, Planning Phase Log). Darren's ability to mentor the group as science IKO was a key factor in the development of their SMK with regard to light and shadows in LS2. His expertise highlights the importance of having a KO with extensive knowledge of the topic at hand (Takahashi and MacDougal, 2016). Interestingly, Darren, as science IKO, revealed a discord between his SMK and his own level of confidence to teach science, echoing a finding of Magnusson et al. (1999) that SMK is not a guarantee of ability to teach science effectively. They caution that having SMK does not ensure teachers will transform it "into representations that will help students comprehend targeted concepts" (p.18).

Wenger- Trayner and Wenger-Trayner (2020) assert that the more successful internal enabling value is, the less visible it tends to be, since good design enables social learning rather than directs it. While acting as IKO, I did not use that term to refer to myself in the LS group. However, at the final meeting of LS3 Brian, in reference to me, commented that “You were a knowable [sic] other even though you didn’t realise it, but you were. A lot of the time you were the knowable [sic] other. It was very important” (Focus Group). Caroline also valued the preparations I made in advance of each meeting, referencing how I “obviously [came] in with a plan, everyday we know what we’re going to do...I loved that you would come and say, OK, we’re going to do this, this and this today” (LS3, Focus Group). She surmised that I “made all those big decisions for us, which I like, you’re just leading us”. Her comments link to efficiency which Wenger-Trayner and Wenger-Trayner (2020) identify as an indicator of internal enabling value. They note how meetings which run productively, as described above by Caroline, are a positive example of enabling value.

While Brian and Caroline appeared to view me as an IKO, without using the term directly, my own personal reflective logs, written after each LS meeting over the three cycles, record how it took time for me to feel comfortable in the role. My first recorded log (LS1 Meeting 1) notes how I “didn’t really feel like a KO since the presentation was given by the LS KO”, but at the same time my “confidence had increased by the end” as I felt “I had shown some leadership”, albeit “a small amount”. This log includes phrases such as “feeling a bit of pressure” and “nervous” in advance of “hosting external KOs” and being conscious of “colleagues giving up their free time”. However, since the “informal feedback was very positive” I deduced that “anyone who stays with the project now will do so out of their own interest”. This would suggest that I felt uncomfortable with an IKO label which I did not feel I had

earned, due to my own lack of LS experience, as well as a sense of responsibility towards colleagues, who were voluntarily participating in the research study.

At the first meeting I experienced a sense of conflict between my role as researcher, IKO and participant teacher. The LS KO invited the teachers to identify what they would consider to be the ideals for the teaching and learning of science, as well as their actual practice and whether there was a gap between the two. However, when asked for feedback it “stopped with the person beside me”. I observed how, from my point of view, this “made it difficult to feel like a ‘real’ participant”. It underlined for me, at any early stage, that I was walking the boundary between being a participant teacher, and an emergent IKO, not fully at ease in either role. I perceived I had too much experience in the area of science to be regarded as the same as the other participant teachers, and conversely not enough experience of LS to have earned an IKO badge.

Data also highlight how I was conscious of not becoming too vocal at meetings, aiming to leave space for others to share their views. After LS1 Meeting 2, I described how “I tried to let others give feedback first so as not to be talking too much” in case I was “influencing the conversation”. Similarly, after LS1 Meeting 4, I wrote how “I felt I was talking too much today” and wondered “am I too invested?” Overall, I aimed to “provide guidance without pushing my own agenda too much” (LS1 Meeting 2). At the same time I was “aware of personal bias” in terms of teachers’ orientations, “knowing that I am interested in [scientific] skills”. I wondered “am I pushing them because they link to my interest? Or because I have written about them previously in a literature review? Or is it a genuine gap for our students?” I concluded that it was the latter but that I was “mindful of bias”. As it happened, some of the other teachers mentioned

skills as areas of interest in the first meeting, so it would appear that I was not alone in advocating the development of our process orientation to teaching science.

I was eager that the LS project would not be regarded as “my project” but rather “our project” by the group and recorded how I emphasised the phrase “our project” during the group meetings (LS1 Meeting 2). I was hopeful that as the process progressed this shift would occur naturally, wondering if “perhaps when the research theme and topic are nailed down...it will really be a group project then”. I was particularly “delighted when [Caroline] took it upon herself to add icons to the children's worksheets” (LS1 Meeting 9) as this indicated buy-in from others. Similarly I logged how I was “heartened that [Brian and Caroline] took detailed notes without being asked to” at the LS1 mock lesson. I inferred that it “suggests high interest and commitment to the project” (LS1 Meeting 10). Such recordings highlight how it was significant to me that the other teachers were invested in the project like I was, albeit in a different manner.

Personal logs show the successes and challenges of developing my role as IKO during LS1. I observed how I was able to “lead the conversation on the research theme” during LS1 Meeting 3. I recorded how notes from earlier meetings and the Mills College website itself gave me the confidence to do so. I had planned what to say in advance. At the end of LS1 Meeting 4, I wrote how I “took the initiative to suggest the next meeting should only be teachers”. I believed that, in the absence of EKO's, we would be able “to thrash out what our ideas for lessons should be”, thereby “taking ownership of our project”. However, I later reflected on “how difficult it is to be an IKO when I have no experience of LS myself” (LS1 Meeting 7). I questioned “was this too ambitious?” I felt a sense of guilt that “it wasn't until our third teacher meeting (third hour of work) that we started to get our heads around the TLP”, which I felt “all

falls back on me”. Possibly the lowest point of LS1 was when I perceived “I didn’t have a proper understanding of what I was trying to do and therefore I led the group in the wrong way”. At that point, having a meeting with the two EKO’s on my own (described in the previous section above) to discuss the research theme and unit plan was “invaluable” and a turning point in the first cycle which from then on progressed without significant obstacles, save from Covid-19 restrictions, to its completion.

Data from group meetings highlight the role I had in steering the LS teachers through the process, most especially during LS2 and LS3. Once again at the beginning of LS2 I recorded how “I think I need to remind myself that although this is ‘my’ research it’s ‘our project’”, and returned to pondering “do I take over?” at group meetings. In contrast to LS1, I wrote how after the first LS2 meeting “I did have a sense of having the ability to guide this LS through”. I reflected on how I “would not have felt like this in LS1” where I was, in my own words, “heavily reliant on EKO’s”. This represents a development in my role as IKO. I also contemplated the voluntary nature of the participants as LS2 commenced, asking “do I also need to stop thanking participants [for being here] and just accept that perhaps they’re there because they want to be and it’s beneficial to them too?!” This too suggested a change of mindset from LS1.

I described in LS2 (Meeting 2) how I perceived myself as “guiding where we’re going, keeping the focus on children working as scientists”. I was concerned that we were “in danger of getting caught up in ‘perfect lesson’ planning”, focusing too much on the nitty gritty rather than the overall goal. This is interesting, given that when I was struggling during LS1 and reached out to the EKO’s for support they “kept emphasising the broad research goal”. Their advice enabled me to guide the LS group through the design of the unit plan and subsequently the research lesson. It would appear that their

guidance stayed with me at the onset of LS2. I observed after the next meeting how valuable the personal logs were to me. I wrote how “this journal is helping me reflect on things I want to focus on”. I referred to my worry the previous week of “getting caught up on the ‘perfect lesson’” and how as a result I “rowed back today to the research goal of working as scientists” and focused on the unit plan. As a result I felt “happier” after Meeting 3, grounded in the fact that we had an “overall plan now”, as opposed to directing our attention on one lesson without giving due attention to the research theme itself.

At the same time, LS2 was not without its challenges. I wrote that “I do feel like LS KO but not really science KO”. This was rooted in the fact that during both LS1 and LS2, I was building my own SMK for teaching about falling objects and light, in line with the other LS teachers. In addition, I was in the presence of Darren, a science graduate, who duly assumed the role of science IKO when we set about conducting LS2. While our EKO's each had an area of expertise - one in LS and one in science education, I continued to doubt my ability to wear both hats as IKO, given the gaps in my own SMK for teaching science. While I could reach out to my supervisors as EKO's whenever I felt it was necessary, I also acknowledged the Mills College website (<https://lessonresearch.net/>) as a “very helpful” source of support. I appreciated its “step-by-step instructions which I look[ed] over in advance of each meeting to help plan what to do” (LS2 Meeting 3). I used this practice as a means to compose an agenda in advance of each meeting with the teachers which I shared via WhatsApp. I believed this strategy “works well as we all know what needs to be covered and it gives me a focus” (Meeting 6). Furthermore, I believe that having a resource which guided me on how to conduct a LS cycle also served as a confidence booster as we moved away from relying on the EKO's. It almost seems as if the Mills College website and Darren himself

were substitutes for the LS EKO and the science EKO in LS2. This would indicate that although my place as IKO was more established than LS1 I still needed external support during LS2, even if it was in different forms.

As LS2 came to a conclusion I reflected how during the Focus Group I was conscious of walking the boundary line again. I described how I “shared some of my opinions honestly but was concerned that I might influence the conversation too much” so I tried to leave space for the other teachers to contribute. That said, I concluded how “it did feel more like a chat so that was good”. My attempts to guide the process in an almost understated manner could connect to the assertion of Wenger-Trayner and Wenger-Trayner (2020) that the more successful internal enabling value is, the less visible it tends to be. They suggest that good design enables social learning rather than directs it. I consciously never referred to myself as IKO in front of the group. Perhaps that initially stemmed from my lack of confidence in having earned the title, as described earlier. At the same time, I was keen for the project to be viewed as “our project” rather than “my project” as outlined above. It could be inferred that this sense of collaboration within the group jarred with the notion of marking myself as different through describing myself as a knowledgeable other. This made it all the more noteworthy when at the final Focus Group in LS3 Brian told me “you were a knowable [sic] other even though you didn’t realise it, but you were”. It could be seen as interesting that although the sharing of ideas and vulnerabilities was viewed as a valuable aspect of the collaborative nature of LS, I chose not to share this aspect of my role with the other participants. On the other hand, it could also be seen as interesting that despite my efforts to almost conceal my role as IKO within the group, I was still spotted.

Moving on to LS3, some of the successes I identified earlier in the process were still worthy of celebration when they occurred. I described how it was “great” that Caroline added ideas to the shared folder because it meant that “I’m not the one pushing everything” (Meeting 2). Once again, I valued when the other teachers took the initiative themselves as an indicator that it really was “our project”. Similarly, later on in LS3, I wrote that “my role is made so much easier because of the buy-in and commitment from the other teachers”. I added that “this makes me feel like I am not forcing the project, it really is a collaborative group, a team effort”. I perceived that as an achievement of the research study. I believed that I was “guiding the overall process” which almost seems to align with the guided inquiry orientation promoted by the teachers during LS2 and LS3. I aimed to be a facilitator of the teachers’ learning, rather than controlling it. Interestingly, I observed that I felt “more like IKO when we’re working on the TLP” (Meeting 5). Fulfilling our obligation to complete those records of each LS process was an area where I felt comfortable assuming a leadership role.

As we neared the end of LS3, I considered the importance of reaching out beyond the group to share some of our experiences with another stakeholder, the principal of the school. I recorded that we held a “brief chat about approaching the principal with a view to giving feedback at the end of the cycle” (Meeting 7). I wondered if my eagerness to do so was influenced by my engagement with the Value Creation Framework and a resulting concern that it was important to share our worthwhile experience outside of the group itself. At the same time, I wrote that I felt it was “important to give feedback as a team”, believing that giving feedback together would hold more weight than me doing so alone. Once again the notion that it was “our project” came to the fore.

Considering the effect data outlined in the previous chapter, it would appear that in my role as IKO I supported the teachers to reflect on the orientations to teaching science they wished to promote in the classroom. In practice, this was initiated through focusing as a group on the research theme, or long-term goal we would follow. At the beginning of both LS2 and LS3, I asked the teachers to consider the research theme and on each occasion they elected to retain the LS1 research theme that “all children [would] have the opportunity to work scientifically”. Later on, as we began working on the TLP, I reminded the teachers that “the most important thing to keep in mind the whole time is our overall research goal...that the children will work as scientists” (LS2, Meeting 3). I incorporated this into the research lesson plan, suggesting that the children would be initially told “ today you’re going to work as scientists, and sometimes scientists create a model to try and explain...” (LS2, Meeting 5). Furthermore, I proposed that the lesson would end by reemphasising “how they were working as scientists today: asking questions, analysing results, creating models”. In this manner, I connected the overall research theme with the procession orientation towards teaching science and its focus on skills development.

In terms of the development of teachers’ SMK, I encouraged them to contemplate “what we find hard to teach” while selecting the content topic for LS2. This resulted in Caroline sharing her experience of finding it a challenge to teach about light and shadows, the topics which were chosen. I later described how we could use the concept cartoons “to build up our own confidence” since “from a teacher point of view you can read what a scientist might say” (LS2, Meeting 1). At the end of LS2 Meeting 2, I instigated a “play session” with the materials which the teachers later categorised as very valuable to their developing SMK.

Through my role as IKO, I maintained focus on children's learning through the LS process. I used our reflection from LS1 to inform the group at the beginning of LS2 that we had identified how the children had spent too long writing predictions in the LS1 research lesson. As a result, I suggested that perhaps it would be more beneficial to them if "we're recording and they're doing", affording the children more time to engage practically in the lesson, while the observing teachers recorded their thoughts (LS2, Meeting1). That is how the research lesson came to pass. At the same meeting, I reminded the teachers how we had focused on the children during LS1 through ascertaining "their concept level at the beginning...and then try and get it somehow again at the end of the lesson". Furthermore, when identifying a theme for LS2 I asked the teachers to "focus on the children, what they find hard to do or grasp". When the theme of light was selected, rather than blindly following the curriculum guidelines I asked the teachers, "where do we think the children are at?", having experienced periods of school closure the previous year due to Covid-19. I proposed using concept cartoons as a means to elicit children's thinking since "they give the children something to talk about because the characters are already there sharing their ideas" (LS2, Meeting 1). Ultimately, during the LS2 Post-Lesson Reflection meeting, I returned to the children, stating "so we wanted to bring them on in terms of light, and we also wanted to see if they would be able to analyse their findings. So how do we feel they did with that?" While it was working collaboratively which ultimately led to the positive impact LS had on children's learning outlined in the previous chapter, it is evident that, as IKO, I prioritised the students during the group meetings.

My final LS3 log entry notes an "overwhelming sense of pride observing the research lesson" (Meeting 10). This was based on the fact that "the children showed deep understanding of pulleys (in the main) and achieved what we set out for them - an

understanding of how to create a compound pulley and an appreciation that they make things easier to lift". This would suggest that while supporting the teachers to develop their own sense of agency was important to me, ultimately a positive impact on children's learning was a key factor in determining the success of the LS project. It also shows progression in my own role as IKO, from the inward looking notes of the first meeting in LS1, recording how "nervous" I was, to the outward looking nature of the final entry, focused on the most important stakeholders in the process, the children themselves.

Wenger-Trayner and Wenger-Trayner (2020) ascertain that people who do the enabling help create the conditions for caring about what matters to participants, for engaging uncertainty and for paying attention. The following exchange between Brian and Caroline suggests that this was achieved. Brian explained how he felt "very listened to by everybody and your opinion is valued, so that's really important". He associated that with my role as IKO, stating "that was down to you, Researcher, because you kind of set up that feeling, so that was really important". (LS3, Focus Group). Caroline supported his view by sharing that she felt that "the way that you've set it up, we don't feel like, oh God, it's Researcher, so you can't say anything stupid or tell her you don't know something, because you've already set up that atmosphere of you can say you don't know and that's fine and we'll figure it out together". She identified my role as "you are the leader but we don't feel like we're being led. It's very kind of, you know, collaborative" (LS3, Focus Group). This would appear to echo the assertion of Wenger Traynor and Wenger Traynor (2020) that the more successful internal enabling value is, the less visible it tends to be. It would also seem that the democratic nature of the LS group was of benefit, connecting to the assertion of Ostovar-Nameghi and

Sheikhahmadi (2016) that teacher collaboration is conducive to professional development and growth if it is democratic rather than dictated.

Wenger-Trayner and Wenger Trayner (2020) list sharing leadership and facilitation tasks among participants as examples of enabling value. Whereas I acted as teacher for the LS1 research lesson on paper spinners, Caroline volunteered to act as teacher for the LS2 research lesson on light and shadows. She observed how “I never would have volunteered or even accepted being the teacher in [LS1]” (LS2, Focus Group). On the other hand, Caroline described how her experience of LS1 and her developing sense of confidence supported her to carry out the role in LS2. She shared how “I had seen [a LS cycle], you know, the whole way through, and I had watched you teach the lesson, and I had a little bit more confidence that I would be able to teach a lesson and have people watch me”. It would appear that watching me facilitate the first research lesson had encouraged Caroline to undertake the role in LS2.

When it came to LS3, Caroline offered the teacher role back to the group and I asked Brian if he “would like to experience being the teacher...to tick a LS box?” (Meeting 1), to which he agreed. He later expressed a concern that he was “not a knowable [sic] other” but I encouraged him through explaining that he “didn’t have to be”. As IKO, I reassured Brian that he had the necessary skills to facilitate the research lesson before he took on the role. He then concluded that he would “be learning an awful lot doing this which is great” (Meeting 5). Furthermore, I suggested that Brian would observe Caroline teaching the earlier lessons in the unit plan, as I believed it “would help...[to] know what had come up already” (Meeting 5). He concurred that he would “be delighted...[as] it would be hard to come in and teach cold if [he] hadn’t been part of the rest of it”. In this manner, I offered a practical way through which Brian could build an awareness of the children’s engagement in the earlier lessons of the unit

plan, therefore boosting both his knowledge of their conceptual understandings of light and shadows and his confidence in advance of the research lesson itself. As IKO, I supported him to share in the leadership roles in the LS process.

Brian and Caroline also shared the value they placed on having internal leadership, in comparison to external mentorship. Brian was keen “not to disrespect” the EKO’s but explained how he was “very aware that these are people coming from an academic background who have so much knowledge and so much experience”. Caroline felt that was “intimidating” whereas they knew me “as a person” (LS3 Focus Group). In addition they viewed me as a “classroom practitioner...someone who’s in the actual teaching and learning every day”, an aspect of my role that Brian “really valued”. He felt that “you can kind of bring up things that you would say, yeah, Researcher knows what that’s like”, to which Caroline agreed. It is evident that they both valued the presence of an internal mentor to the LS process. This is at odds with the value placed on the EKO’s at the beginning of LS1. However, it does link to the assertion of Wenger-Trayner and Wenger-Trayner (2020) that the emergence of internal enabling value is a good indication that a group is becoming self-sufficient, and a sign that the SLS is creating enough value for participants that they identify with it and want to sustain it. In addition, Wenger-Trayner and Wenger-Trayner (2020) observe that there is a flow between external and internal enabling value. They suggest that “techniques provided through external enabling should ideally be absorbed into the repertoire of participants in a space” (p.104). It could be argued that, in this case, the internal enabling value attributed to my actions as IKO, and through the development of participants’ sense of agency, was a result of the EKO’s mentorship during LS1. Both elements, the external enabling value which initiated LS, and the internal enabling value that emerged during it, were of central importance to the process.

6.8 The Wider Impact of LS (Transformative Value)

Wenger-Trayner and Wenger-Trayner (2020) describe transformative value as when the difference participants care to make has broader effects. However, they note that it can be difficult to assess, given its wide scope. Given the short time frame of this research, it is difficult to measure any potential transformative value, but reference will be made to potential transformative value that participants referenced themselves.

The teachers remarked on how an article discussing Japanese LS (Lewis & Tsuchida, 1998) evoked “a sense of wanting to improve the person as a teacher, as well as improving the culture within the school and the curriculum” (LS1, Meeting 2). They identified this feature of the article, which pointed to the potential broader impact of LS as “significant”. The teachers also noted that “there was a hope that something as small as a research lesson would have a wider impact, on the curriculum and on how teaching and learning would progress” (LS1, Meeting 2 Notes). This highlights that from the outset the LS teachers were enthusiastic about the potential of LS to have a far-reaching impact, beyond that of the research lesson itself. They had an expectation of the transformative value of LS.

In terms of actual realised transformative value, one of the teachers, Caroline, commented on the impact of her participation in LS1 on the wider curriculum, noting that she had “never been more excited to teach science, and the idea of allowing the children to discover and learn independently has permeated into my teaching of other subjects as well” (LS1, Teaching/Reflective Phase Log). This would suggest that the development of Caroline’s child-centred orientations to teaching science had expanded to other areas of the curriculum. Caroline further elaborated on this in the LS1 focus group interview, explaining that she believed LS had improved her approach to teaching

all of the Social, Environmental and Scientific Education¹⁴ (SESE) subjects, as opposed to just science which she described as “great”. This relates to the finding of Ní Shúilleabháin and Seery (2018), that LS can develop new pedagogical practices both inside and outside the study.

In addition, Caroline believed that LS1 enabled her “to think very specifically on what you want to teach” (Focus Group). She believed that this meant “when we were observing the lesson, we already had in our heads the type of thing that we were looking out for...to hear if your children understood or had a concept of whatever”. In contrast, prior to LS she “felt like you were just getting the lesson done...you didn't really check at the end of the lesson if anything had been learned. It was just box ticked, *cuntas míosúil* (monthly report) done”. Caroline thought that LS gave her a clear awareness of the aim of her unit of work which she viewed as “one of the big things about Lesson Study that was really good”. Similarly, Anna spoke about how LS1 was “so focused..I just felt that that gave us the opportunity to really hone in on what we were looking for”. Likewise, Darren characterised the process as “brilliant” since it brought science teaching “down to something very simple as to, what do you want the children to learn, how can you observe it”. The teachers' words suggest that LS had a positive impact on the development of focused lesson goals and the ability to assess children's learning as a result.

Furthermore, Caroline described how she aimed to transfer her LS experience to other strands of the curriculum, when planning “a series of lessons where from the start, I know that this is my end goal, because I find that so helpful in teaching the lessons” (LS2, Post-Lesson Reflection Meeting). Caroline hoped to apply the goal-

¹⁴ Social, Environmental and Scientific Education comprises history, geography and science.

driven, unit plan approach of LS to other areas of the science curriculum, highlighting a potential transformative impact of LS. Her words link to the comment of Murphy et al. (2023) whereby the clear articulation of learning goals in curriculum frameworks, and teacher involvement in their design, is fundamental to seeing improved STEM experiences for primary school children.

While Caroline commented on how participation in LS1 could potentially influence her teaching of the wider curriculum, Brian seemed to develop that opinion during LS2. He believed “that in planning one unit effectively, sincerely and with genuine consideration for what would actually happen in the classroom, we impacted how we would teach not only science, but other subjects too” (Planning Phase Log). This belief was sustained by Brian during LS3 whereby he opined that LS had “become embedded in what we do and...has certainly influenced other areas of the curriculum and the approach that is taken to planning lessons” (Planning/Teaching Reflective Log). He asserted that LS had “encouraged a more introspective view on how to teach. This has been transformative” (Planning/ Teaching Reflective Log). Brian’s comments point to the potential long-term impact of LS on teaching and learning, beyond the research study itself.

It has been discussed earlier how LS afforded the teachers an opportunity to reflect critically on their use of the PSC (DES, 1999a). For some, such as Brian and Caroline, they concluded after experiencing LS that they would shift from a previous practice of teaching many topics in a superficial manner, to spending more time on less content in the classroom. Brian, in particular, expressed a wish to “abandon my preoccupation with strands and strand units”. Interestingly, the manner in which the LS3 unit plan was devised suggested a change in the manner in which the LS teachers used the PSC (DES, 1999a). During LS1 and LS2, the teachers had consulted the

curriculum as a means to devise the unit plan lessons. However, in LS3 there was a shift whereby they chose the topic of pulleys, in line with the PSC (DES, 1999a) but created a set of lessons based on the resources they encountered during the Study Phase and the subsequent investigations they embarked on themselves. It could be argued that the teachers were less reliant on sourcing content from the PSC (DES, 1999a) as a result of developing their own SMK during the LS3 Study Phase.

Brian described how the group “formulated a very feasible series of lessons with relative independence and could then use the curriculum to affirm our practice” (LS3, Study Phase Log). He characterised this “as a real triumph”. In contrast to his approach of “trying to do too much” (LS2, Post-Lesson Reflection Meeting) prior to LS, he observed that in LS3 “we were less burdened by the demands of the curriculum and it felt as though the curriculum was supporting us and our context for what felt like the first time”. Brian’s words indicate a broader effect of LS on the teachers’ use of the curriculum as a support material rather than a didactic resource. The teachers’ comments are particularly timely given the publication of the *Draft Science, Technology and Engineering Education Specification* (NCCA, 2024), where there is a move from the current lists of specific learning objectives to broader learning outcomes.

Caroline revealed the value she placed on LS outside the cycles themselves as she explained why she stayed in the group for the final cycle. She spoke about how she had “been really enjoying it” and how LS was “always in the back of my mind” at other times of the school year (LS3, Meeting 1). She described such occasions as when she felt that she was “not getting [science] taught properly” or when there were “bits and pieces of science” that she perceived the children “were not really getting”. Caroline shared that in these instances she would say to herself “Oh well there’s always Lesson Study”, implying that she associated LS with a positive experience of teaching and

learning science. Her words link to the research of Ding et. al (2024), who in a review of LS in mathematics instruction from 2015 to 2022, found that LS had a positive impact on both instruction and student learning.

Interestingly, Brian noted a change in mindset, an indicator of transformative value, after one cycle of LS. He shared his view that “there’s a sense that you have to come out of CPL with either a template or a resource. Whereas to be fair, at the end of this, we didn't come up with anything except a change of mindset, and a change of attitude” (LS1, Focus Group Interview). This indicates the potential power of one LS cycle to influence positive change for individual teachers.

6.9 Conclusion

Data gathered during LS1, LS2 and LS3 led to the development of themes regarding the value teachers attributed to LS as a form of CPL for science, in other words examples of contribution data. These include the importance of collaboration in CPL and the duration of LS which are forms of immediate value. Potential value was noted through an increase in teacher confidence to teach science. Some teachers identified opportunities for reflection as a positive feature of LS, which could be described as strategic value. The development of a sense of ownership of the CPL, while at the same time benefiting from the mentorship of the KOs, were identified as significant aspects of LS both connecting to enabling value. Two teachers commented on the positive impact of LS on their approaches to teaching both science and other subjects of the curriculum which could be deemed indicators of transformative value. These findings suggest that LS as a SLS has features of effective science CPL, as highlighted in the literature review.

Wenger-Trayner and Wenger-Trayner (2020) describe how both effect and contribution data are informative, but that it is together that they achieve their full scope to create a powerful image of the value of a social learning space. The findings of this study concur with such a view. The effect data outlined in the previous chapter highlighted the impact of LS on the teaching and learning of science, in other words *what* value was created: the development of teachers' orientations to teaching science, an increase in their SMK, and the subsequent positive influence on children's learning. The contribution data shared in this chapter underline *how* LS achieved this: through collaboration, its long duration, building teacher confidence, offering opportunities for reflection and teacher agency as part of CPL while benefiting from both external and internal mentorship. The combination of both data sets, effect and contribution, creates a compelling case for the use of LS as an effective method of CPL.

CHAPTER 7: DISCUSSION AND CONCLUSION

7.1 Introduction

This research study explored LS as a CPL methodology for primary science. Data showed that LS had a positive effect on the development of teachers' orientations to teach science and their SMK, which ultimately benefited children's learning in terms of conceptual understanding and the development of scientific skills. Several features of LS were identified as having contributed to these effects: its collaborative nature, extended duration, impact on teacher confidence, opportunities for reflection and teacher agency, and the support of internal and external mentors. This concluding chapter begins with an overview of the rationale for the study, and the subsequent research methodology that was undertaken to address the identified research questions. The key findings of the study are discussed, followed by a presentation of the contribution to knowledge made by this research. Recommendations are proposed for future research, practice and policy. A short personal reflection will be included before the concluding remarks.

7.2 Overview of the Study

The need for increased levels of PCK and SMK among teachers in addition to a lack of confidence to teach science and low levels of participation in CPL were all identified as factors that hinder the teaching of primary science in Ireland and internationally. Furthermore, research reveals that there is a need to develop both the use of IBSE teaching methodologies and children's scientific skills. LS was identified as an effective method of CPL. In light of these challenges, this study aimed to explore and evaluate the use of LS as a CPL methodology for primary science. It was based on the following broad research questions:

1. What is the effect of school-based Lesson Study on the development of primary teachers' pedagogical content knowledge (PCK) in science?
2. What features of school-based Lesson Study are most effective in supporting the teaching of primary science?

A review of the literature led to the identification of a conceptualisation of PCK needed to teach science (Magnusson et al., 1999). While the conceptualisation lists five components, this research study focused on one, teachers' orientations, which "refer to teachers' knowledge and beliefs about the purposes and goals for teaching science" (Magnusson et al, 1999, p.5). This led to the development of a sub-question connected to the first broad research question above:

What is the effect of school-based Lesson Study on the development of teachers' orientations towards science?

A sub-question was constructed from the second research question above, based on my developing role as IKO in the LS process:

What is the experience of an IKO in school-based LS?

Consideration was also given to the nature of scientific inquiry and IBSE. Social Learning Theory was examined as part of the theoretical framework for the study, which led to an identification of LS as a SLS, a more recent development in the area of COP.

Three LS cycles were conducted over the course of three school years in Greenwood School. The project began with five participants in LS1 (including me in the triple role of participating teacher, IKO and researcher), continuing as four participants in LS2 and concluding with three teachers in LS3. My two supervisors

acted as external mentors, in the role of EKO's. The teachers followed the LS phases of Study, Plan, Teach and Reflect, and conducted a live research lesson with students from Greenwood School in each cycle.

From a methodological perspective the study was viewed as an evaluative, instrumental, collective case study. Data were gathered in the form of LS Meeting notes (LS1), LS Meeting audio recordings (LS2 & LS3), teachers' reflective logs, IKO journal and student work samples. Reflexive thematic analysis was utilised, and data were examined in terms of the effect of LS on PCK, with particular focus on teacher orientations (Research Question 1) and the features pertaining to LS which were effective in supporting the teaching of primary science (Research Question 2). Teachers orientations were considered in light of a framework designed for this research, based on the work of Banchi and Bell (2008), Lederman (2009) and Magnusson et al. (1999). The valuable attributes of LS were determined in accordance with the Value Creation Framework of Wenger-Trayner and Wenger-Trayner (2020). The overall findings were discussed in the previous two chapters. As part of this concluding chapter focus will now be placed on the key findings which emerged as a result of this study.

7.3 Summary and Discussion of Key Findings

The key findings of this study are organised according to two themes: those relating to science teaching, and those specifically connected to LS as a CPL methodology for primary science. They are set out in Table 7.1 below.

Table 7.1

Key Findings of this Study

Impact of LS on Science Teaching	LS as a CPL Methodology
Teachers' orientations are complex and can evolve and expand through school-based LS	The importance of the Study Phase
Identification of a link between teachers' orientations and SMK	An account of the experience of an IKO
Key role of the teacher in IBSE	Teacher agency as a feature of LS
	Application of the Value Creation Framework to LS
	School-based collaboration as a key aspect of LS

Each of these findings will now be discussed individually.

7.3.1 Impact of LS on Science Teaching

Teachers' orientations can evolve and expand through school-based LS

Ladachart et al. (2022) state that “orientations to teaching science are considered an overarching component of PCK” (p.980). Findings in this study related to the impact of LS on primary teachers' orientations to teaching science. In this section a summary will be provided regarding the evolution and expansion of teachers' orientations as a result of participation in school-based LS. Furthermore, a recommendation for a review of Magnusson et al.'s (1999) conceptualisation of teachers' orientations, can be made in light of these findings. As such, the Framework for Analysis of Teachers'

Orientations (Table 4.7) created for this research study makes a key contribution to knowledge, reflecting the complexity of teachers' orientations to teaching science.

The teachers' existing orientations were identified during preliminary discussions about how they were teaching science before engagement with the LS and what they viewed as their ideal approach. Findings revealed that teachers' existing orientations were varied, including a confirmation inquiry style to teaching for some, while others viewed themselves as facilitators of scientific skills development and child-led exploration. Overall, the teachers in this study believed that an ideal approach to primary science incorporated an inquiry-based, problem-solving approach alongside a process orientation focused on the development of children's scientific skills. They also favoured using more child-centred approaches to teaching science.

Findings revealed that LS had a positive impact on the development of teachers' orientations. For those teachers who had initially focused on skills development and child-led approaches, LS confirmed this manner of teaching primary science as preferable for them. In contrast, for the teachers who tended to adopt a more recipe-style, confirmation inquiry approach to teaching science prior to LS, the experience appeared to have led to a shift in mindset towards more child-centred inquiry approaches. In LS1, this shift was manifested in a structured inquiry, whereby the teacher directed the process of dropping paper spinners but the children analysed their own observations of what happened when they dropped the spinners. In LS2 and LS3, child-centred inquiry developed further to include guided inquiry, whereby the teachers scaffolded the children as they selected their own approaches to creating models of the shadows created during the day, and attempted to create a compound pulley independently, rather than merely following a more "recipe style" approach to inquiry. This indicates that the teachers' approach to facilitating an inquiry orientation evolved

and expanded from the beginning of LS to its conclusion. It would appear that LS had a positive impact on the development of these primary teachers' inquiry orientations in science, most especially in the area of child-centred inquiry.

An inquiry orientation is described by Magnusson et al. (1999) as having the goal of “representing science as inquiry” (p.6) and characterised by being “investigation-centred, the teacher supports students in defining and investigating problems, drawing conclusions, and assessing the validity of knowledge from their conclusions” (p.7). Consideration of literature surrounding IBSE methodologies as part of this study, as well as the inquiry orientations employed by the teachers both before and during LS suggest that Magnusson et al.'s definition of inquiry could be expanded further.

Literature highlights how IBSE can range from teacher-directed to open inquiry. Open inquiry is not named as such in the Magnusson et al. framework. However, they do refer to a “discovery” orientation whose goal is to “provide opportunities for students on their own to discover targeted science concepts” (p.6). This orientation is characterised as “student-centred” whereby “students explore the natural world following their own interests and discover patterns of how the world works during their exploration”. (p.7). As such, this orientation would seem to relate to open inquiry, as described by Cuevas et al. (2005). Furthermore, Magnusson et al. do not make specific reference to teacher-directed inquiry. On the other hand, Banchi and Bell (2008), in their conceptualisation of inquiry subdivide teacher-centred inquiry into confirmation inquiry and structured inquiry. In confirmation inquiry, students are provided with the question and the procedure, and the results are known in advance. Two of the teachers in this study, Caroline and Darren, shared how they employed this approach to teaching science prior to LS. On the other hand, in structured inquiry, the teacher provides the

question and the procedure, but the students themselves generate their own explanations, supported by the evidence they have collected as part of the scientific investigation. This was the orientation utilised during the paper spinners investigation in LS1, and when the students recorded shadows formed at different times of the day in LS2. It would seem that the definition of inquiry proffered by Magnusson et al. (1999) could be extended to include reference to different types of teacher-directed inquiry.

The process orientation, through which students are engaged in hands-on activities that support them in developing and applying science skills, was prevalent across all three LS cycles but evolved from LS1 to LS3. It began with a focus on specific science skills in LS1 (predicting) and LS2 (analysing and communicating). However, by the end of LS2, the teachers had expanded their process orientation from focussing on individual skills, to the development of numerous scientific skills simultaneously. This method of applying a process orientation in which several skills were emphasised together continued in LS3. This would suggest a change in the process orientation during LS, from explicit focus on individual skills to a broader emphasis on multiple skills, in the same lesson. Magnusson et al. (1999) characterise a process orientation as “teacher introduces students to the thinking processes employed by scientists to acquire new knowledge. Students engage in activities to develop thinking process and integrated thinking skills” (p.7). Data here suggest that there are two further aspects to the process orientation: activities that focus on the development of individual scientific skills, and activities that focus on multiple skills simultaneously. This is supported by the research of Murphy et al. (2023) who reviewed 21 studies that focused on the development of scientific skills. They found that while the majority of studies focused on multiple skills at the same time, a small number looked at individual skills. It would

seem that Magnusson et al. 's (1999) description of a process orientation could therefore be expanded to reflect these additional aspects of scientific skills development.

Furthermore, the orientations identified by Magnusson et al. could be broadened to include that of unstructured exploration, as evidenced in this research. Unstructured exploration, adapted from Lederman (2009), is one in which the teacher provides the students with resources and affords them the freedom to explore concepts themselves. They do not have a particular problem to solve or question to investigate. The approach affords the students the opportunity to share their ideas and ask questions. This allows teachers to build awareness of students' prior knowledge of a topic. This approach is typically employed at the beginning of a new unit of work. Caroline shared how she utilised this methodology in the timeframe between the end of LS1 and the start of LS2. It was also in evidence during LS2 and LS3 when the teachers expressed a desire to include opportunities for the children to explore light materials and pulleys in an unstructured manner. So, while it is clear that Magnusson et al. (1999) created a comprehensive list of orientations associated with the teaching of science, it would seem that it could be extended to include more specific references to teacher-directed inquiry and unstructured exploration. As such, the Framework for Analysis of Teachers' Orientations created for this research study enhances the conceptualisation of teachers' orientations towards the teaching of science.

Overall, data reveal that LS supported teachers to develop their ideal orientations, as identified at the beginning of the study. For some, this involved a confirmation of the skills-focused, child-centred orientations they already espoused; for others, LS was the catalyst for a shift away from more teacher-centred confirmation style approaches to inquiry. This echoes the finding of Flanagan et al. (2024) who found

that LS appeared to have motivated teachers to reflect on their role within the classroom and enabled them to move away from teacher-led approaches to STEM.

Findings from the current study reveal that LS supported the teachers not only to pursue particular orientations but to also deepen their understanding of such orientations during the process. For example, they utilised the process orientation to both focus explicitly on individual skills, such as predicting in LS1, and promote multiple skills simultaneously as in LS2 and LS3. The development of an inquiry orientation expanded from a confirmation inquiry style prior to LS for some teachers, to incorporate both structured inquiry and guided inquiry by the end of the process. There was also a nod towards child-led inquiry in the planned follow-up to the LS1 research lesson, although this was not observed in practice. It would appear that through broadening their own understandings of inquiry and process orientations, the teachers simultaneously developed their ability to design a variety of lessons reflecting these approaches. This in turn led to the students engaging in a range of scientific activities, for example, from focusing on one skill in a lesson to experiencing many skills together, and from analysing their findings in a structured inquiry to applying their own approach in a guided inquiry. A deeper knowledge of the orientations the teachers wished to promote had a positive impact on children's engagement with science in the classroom.

Findings also show that teachers can have multiple orientations to teaching science, as stated by Magnusson et al. (1999). Data highlight how the teachers developed several orientations at the same time as they progressed through the LS process. It is evident that these multiple orientations can co-exist and be promoted simultaneously in the classroom. For example, the process orientation permeated each LS cycle, utilised alongside the varying types of inquiry that were incorporated into the three unit plans. In this manner, just as the teachers developed various orientations

concurrently, the students were afforded opportunities to engage with multiple orientations simultaneously in the classroom. As a result, the children developed their skills of inquiry in tandem with their scientific process skills, both highlighted in the literature review as areas of concern in the learning of science in Ireland.

Identification of a link between SMK and Teacher Orientations

Appleton (2008) states that, without science PCK, a teacher lacks knowledge of what to teach and how to teach. He goes on to note that one of the foundational bases of science PCK is SMK. This research study established a link between developing teachers' orientations to teaching science and building their SMK. In each LS cycle, the teachers elected to focus on a topic in which they themselves lacked science subject knowledge. In LS1, they developed their knowledge of air resistance by investigating paper spinners themselves in advance of teaching the lesson. During the LS2 & LS3 Study Phases, the teachers engaged collaboratively in what they entitled "play sessions", building their SMK of both light and shadows and pulleys. In each LS cycle, the development of teacher SMK had a direct impact on the unit plan and research lessons they designed. Through developing their own SMK of the topics, the teachers had a greater understanding of students' preconceptions, and a greater confidence to incorporate structured and guided inquiry into the research lesson designs. As was highlighted in Chapter 5, when the teachers developed their orientations and SMK simultaneously through LS, there was a positive impact on children's learning in terms of scientific concepts and process skills. It would seem that teacher orientations and SMK should be developed in tandem during both ITE and in-service training for primary science.

Key Role of the Teacher in IBSE

Sjøberg (2019) states that a key finding in relation to literature on inquiry-based science teaching is that “success depends strongly on the degree of involvement and guidance by the teacher in all phases of the work” (p.11). In the current study, data reveal how, regardless of a teacher-directed or child-centred approach to inquiry, teacher guidance was a key feature of inquiry-based learning. With regard to the teacher-directed approaches utilised, the teachers discussed how most children required scaffolding to analyse their findings after a teacher-directed structured inquiry in LS2. The students' record sheets showed some inaccuracies in relation to the shadows they noted at different times of the day. This emphasised that teacher support was crucial to the development of these students' accurate scientific conceptions of light and shadows. The success of the structured inquiry was dependent on the involvement of the teacher, as stated by Sjøberg (2019) above.

In both LS2 and LS3 the participants indicated that they believed that teacher support was also a key feature of guided inquiry, despite its child-centred focus. Brian underlined his belief in the importance of teacher support through stating that scaffolding is crucial for all children, regardless of individual levels of student achievement. On the other hand, Michelle placed particular emphasis on the need for teacher support for those identified as lower achieving students. She noted how crucial teacher support was to these children when they created models of shadows created at different times of the day during LS2. During the LS3 research lesson, Michelle decided to intervene and guide children who were in need of support as they created compound pulleys. When her observations were combined with the children's written work samples, it was evident that, while guided inquiry led to progression in many children's conceptual understanding of the topic, some children still needed further consolidation

of their knowledge of pulleys at the end of the unit plan. In light of this, it is worth considering whether the child-centred nature of guided inquiry impeded some children's learning, and perhaps a more teacher-centred confirmation inquiry approach would have better supported their conceptual understanding of pulleys. It would seem that even when child-centred approaches are incorporated into scientific inquiry in the classroom, the teacher still has a key role to play in directing the learning. This research further highlights the importance of teacher scaffolding as part of IBSE, confirming the finding of Aditomo and Klieme (2020).

Harlen (2021) states that teachers require the ability to judge the level of guidance students require, in order to balance helping them when needed, while also supporting them to think for themselves. She asserts that teachers need to develop pedagogical skills such as focused questioning and scaffolding alternative ideas for students to consider. Some LS teachers, such as Caroline and Darren, themselves experienced a shift from more teacher-directed investigations, such as confirmation (before LS) and structured inquiries (LS1), to incorporating more child-led approaches such as guided inquiry and unstructured exploration (LS2 and LS3). Based on Harlen's assertion (2021), it could be suggested that teachers need to develop their own skills in order to best support children during child-centred inquiry-based learning approaches such as guided inquiry and open inquiry.

7.3.2 Key Findings with regard to LS

The Importance of the Study Phase

The Study Phase consisted of the teachers collaboratively identifying their long-term goal, or research theme, for the students before selecting the individual topics for each LS cycle (falling objects in LS1, light and shadows in LS2 and pulleys in LS3).

They subsequently utilised the Study Phase to engage with support materials related to each topic, before continuing on to design the unit plans and research lessons in the Planning Phase. A number of key findings regarding the importance of the Study Phase emerged from the data. These included opportunities for the teachers to reflect on their orientations, the development of SMK, experiencing the inquiries that they would teach, and the involvement of the EKO's. Each of these findings will now be considered in turn.

The LS1 Study Phase offered the teachers an opportunity to reflect on the orientations they utilised prior to the study and what their ideal version of science teaching and learning would entail. This reflection acted as a catalyst for the development of new orientations as a result of LS for some teachers, and the embedding of existing orientations for others. This key aspect of LS was grounded in the Study Phase.

The Study Phases were crucial to the development of teacher SMK, an essential component of PCK (Appleton, 2008). It became apparent that the hands-on “play sessions”, as the teachers deemed them, when they physically explored the school’s resources relating to light and shadows and pulleys in LS2 and LS3 were a highly valued aspect of the LS process. The “play sessions” assisted the development of the teachers’ own SMK which in turn supported students’ learning, such as when Caroline confirmed to a student during LS2 that a torch contained mirrors, based on her own learning in the Study Phase. The Study Phase “play sessions” influenced the design of the unit plans and research lessons. This was evident, for example, during LS3, when the teachers based the pulleys lessons on the fixed, movable and compound pulleys they explored during the Study Phase. This approach echoes the work of Murphy et al. (2015) who provided teachers with the opportunity to engage with the various inquiries

about science and inquiries in science prior to teaching them in their classrooms. The teachers in their study believed that the hands-on inquiry approach enabled them to experience similar situations to those faced by their pupils in the classroom, which they viewed as valuable since it gave them an insight into some of the problems their pupils might encounter in the classroom. It would appear that something similar occurred in this study - the LS teachers themselves encountered challenges as they developed their knowledge of pulleys in the LS3 Study Phase. However, this enabled the teachers to anticipate the obstacles the children would face during the unit plan lessons, hence building an awareness of how to support them.

In addition, the Study Phase was key in establishing the relationship between the EKO and the group during LS1. The EKO with expertise in LS introduced the group to the process in the first meeting, including approximately how many hours a LS cycle could take. Hourigan and Leavy (2021) also note that as LS facilitators introducing the process to in-service teachers, they became aware of the necessity to focus on what was involved for participating teachers. The EKO with expertise in science sourced suitable readings for the teachers to consider during the Study Phase. Teachers later shared how they believed the EKOs guided them in the right direction at the beginning of the process. One teacher, Anna, shared how she felt participant commitment levels could have subsided without the influence of the EKOs at the beginning of LS1. It is evident that external mentorship was a significant feature of the LS1 Study Phase, and that the mentorship was deemed valuable by the participants.

Findings showed how the Study Phase was key to the development of both teacher orientations and SMK which impacted the design of the learning experiences for the children during the Planning Phase. The Study Phase was also important in establishing a relationship with the EKOs. It is noteworthy that a recent review of LS

in mathematics education from 2015 to 2022 by Ding et al. (2024) found that many studies combined the Study Phase with the Planning Phase. The authors observe that such “practice does not seem to align with the essence of Japanese LS, which regards studying teaching materials as a critical separate phase” (p.91). It would appear that this research study, emphasises the importance of the Study Phase as crucial in its own right.

An In-depth Account of the Experience of an IKO

This study provides an in-depth exploration of the experience of becoming IKO in school-based LS in an Irish setting. This is a novel aspect of this piece of research. My reflective journals, written after each meeting across the three LS cycles, provided a rich, chronological account of my developing role, including successes and challenges. In effect, I wore three hats during LS: researcher, participant teacher and IKO. Findings highlight the conflict that existed in simultaneously acting as participant teacher and IKO. I was keenly aware that my experience as a facilitator of science CPL marked me as different to the other teachers, whereas conversely, I did not believe I had earned the badge of IKO at the beginning of LS1, and viewed myself more as a facilitator of LS. In this way I felt marginal in both the teacher group and the KO group, aligning with the experience of a supervisor who spanned the boundary between workers and management described by Wenger (1998).

It has already been stated that external mentorship from the EKO's made a key contribution to the establishment and progression of the LS group, most especially during the first Study Phase. However, it is also evident that external mentorship was key to my developing role of IKO during LS1 and enabled me to perform the role independently during LS2 and LS3. Indeed, my personal reflective journal records how I believed I would not have been able to guide the group through the initial weeks,

without EKO support. This extended to the LS1 Planning Phase when I felt that I had led the teachers “down the garden path” during meetings when the EKOs were absent. In the end, this issue was resolved after I met the EKOs, on my own, for a discussion on the challenges I was encountering. I subsequently felt enabled to lead the teachers through the TLP effectively. I later reflected that although I labelled myself IKO, in reality I was more of a facilitator of LS in LS1, a term used by Lewis (2016) to describe those who lead LS without experience of the process as participant teachers. It would seem preferable to have enjoyed the role of LS participant teacher solely, in advance of undertaking the role of IKO in this study. Assuming both roles simultaneously for the first time was not without difficulty and EKO support was key, particularly in LS1. It would appear that those undertaking the role of IKO should try to engage in a cycle of LS solely as a participant teacher in advance.

Findings show that it took time to feel comfortable in the role of IKO, but that by LS2 I had confidence in my ability to steer the group as LS IKO, whereas I still turned to Darren, with his background in science, as the science IKO. Data point to my efforts to share my opinions honestly, while leaving space for others to contribute, attempting not to unduly influence the selection of the research theme or the design of the unit plans and research lessons. I shared the leadership and facilitation tasks, such as the role of teacher in the research lessons. Comments by the teachers during their reflections on LS suggest that they felt I influenced the creation of a space where they felt their opinions were valued and that they could share their vulnerabilities. They were also in favour of receiving CPL from an internal mentor, a classroom practitioner who they felt they could relate to on a personal level. This research highlights the value of internal mentorship as an aspect of CPL, but underlines the need for external mentorship for those who undertake such a role.

Teacher Agency as an Aspect of LS

Wenger-Trayner and Wenger-Trayner (2020) identify four social learning modes over which participants in a SLS have agency: generating value through participating and caring to make a difference, translating value into something closer to the desired change, framing the creation of value through developing a perspective on what counts as value, and finally evaluating whether a difference has really been made. When applied to this study, the teachers generated value by participating and framed the creation of value through identifying their ideal approaches to teaching science and subsequently designing unit plans and research lessons aimed at fulfilling the research theme they chose themselves. Throughout the process, they reflected on the impact of each phase of LS on both teaching and learning. Wenger-Trayner and Wenger-Trayner (2020) state that when participants take charge of a SLS their learning is more likely to be relevant to the difference they care to make. Lewis and Tsuchida (1998) identified teachers themselves as the agents for change in LS and data generated in this study support that view.

Data reveal that the teachers valued taking ownership of their own learning, as opposed to having change dictated to them from the outside. They began to refer to the research lesson as “our lesson” as LS1 progressed, corresponding with the human connection identified by Lewis et al. (2012) as a feature of well-designed LS. Continuing into LS2, the group began with a critique of LS1 and felt empowered to make what they deemed necessary adaptations to their approach, such as greater emphasis on assessment. Teacher comments highlight how their ability to design the unit plans themselves was a motivating factor, as opposed to teaching lessons which were prepared externally and provided to them for implementation in the classroom.

Data highlight how the LS teachers experienced a shift in mindset regarding their use of the PSC during the process. They revealed how prior to LS they had prioritised covering curriculum content in a way that they perceived to be a superficial manner. On the other hand, during LS they applied a different approach in that they chose to spend longer exploring individual topics. The LS teachers believed that taking the time to engage with individual topics in an in-depth manner led to an increase in children's conceptual understanding and scientific language, and furthermore supported skills development. This approach appears to align with the "broad" learning outcomes that will be a feature of the incoming STE curriculum which aim to "facilitate teacher agency and flexibility in schools" (NCCA, 2024, p.9).

Participation in LS led the teachers to consider CPL in general. They criticised CPL in the transmissive style (Kennedy, 2014) whereby in Brian's words it "give[s] teachers stuff as opposed to saying to teachers, you have to kind of discover stuff for yourself" (LS1, Focus Group Interview). Rather he showed a preference for a transformative style of CPL (Kennedy, 2014) which increases capacity for teacher autonomy. Caroline supported his view, through her assertion that LS was "so much better" than any CPL she had participated in up to that point, due to what she described as its "teach a man to fish" style (LS1, Focus Group). It is evident that teacher agency was a key feature of LS, one which participants believed should be extended to CPL in general.

Application of the Value Creation Framework to Lesson Study

The value creation framework has been utilised as an analytical tool in research (Baas et al., 2023; Clarke et al., 2021; Cowan & Menchaca, 2014; Hanley et al., 2018; Juergensen et al., 2024). However, its use in the analysis of LS as a CPL methodology,

as in this research study, is innovative. Participant agency is at the heart of learning in LS as highlighted earlier in the literature review and reinforced by the findings. Wenger-Trayner and Wenger-Trayner (2020) observe that the practice of evaluation often hands agency to outside forces, whereas “using the value creation framework allows the process of evaluating to honour the agency of participants” (p.189). In this manner, through analysing the teachers’ own words, their value creation stories, the values they associated with LS as a CPL methodology were determined.

Using the value creation framework enabled the identification of collaboration and the duration of LS as examples of immediate value associated with the process. An increase in teacher confidence was observed as an example of potential value, while the opportunities for reflection offered by LS were deemed types of strategic value. Enabling value was established through the increased teacher agency in this form of CPL, as well as a result of the internal and external mentorship. The wider impact of LS across other areas of the curriculum was classified as an example of transformative value. Realised value, relating to the difference participants care to make, could be connected to the development of teachers’ orientations to science and their SMK. Not all types of value associated with the framework were visible in this study. For example, orienting value, which goes beyond the SLS to external audiences, was not measured in this study, given its small-scale, short-term nature.

The value creation framework enabled the creation of a plausible account of the positive contribution LS can make as a CPL methodology. Guldborg et al. (2021) state that a key strength of the framework is that it treats all participants in a SLS as co-researchers engaged in a process of investigating, sharing and reflecting on what does or does not work in their practice. Teacher agency was at the core of the value creation framework, as the values associated with LS were identified through consideration of

their thoughts and reflections on the process. In this manner, the value creation framework provided an important understanding of the values created by a group of teachers participating in a SLS.

School-based Collaboration as a Key Aspect of LS

Collaboration contributed significantly to the overall effectiveness of LS in terms of its impact on teachers and ultimately the lessons they cooperatively designed for their students. It was during the LS1 Study Phase that the teachers first began to collaboratively share their vulnerabilities when it came to teaching science, which was identified as a positive experience. The openness of the conversations between colleagues was described as an important aspect of the process. The teachers also highlighted collaborative planning as an attribute of LS - it was their collective discussions which led to the design of each TLP and research lesson. The particular benefits of school-based LS revealed here have also been recognised in the work of Dooley et al. (2014) and Flanagan (2024). Desimone et al. (2002) also found that “collective participation of groups of teachers from the same school...as opposed to the participation of individual teachers from many schools” was a key feature of effective professional learning. Ostovar-Nameghi and Sheikahmadi (2016) identify features of effective teacher collaboration, namely regular meetings to share problems and discuss solutions, a shift from training courses to study groups, peer observation and mentoring, and a move away from externally imposed initiatives. It would seem that school-based LS, in the manner of this study, possesses such attributes.

The *STEM Education Policy Statement 2017-2026* (DES, 2017) also advocates collaborative approaches among teachers. This is of significance, given the publication of *A Quality Framework for Primary School and Special Schools* (DES, 2022)

developed by the Inspectorate, which lists teachers' collective/collaborative practice as one of the four domains of learning and teaching. The framework views "career-long professional learning as central to the teacher's work and firmly situates reflection and collaboration at its heart". Findings from this study suggest that teachers identified collaboration as an immediate value associated with LS, which ties in with best practice as identified by the Inspectorate (DES, 2022). Collaboration among colleagues, as opposed to collaboration with teachers from different schools, was a particularly valuable aspect of this research study.

7.3.3 Summary of Key Findings

The key findings outlined above have been divided into those which apply to the teaching of science and those which apply to LS as a CPL methodology. In terms of science teaching, key findings included how teachers' orientations can evolve and expand through school-based LS, the establishment of a link between the development of teacher orientations and SMK, and the key role of the teacher in IBSE. Furthermore, this study contributes to the knowledge on teachers' orientations through the development of a Framework for Analysis of Teachers' Orientations, expanding on the conceptualisation of orientations constructed by Magnusson et al. (1999). Additional key findings were identified that are specific to LS as a CPL methodology. These included an affirmation of the importance of the Study Phase, the inclusion of an account of the experience of becoming IKO, the importance of teacher agency and school-based collaboration as aspects of LS, and an application of the Value Creation Framework as a tool for analysis of LS as a SLS. It is hoped that such findings will contribute to the body of knowledge associated with science teaching on one hand, and LS as a CPL methodology on the other.

7.4 Contribution to Knowledge

The Conceptual Framework associated with this study (Figure 4.3) included potential outcomes. It is now possible to determine the extent to which those outcomes manifested as a result of the LS intervention. The creation of a Framework for Analysis of Teachers' Orientation in this study has led to an expanded conceptualisation of teachers' orientations toward the teaching of science. This collective case study provides an insight into how the development of teachers' orientations and SMK can combine to positively impact children's learning in science. It identified features of LS as an effective CPL methodology, including collaboration, teacher agency, opportunities for reflection, support from mentors and extended duration. This thesis gives an in-depth account of the experience of becoming IKO in school-based LS. Finally, through the application of the Value Creation Framework to the dataset, this research study leads to an improved understanding of SLS as a theoretical underpinning of school-based LS.

7.5 Limitations of the Study

This research study evaluated the effect of school-based LS as a CPL methodology for primary science and contributed to knowledge on the teaching of primary science, and LS as a CPL methodology. However, it is important to acknowledge these findings within the limitations of the study. The limitations of the study are connected to the methodology of the study, in particular the selection of the research site and participants, data collection during LS1, and my role as researcher.

7.5.1 The Research Site and Participants

I had worked as a teacher in Greenwood School for 15 years at the beginning of this research study. As a full-time teacher and part-time student, convenience and

availability did play a part in research site selection. The participant teachers were therefore an example of a convenience sample, described as a “less desirable” means of type of sampling by Creswell and Creswell (p.162, 2023). It should be acknowledged that given the voluntary nature of participation, it is possible that bias could have influenced participant teachers. For example, perhaps they were already positively disposed to primary science, or they could have been motivated to help me, their colleague, to achieve an academic qualification. Creswell and Poth (2018) state that multiple strategies of validation should be utilised when one’s own workplace is the research site, in order to ensure that the account is accurate and insightful. In order to overcome the limitation of gathering data in my workplace I utilised several strategies recommended by research. Multiple methods of data collection including teachers’ reflective logs, audio data from LS meetings and focus group interview transcripts to identify quotes which illustrated their individual perspectives. Member checks (Merriam & Tisdell, 2016) were conducted which afforded participants the chance to examine the findings and analysis to determine if they were an accurate depiction of their interpretation of LS. The same researchers advocate for adequate time spent on data collection. It would appear that conducting three cycles of LS generated enough data to address the research questions and that saturation point in terms of developed themes was reached by the end of LS3. In this manner I addressed the limitation of the convenience sample.

It was hoped that the sample of teachers would grow after LS1, based on the teachers' positive experiences, in the manner of a snowball sample (Cohen & Arieli, 2011). However, this did not occur, despite issuing an invitation to all teachers in Greenwood School, in advance of LS2 and LS3. The addition of new members could have provided an interesting account of the experience of newcomers joining an

established LS group. In fact the sample decreased in size by one teacher going from LS1 to LS2, and again from LS2 to LS3. This meant that LS3 data was recorded from just three participants, including me. At the same time, data gathered provides a rich account of the complete LS experience of Brian, Caroline and me. So while the sample size could be viewed as a limitation, the findings generated offer an in-depth account of school-based LS and makes a worthwhile contribution to research in this field. Furthermore, in order to authentically develop my role of IKO, it was necessary for me to be an insider in the field.

7.5.2 Data Collection during LS1

Covid-19 had a significant impact on LS1 which began in March 2020 and concluded in October 2020. While the introductory meeting took place face-to-face in Greenwood School, thereafter all meetings took place online. Some of the teachers referenced challenges to the Planning Phase, due to remote meetings. When schools reopened in September 2020 social distancing measures were in place, which the teachers had a negative impact on the children's engagement with the research lesson. They were required to stay one metre apart from their peers, and the lesson took place in the school PE hall in the presence of seven adults who all wore face masks, which in itself was an unnatural environment for a science lesson. This was at odds with the recommendation of Shaw et al. (2011) that a relaxed atmosphere should be created prior to data collection. However, it could be argued that given the necessity to follow the school's Covid-19 policy, there was no other way in which the research lesson could have been conducted at the time. Furthermore, children's work samples were placed in a plastic box at the end of the research lesson and isolated for 48 hours. This meant that valuable data were excluded from the post-lesson reflection meeting that took place on the evening of the research lesson. However, the teachers observation logs made a

valuable contribution to the meeting, in terms of how the children engaged with the lesson. I was subsequently in a position to examine the work samples myself, some of which have been included in the findings of Chapter 5.

Permission for audio recordings of LS meetings was not sought from DCU's REC in advance of LS1, and in hindsight this was a limitation of the data set. When the EKO's attended meetings one of them took written notes, however as LS1 progressed we, as participant teachers, began to conduct meetings that were independent of our external mentors. At such meetings I found it very difficult to conduct the meeting, as IKO, and simultaneously record participant contributions to the conversation. As a result an amendment was submitted to REC in advance of LS2 and permission was granted to gather audio data of meetings. This led to the gathering of a richer data set during LS2 and LS3 which enabled a deeper analysis of the LS process.

7.5.3 My Role as Researcher

My role as researcher in this study had the potential to be a limitation, given that it included being both participant teacher and IKO in LS based in my own school. I consulted methodological research literature in order to best address this issue. Creswell and Poth (2018) caution that collecting data in one's own workplace may introduce a power imbalance between the researcher and the individuals being researched. The other participants, as my colleagues, were aware of my background as a facilitator of science CPL in both ITE and with in-service teachers. Three of the four participants had previously taken part in six two-hour Croke Park workshops that I co-facilitated. As a result, I was conscious of not unduly influencing the approach taken to the unit plans and research lessons. While I did offer my opinion during LS meetings, my personal logs record how I was concerned with not being too vocal, and focused on

affording the other participants opportunities to share their ideas before I spoke. In this manner I attempted to be a good listener, listed as a desired skill of case study investigators by Yin (2009).

I was also aware of my personal philosophy of science and how it could potentially sway the direction of planning. For example, I wondered if my own interest in promoting scientific skills affected the group's decision to hone in on the process orientation. However, data show that I was not the only teacher to mention skills development as an area of interest at the outset of LS1. Furthermore, I am aware that this thesis presents my interpretation of what happened during LS. At the same time, I based my findings on multiple methods of data collection (Creswell & Creswell, 2023) in order to create an insightful account of the teachers' experience of LS.

7.6 Recommendations

The findings of this research study have led to recommendations for future research, classroom practice and educational policy which will now be outlined.

7.6.1 Replicate the Study of LS as a CPL Methodology in Primary Science

This study provides a critical evaluation of the effect of school-based LS as a CPL methodology for primary science. However, findings are based on a small sample of teachers, based in one primary school, and therefore not generalisable. This study could be replicated in other sites, which would contribute further to the knowledge base surrounding LS as a CPL methodology for primary science.

7.6.2 Further Exploration of the Role of IKO in LS

This study provides an in-depth exploration of the experience of becoming IKO in school-based LS in Ireland, thus adding to the literature on LS itself. It would be beneficial to further investigate the experience of IKOs in LS. In particular, it would be

useful if research be conducted by former LS participants who undertake the IKO role. It is evident from this research that much of the challenges I experienced in LS1 stemmed from the fact that I had no prior experience of LS myself as a participant.

7.6.3 Recommendations for Classroom Practice

Scientific Inquiry as a Key Pedagogical Practice

Scientific Inquiry is listed as a key pedagogical practice in the *Draft Science, Technology and Engineering Education Specification* (NCCA, 2024). The LS research lessons, which included both structured inquiry and guided inquiry approaches, had a positive impact on children's learning through the development of conceptual knowledge and scientific skills. However, observing teachers noted the key role the teacher of the research lessons played in scaffolding children's learning, particularly those of lower ability. Findings here support the view of Sjøberg (2019) that the success of IBSE depends strongly on the degree of involvement and guidance by the teacher. This research study affirms the benefits of IBSE and recommends supporting teachers to develop their PCK in IBSE in order to effectively support the teaching and learning of science through inquiry.

Explicit Teaching of Scientific Skills

In LS1 the teachers made a specific attempt to teach the children how to predict. It was evident that at the beginning of the lesson, many were unsure how to predict, and uncomfortable doing so. Data suggest that it was still a challenge for some children after the research lesson and required more engagement with lessons focusing on prediction. It would appear that teachers need to spend time explicitly teaching scientific skills in order for a process orientation to transfer successfully into student

learning. Murphy et al. (2023) also observe the importance of explicitly teaching scientific skills, a finding that is reinforced by this research study. Forthcoming materials from the NCCA to support implementation of the new STE curriculum should highlight the explicit teaching of scientific skills and include exemplars on how to do so. Teachers should be provided with clear descriptors of skills pertinent to the STE curriculum and rubrics for assessment of skills development, as recommended by Murphy et al. (2023).

7.6.4 Recommendations for Educational Policy

Need for Development of Teachers' Orientations toward Science in tandem with SMK

Shulman (1986) identified SMK as one of the three types of content knowledge necessary for teaching. Literature consulted at the beginning of this research study highlighted that many Irish primary teachers appear to lack adequate science subject matter knowledge (SMK), particularly in the area of physical sciences (Clerkin et al., 2017; Murphy et al 2023; Smith, 2014; . This also applied to those in ITE (Murphy & Smith, 2012). Data here substantiate the literature: the LS teachers chose to pursue scientific topics in which they lacked SMK , and as a result, found difficult to teach or avoided teaching. Findings of this study reveal that developing teachers' SMK simultaneously supported the development of their orientations to teaching science and had a positive impact on children's learning in terms of conceptual knowledge of science and scientific process skills. It is imperative, therefore, that teachers receive support to develop their orientations and SMK simultaneously through CPL opportunities, such as LS. This time of curriculum change, when teachers will naturally be in receipt of extra CPL, would seem an opportune time to do so. It is also imperative

that the online support materials which will accompany the new STE curriculum include background information on specific science concepts, in order to support teachers to develop their own SMK.

Retention of Sustained CPL for Teachers

Oide, the professional support service for teachers and school leaders in Ireland currently offers in-school support on a sustained basis. This involves Oide Professional Learning Leaders supporting schools over a period of time, enabling schools to drive and embed change as independent communities of learners (Oide, n.d.). LS, as conducted in this research study, would appear to bear the hallmarks of this manner of sustained support. Participant teachers formed an independent community of learners after receiving initial external support from the EKO's. Participants identified the extended duration of the process as a key feature, aligning with the effective features of professional development, as listed by Darling Hammond et al. (2017). It would seem prudent that funding is provided to Oide to maintain the model of sustained support for Irish primary schools.

Need for Collaborative, Reflective, Contextualised CPL

In addition to CPL of sustained duration, Darling Hammond et al. (2017) recommend opportunities for collaboration and reflection. Data here reveals that collaboration with colleagues was deemed an attribute of LS by all teachers. They valued the chance to share ideas and vulnerabilities and design lessons together. Reflection was also identified as an advantage of LS. Considered reflection on current practice at the start of LS was the catalyst for the development of teacher orientations to science which in turn had a positive impact on children's learning in terms of both conceptual understanding and skills development. This study shows that CPL should

include opportunities for collaboration and reflection amongst colleagues, focused on the needs of individual schools. Indeed, the national framework for teacher learning, Cosán (The Teaching Council, 2016), aimed to “commence an examination of the potential ways in which time for reflective practice and collaborating with other teachers could be provided for” as one of its medium term actions. Such time allocations could lead to an avoidance of teachers having to participate in the LS during their personal time, a feature of the process which was deemed a barrier by some participants in this research, and also in the work of Flanagan et al. (2024) and Hourigan and Leavy (2024). LS will not flourish in a research atmosphere grounded in volunteerism. For teachers to really engage in the process it will have to be backed by Oide and funded by the Department of Education.

7.7 Personal Reflection

This research study began as my attempt to attain an academic qualification, which has remained the overall aim. However, in all the thousands of words typed (and edited and re-typed), it is not until now at the end of the process that I have paused to consider how the research, undertaken over a period of years, has shaped me personally.

I came to this researcher as a teacher who held a Master of Education degree and had an interest in promoting the teaching and learning of primary science, based on my experience as a facilitator of CPL and ITE modules. My work with in-service teachers, including those in Greenwood School where I taught at the time, showed a discord between engaging CPL workshops and transfer into classroom practice. It just did not seem that many, if any, teachers were taking what they appeared to enjoy in a one-off workshop and trying it in the classroom. This was the catalyst to research effective CPL methodologies, including LS, which one of my supervisors had

experience of in the area of mathematics. Through my engagement with LS in this study I believe it is a worthwhile CPL methodology, offering opportunities for sustained, collaborative, agentic, reflective learning.

My own understanding of science education has developed as a result of this research. It seems a long time ago now since I was engaging with literature on the history of scientific inquiry as the “Beast from the East” raged over Ireland in 2018. At the time I wondered what possible impact learning about the philosophy of Bacon, Popper or Kuhn could have on my life as an Irish primary teacher. However, familiarising myself with their work has led to a deeper understanding of how children explore science – for example, making observations in the manner of Bacon, challenging existing ideas with new information in the style of Kuhn, persevering in the face of obstacles like Lakatos. Furthermore, this research has reaffirmed my adherence to an IBSE approach to teaching science, including emphasis on the explicit teaching of scientific skills. If we want our children to be STEM literate citizens in the future it is imperative that we support them to work like scientists in the classrooms of today.

Finally, there were many times during the writing of this thesis that my supervisors asked “but what about you?” when sharing feedback on my writing. Just as the teachers avoided teaching the scientific topics they felt uncomfortable with, I applied the same strategy to my experience as IKO for a long time. However, I can now say that taking the step to share and reflect on the contents of my personal reflective logs is, in my opinion, a key feature of this thesis. The successes and challenges I experienced will hopefully contribute to the knowledge surrounding this aspect of LS, and may even support someone else who undertakes the role in the future.

7.8 Conclusion

This research study aimed to explore school-based LS as a CPL methodology for primary science. Findings reveal that LS enabled teachers to develop their orientations to science, a key aspect of PCK, as well as their SMK. Both teacher PCK and SMK were identified as challenges to the teaching of primary science in Ireland at the outset of this work. Furthermore LS supported the teachers to explicitly focus on the development of children's scientific skills, and promoted the use of inquiry-based approaches to science in the classroom. School-based LS appears to possess many of the attributes of effective CPL, including sustained duration, opportunities for collaboration, teacher agency and reflection, and support from both external and internal mentors. It had a positive impact on both the teachers and students who took part. To conclude, it is hoped that this research study has contributed to the knowledge base on both primary science and LS in Ireland, most especially at this exciting time of curriculum change.

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APPENDIX A STUDY PHASE REFLECTIVE LOG

Study Phase Reflection Cycle 1

A reminder: The study phase involved us as a team of teachers, with guidance from our knowledgeable others, identifying long-term goals for our students, choosing an area of science to investigate with our students, and examining the curriculum, research articles and other supporting documents pertaining to our topic of interest.

Please complete a written reflection on the study phase below. You may like to consider some of the following as a guide, however this is not a requisite.

- Ways in which your own views of science have been confirmed/challenged and why.
- Ways in which your approach to teaching science may have been confirmed/challenged and why.
- Aspects of the Study Phase that you found beneficial/challenging and why.
- Aspects of the Study Phase that you would change/keep the same for a future cycle of Lesson Study and why.

My Reflection:

APPENDIX B PLANNING PHASE REFLECTIVE LOG

Planning Phase Reflection

A reminder: The planning phase involved us as a team of teachers, with guidance from our knowledgeable others, planning a lesson in depth. Our lesson stems from our research goal of giving all children the opportunity to work scientifically. We devised a Teaching-Learning Plan where we articulated the lesson goals and the lesson plan. We engaged in a mock lesson whereby some of us were participants in the lesson, some of us acted as observers and one of us acted as teacher/facilitator. This enabled us to assess the flow of the lesson, anticipate student thinking, and identify data to be collected in the research lesson itself.

Please complete a written reflection on the planning phase below. You may like to consider some of the following as a guide, however this is not a requisite.

- Ways in which your own views of science have been confirmed/challenged and why.
- Ways in which your approach to teaching science may have been confirmed/challenged and why.
- Aspects of the Planning Phase that you found beneficial/challenging and why.
- Aspects of the Planning Phase that you would change/keep the same for a future cycle of Lesson Study and why.
- You may like to include some reflection on the impact, as you see it, of virtual meetings and school closure on the planning phase.

My Reflection:

APPENDIX C TEACHING AND REFLECTIVE PHASE LOG

Teaching Phase and Reflective Phase

A reminder: The teaching phase involved us putting our research lesson into action. One team member taught the lesson and the other member observed the students and recorded the students' observations. The reflective phase involved us meeting after the research lesson to discuss our data on student thinking and learning. Our external knowledgeable others provided further commentary. We reflected on our research lesson and on the Lesson Study cycle as a whole.

Please complete a written reflection on the teaching and reflective phases below. You may like to consider some of the following as a guide, however this is not a requisite.

- Ways in which your own views of science have been confirmed/challenged and why / why not.
- Ways in which your approach to teaching science may have been confirmed/challenged and why / why not.
- Aspects of the phases that you found beneficial/challenging and why.
- Aspects of the phases that you would change/keep the same for a future cycle of Lesson Study and why.
- You may like to include some reflection on the impact, as you see it, of Covid-19 restrictions on these phases.

My Reflection:

APPENDIX D LESSON OBSERVATION LOG LS1

Title of Lesson: Investigating Paper Spinners

Goals of the Lesson:









- Children will predict what might happen when they drop a paper spinner to the ground and give a reason for their predictions.
- Children will observe what happens when they drop a paper spinner and record their observations.
- Children will predict and observe how changing properties (e.g. starting height, starting position, size) of the paper spinner will affect the manner in which it falls.
- Children will attempt to explain their results.
- Children will recognise that air causes the paper spinner to slow down as it falls.
-

Observation Objectives:

- Listen as two children predict what might happen when they drop a paper spinner to the ground.
- Record if the children can make a prediction, i.e. give a reason for their thinking.
- Listen to and record some of the language the children use as they describe what they see.
- Listen as the children attempt to explain their results and record same.
- Listen to the children in order to analyse whether or not they recognise that air causes the paper spinner to slow down as it falls.
- Listen as the children discuss what other questions they could investigate using their paper spinners and record some of their thinking.

Time (Activity)	Observation	Significance
Other observations not connected to specific activities:		
Conclusions:		
Further questions raised:		

APPENDIX E CHILDREN'S WORKSHEET LS1

Spinner Starting Point:	What I think will happen when I drop it:	My reason for thinking this:	What I saw when I dropped it:	My explanation for why this happened:
Wings are at the top 				
Wings are at the bottom 				
Spinner is turned on its side 				
Throw the spinner into the air 				

Do you think a small spinner would fall slower than a big spinner? Why?	What happened when you dropped the large and small spinner?
Have you any other questions about the spinner that you would like to investigate?	

APPENDIX F SAMPLE FOCUS GROUP QUESTIONS

- Why did you decide to participate in LS? Was the process what you expected?
- Has LS developed your confidence in teaching science through inquiry-based approaches? If so, can you say how? Can you give an example?
- Is there any way that LS might be changed to enhance teachers' confidence in teaching science?
- Do you believe LS has developed your competence in teaching science through inquiry-based approaches? If so, how? Can you give an example?
- Is there any way that LS might be changed to enhance teachers' competence in teaching science?
- Do you think the research lesson had an impact on children's scientific thinking? Can you explain why/why not?
- Do you think the research lesson had an impact on children's scientific skills? Can you explain why/why not?
- What do you think is the greatest impact of LS on science teaching and learning? Why do you think this?
- What are your thoughts on LS as a form of CPL? How does LS compare to other types of CPL you have engaged with, in science and other subjects?
- What impact do you think school closure and subsequent Covid-19 restrictions in school had on this cycle of LS?
Would you recommend LS to teachers in other schools? Why/Why not?

APPENDIX G LETTER TO PRINCIPAL

[Insert date]
Dear Principal

As part of my Ph.D studies in Dublin City University (DCU) I am researching how to teach science through the use of Lesson Study. This process is concerned with studying actual teaching and how children respond to the science being taught and with developing resources for use with teachers. This will involve a group of teachers in the school (maximum of 8) volunteering to prepare a science lesson that will be taught to a class. One of the group of teachers will teach the lesson and the others will observe the teaching and how the activities that are planned help children's understanding of science. I will participate as one of the teachers in the process and as an internal 'knowledgeable other' or expert, to guide the process. We will receive support from my two supervisors throughout the process.

The science lesson will be observed by participant teachers and my two supervisors. The teachers will record observation notes and children's written work will be collected. All data collected will be anonymised through the use of a coding system. I will not say the name of the school or give children's full names in written publications of my research. All paper data collected will be shredded at the end of my research.

The children will benefit in that participation in the lesson will be aimed at developing their scientific knowledge and skills. The teachers will participate in a lesson study cycle (of which the lesson is part). Following on from the lesson the teachers will engage in an in-depth analysis and reflection on the teaching and learning that occurred in the lesson. Participation in the lesson study cycle will hopefully have a positive impact on these teachers' future teaching of science, and therefore on children's learning.

The level of risk for the children and teachers participating in this research is deemed low. Only equipment and scientific investigations / experiments that are outlined in the Primary Science Curriculum will be used in the lesson. There is a risk of injury to children and teachers during any hands-on science lesson. A risk assessment of the lesson will be carried out as part of the planning lesson and a risk assessment of the classroom environment will be carried out prior to the lesson. All equipment will be examined for suitability of use.

Children do not have to take part in the research project. They will be welcome to remain in the room to participate in the science lesson but no observations will be noted in relation to them, nor will their work be collected. If they wish to leave the room for the duration of the lesson and sit in another class that will also be permissible.

No children will be identifiable by name, class or school on anything that is written about the study. Only the research team will have access to any notes made. While the findings of teachers' experiences of teaching this lesson may be published and may be presented at educational conferences, names of individuals and schools will not be identifiable and demographic information will be generalised. Confidentiality is subject to legal limitations, meaning that it is possible that the data has to be reported for some legal reason, under Freedom of Information etc. Written responses or comments may be used, with consent, in reports or publications by the researchers or in further promotional literature.

I am very happy to discuss this project further with you and to talk about it with the wider staff at a future date. I would be most grateful if you would complete the form below indicating that you give permission for the school to participate in this project.

If you have concerns about this study and wish to contact an independent person,

please contact:

The Secretary, Dublin City University Research Ethics Committee, c/o Research and Innovation Support, Dublin City University, Dublin 9. Tel 01-7008000, e-mail rec@dcu.ie

Thank you in anticipation

Ms. Mary Boyle

.....

I give permission for the school to participate in science lessons which will be observed by a group of teachers and two college supervisors for research purposes.

Signed _____

APPENDIX H LETTER TO BOARD OF MANAGEMENT

[Insert date]

Dear Chairperson

As part of my Ph.D studies in Dublin City University (DCU) I am researching how to teach science through the use of Lesson Study. This process is concerned with studying actual teaching and how children respond to the science being taught and with developing resources for use with teachers. This will involve a group of teachers in the school (maximum of 8) volunteering to prepare a science lesson that will be taught to a class. One of the group of teachers will teach the lesson and the others will observe the teaching and how the activities that are planned help children's understanding of science. I will participate as one of the teachers in the process and as an internal 'knowledgeable other' or expert, to guide the process. We will receive support from my two supervisors throughout the process.

The science lesson will be observed by participant teachers and my two supervisors. The teachers will record observation notes and children's written work will be collected. All data collected will be anonymised through the use of a coding system. I will not say the name of the school or give children's full names in written publications of my research. All paper data collected will be shredded at the end of my research.

The children will benefit in that participation in the lesson will be aimed at developing their scientific knowledge and skills. The teachers will participate in a lesson study cycle (of which the lesson is part). Following on from the lesson the teachers will engage in an in-depth analysis and reflection on the teaching and learning that occurred in the lesson. Participation in the lesson study cycle will hopefully have a positive impact on these teachers' future teaching of science, and therefore on children's learning.

The level of risk for the children and teachers participating in this research is deemed low. Only equipment and scientific investigations / experiments that are outlined in the Primary Science Curriculum will be used in the lesson. There is a risk of injury to children and teachers during any hands-on science lesson. A risk assessment of the lesson will be carried out as part of the planning lesson and a risk assessment of the classroom environment will be carried out prior to the lesson. All equipment will be examined for suitability of use.

Children do not have to take part in the research project. They will be welcome to remain in the room to participate in the science lesson but no observations will be noted in relation to them, nor will their work be collected. If they wish to leave the room for the duration of the lesson and go to another classroom that will also be permissible.

No children will be identifiable by name, class or school on anything that is written about the study. Only the research team will have access to any notes made. While the findings of teachers' experiences of teaching this lesson may be published and may be presented at educational conferences, names of individuals and schools will not be identifiable and demographic information will be generalised. Confidentiality is subject to legal limitations, meaning that it is possible that the data has to be reported for some legal reason, under Freedom of Information etc. Written responses or comments may be used, with consent, in reports or publications by the researchers or in further promotional literature.

I am very happy to discuss this project further with you and to talk about it with the wider staff at a future date. I would be most grateful if you would complete the form below indicating that you give permission for the school to participate in this project.

If you have concerns about this study and wish to contact an independent person,

please contact:

The Secretary, Dublin City University Research Ethics Committee, c/o Research and Innovation Support, Dublin City University, Dublin 9. Tel 01-7008000, e-mail rec@dcu.ie

Thank you in anticipation

Ms. Mary Boyle

.....

I give permission for the school to participate in science lessons which will be observed by a group of teachers and two college supervisors for research purposes.

Signed _____

APPENDIX I PLAIN LANGUAGE STATEMENT FOR TEACHERS

Date

Dear Teacher

As part of my Ph.D studies in Dublin City University (DCU) I am researching how to teach science through the use of Lesson Study. This will involve you, as part of a group of teachers collaboratively preparing a lesson that will be taught to a class. One of the group will teach the lesson and the others will observe the teaching and how the activities that are planned help children's understanding of science. You will be asked to keep a reflective journal of your experience of the process. This journal will be anonymised to protect your identity. I will participate as one of the teachers in the process and as an internal 'knowledgeable other' or expert, to guide the process. We will receive support from my two supervisors throughout the process.

The lessons will be observed and you will be asked to keep observation notes. Children's written work will be collected. The observation notes and examples of children's work will be used by the group to aid our reflections on science teaching. Only the members of the group, along with my two supervisors will have access to the data. As part of the post-lesson analysis you will be invited to participate in a focus group interview, reflecting on your experience of Lesson Study.

This Lesson Study may include the use of Zoom as an online portal for conducting our meetings during the cycle, and as a means of conducting our post-cycle focus group interview. The use of Zoom would enable us to continue with our project while adhering to Covid-19 social distancing guidelines, and/or continue our project during any potential period of school closure. Audio recordings only (not video recordings) will be stored of the planning meetings and the focus group interviews. They shall be stored on DCU Google Drive until such time as the interviews have been transcribed. They shall then be deleted. The recordings will only be accessible to me and my supervisors. The DCU Google Drive system is compliant with DCU GDPR/Data Protection requirements. The typed transcripts will be anonymised to protect your identity.

You are welcome to consider whether you wish to participate in any Zoom meeting, and/or interview. You may decline or later withdraw from participation in Zoom meetings with no negative implications for you. You have data protection rights, including the right of access to personal data relating to you, and the right to object to the processing of personal data relating to you.

Participation in the lesson study cycle will hopefully have a positive impact on your future teaching of science, and therefore on children's learning. The level of risk for you participating in this research is deemed low. Only equipment and scientific investigations / experiments that are outlined in the Primary Science Curriculum will be used in the lesson. There is a risk of injury to you during any hands-on science lesson. A risk assessment of the lesson will be carried out as part of the planning lesson and a risk assessment of the classroom environment will be carried out prior to the lesson. All equipment will be examined for suitability of use before the lesson.

I will not say the name of the school or your name in any written publications of my research. However, I cannot guarantee anonymity as people may be aware of the school where I teach. It is important to be aware that confidentiality of information provided is subject to legal limitations, meaning that it is possible that the data has to be reported for some legal reason, under Freedom of Information etc.

Involvement in this project is **voluntary** and you are under no obligation to do so. Furthermore, you may withdraw from the project at any point with no negative implications for you.

If you have any questions, I am very happy to discuss the details of this project further with you. You are also welcome to discuss the project with [REDACTED]

If you have concerns about this study and wish to contact an independent person, please contact:

The Secretary, Dublin City University Research Ethics Committee, c/o Research and Innovation Support, Dublin City University, Dublin 9. Tel 01-7008000, e-mail rec@dcu.ie

Thank you in anticipation

Mary Boyle

APPENDIX J CONSENT FORM TEACHERS

Please complete the following (Circle Yes or No for each question).

Have you read the Plain Language Statement (letter)? **Yes/No**

Do you understand the information provided? **Yes/No**

Have you had an opportunity to ask questions and discuss this study? **Yes/No**

Have you received satisfactory answers to all your questions? **Yes/No**

Do you understand that while all attempts will be made to conceal your identity, anonymity cannot be guaranteed?

Yes/No

Do you understand that you do not have to teach the research lesson? **Yes/No**

I consent to the use of Zoom for Lesson Study planning meetings that will be analysed by my colleague the researcher and by my colleague's supervisors.

Yes/No

I consent to the audio recording of Lesson Study planning meetings that will be analysed by my colleague the researcher and by my colleague's supervisors.

Yes/No

I consent to the use of Zoom for Lesson Study focus group interviews that will be analysed by my colleague the researcher and by my colleague's supervisors.

Yes/No

I consent to the audio recording of Lesson Study focus group interviews that will be analysed by my colleague the researcher and by my colleague's supervisors.

Yes/No

Signed _____

Date _____

APPENDIX K LETTER TO PARENTS

[insert date]

Dear Parents or Guardians,

I am a teacher in your child's school and I am also studying part-time for a Ph.D. degree in Dublin City University (DCU). I am carrying out research in the area of science teaching and learning. I am investigating the teaching and learning of science. The school has kindly agreed to facilitate this research.

A group of teachers in the school (maximum of 8) will prepare a lesson that will be taught to your child's class. One of the group of teachers will teach the lesson and the others will observe the teaching and how the activities that are planned help children's understanding of science. Teachers will keep written observation notes of what the children do and say during the lesson, but they will not identify the children by their full name. Examples of children's written work will be collected but the children will not be asked to write their full names on these sheets. The observation notes and examples of children's work will be used by the group and my two supervisors to discuss science teaching and the ways that it can be improved. When my studies are finished these documents will be shredded.

The children will benefit in that participation in the lesson will be aimed at developing their scientific knowledge and skills. The level of risk for the children and teachers participating in this research is deemed low. Only equipment and scientific investigations / experiments that are outlined in the Primary Science Curriculum will be used in the lesson. There is a risk of injury to children and teachers during any hands-on science lesson, for example they could spill some cold water on themselves, or perhaps scratch themselves with a piece of tin foil. If anything like this happens, your child can tell one of the teachers and they will help him/her. Please be assured that all equipment will be examined for its suitability of use before the lesson.

In reports that I write about the project the school's name or your child's identity will not be stated. Confidentiality is subject to legal limitations, meaning that it is possible that the data has to be reported for some legal reason, under Freedom of Information etc. Written responses or comments may be used, with consent, in reports or publications by the researchers or in further promotional literature.

Your child does not have to take part in the lesson and can withdraw at any point. If your child is not taking part in the lesson, s/he can still sit in on the lesson but we will not use her/his writings for research purposes. Equally your child can choose to leave the room and go to another classroom for the duration of the lesson if that is his/her wish.

I would be most grateful if you would complete the form below indicating that you give permission for your child to be present in the class during the observed lessons. If you wish to ask further questions about the interview or the evaluation, please contact [REDACTED] by telephone [REDACTED], or by email [REDACTED]@gmail.com.

If you have concerns about this study and wish to contact an independent person, please contact:

The Secretary, Dublin City University Research Ethics Committee, c/o Research and Innovation Support, Dublin City University, Dublin 9. Tel 01-7008000, e-mail rec@dcu.ie

Thank you in anticipation

Ms Mary Boyle

.....
INFORMED CONSENT

I give permission for _____ to take part in science lessons
which will be observed for future teaching and research purposes and to use what they say or
write for research purposes.

Yes

No

Signed _____

APPENDIX L CONSENT FORM PARENTS

Please complete the following (Circle Yes or No for each question).

Have you read the Plain Language Statement? **Yes/No**

Do you understand the information provided? **Yes/No**

Have you had an opportunity to ask questions and discuss this study? **Yes/No**

Have you received satisfactory answers to all your questions? **Yes/No**

Do you understand that your child can withdraw from the science lesson at any stage should s/he wish to do so? **Yes/No**

Do you understand that you can withdraw consent for your child's participation in the science lesson at any stage should you wish to do so? **Yes/No**

Signed _____

Date _____

APPENDIX M CHILDREN'S LETTER



We would love it if you could help us out with some science!

Some teachers in the school, including me, want to find out more about teaching science to primary pupils. We will prepare a lesson together, and then one of us will teach it and the rest of us will watch the lesson. We will take some notes to help us remember what you and your classmates did during the science lesson. In the notes that we write about the lesson we will not use your full name. We will look at some of your written science work too.

We will talk about this science lesson to two people who teach others how to be teachers. These two people will also watch the science lesson.

Ms. Boyle might want to talk to other teachers about the lesson. Ms. Boyle will be writing a report about how your class learns science. She will not use your real name or the name of your school in anything she writes.

You can decide to leave this lesson at any time and you will not get into trouble for doing this.

Thank you.

APPENDIX N PLAIN LANGUAGE STATEMENT CHILDREN

To be read to pupils:

We are interested in doing a project on teaching science. The person teaching the lesson is a teacher. Your class teacher and other teachers (list names of teachers) will also be in the room when the lesson is being taught. (The person teaching the lesson) will be teaching the lesson. The teachers will keep notes about what is happening in the lesson but they will not write down your full name on their notes. We might also ask you to show us your activity / investigation sheets but we will not ask you to write your name on your work.

It is hoped that the lesson will help you to develop your knowledge of science and your scientific skills. We have checked all of the equipment to make sure that it is working properly, however there is a very small chance that you could get hurt, for example some cold water might spill on you, or you might scratch yourself with a piece of tin foil. If anything like this happens, you can tell one of the teachers and we will help you.

We will talk about the lesson with the teachers involved in the project and with people who teach others how to be teachers. We will use the lesson to find out how science teaching can be improved. Ms. Boyle will write up a report about the lesson. She will not use your real name or the name of the school in anything she writes.

You do not have to take part in the lesson. If you decide not to take part you can choose to go to another classroom during the lesson or you can choose to stay in our classroom but we will not be talking or writing about your written work or your drawings or anything you say.

Thank you for listening.

APPENDIX O CHILDREN'S ASSENT FORM

My name is _____

I would like to take part in this science project.

Yes _____

No _____

I give permission for teachers to look at some of my written science work.

Yes _____

No _____

I give permission for teachers to watch me doing science with my class.

Yes _____

No _____

I give permission for teachers to write about how I and other pupils in my class learn science.

Yes _____

No _____

I understand that I can stop doing the project at any time, and I will not be in trouble for it.

Yes _____

No _____

I know that my name will be kept secret at all times if people are talking about the lessons.

Yes _____

No _____

Thank you

APPENDIX P TEACHING LEARNING PLAN LS1

Teaching-Learning Plan

Team Members

Lesson Date:	Person responsible for teaching lesson:	Class: <input type="text" value="4th"/>
<input type="text" value="06/10/2020"/>	<input type="text" value="Mary Boyle"/>	

1. Title of Lesson

Refer to [Plan | Step 3: Identify and Examine the Lesson](#)

Investigating Paper Spinners

2. Research Theme

The long-term goals for our students and how we will get there (theory of action)

Refer to [Study | Step 2: Develop a Research Theme](#)

All children will have the opportunity to work scientifically.

3. Background and Research on the Content

- Why we chose to focus on this topic - for example, what is difficult for our students, what we noticed about student learning
- What resources we studied, and what we learned about the content and about student thinking

Refer to [Plan | Step 1: Take Stock](#)

- We have noticed that the children we teach find it difficult to make predictions. We also noted that as teachers we find it difficult to teach children how to predict and

that for some of us we struggle with prediction ourselves as adults (Meeting notes: March 11th & March 31st 2020).

- We find the area of forces, and in particular gravity and falling objects, challenging concepts to teach. We feel that there are shortcomings in our own content knowledge leading to a lack of confidence in this area of the curriculum. This makes it a challenge to support student learning and answer children's questions on this theme. We would like to develop our own scientific content knowledge in this area of the curriculum (Meeting notes: March 31st, 2020).
- Our external science knowledgeable other (KO) and internal KO identified resources which may be suitable for us to study, focusing on gravity and the skill of prediction. We initially looked at the Predict Observe Explain Activities booklet, a reading entitled Children's Ways of Thinking (Harlen), the Primary Science Curriculum and some Concept Cartoons (April 2020).
- After studying the resources we noted the difference between a guess and a prediction - that it is important that we teach children to give a reason or justification for their predictions. We could encourage them to relate ideas to lived experience and aim to reduce the fear of being wrong. (Meeting notes: April 14th 2020).
- We liked the idea of using Concept Cartoons as a means to elicit children's thinking but noted how children with reading difficulties would need further support to access them. There was also a suggestion that it could be preferable to see them in action before using them in the research lesson (Meeting notes: April 14th 2020).
- We supplemented our initial study materials with additional explainer videos from YouTube but still felt that our conceptual knowledge was lacking which made us reluctant to pursue that topic for our research lesson (Meeting notes: April 14th 2020).

4. Rationale for the Design of Instruction

- What we learned from studying our own curriculum and other resources
- Why the unit and lesson are designed as they are - for example, why we chose this particular task, representations, contexts, lesson sequence, etc.
- How the unit and lesson design address the research theme

Refer to [Plan | Step 7: Finalize the Teaching-Learning Plan](#)

- We weren't aware of the trajectory of learning from Infants to 6th class with regard to gravity and questioned whether we would have considered the whole curriculum aside from partaking in Lesson Study. We tend to just focus on the class level we

are teaching at, rather than considering the progression of a strand from Infants to 6th class. (Meeting notes: May 7th 2020)

- We became aware that the term 'gravity' is only included in the learning objectives for 5th and 6th classes. As our focus is on 3rd class we are choosing to investigate falling objects as per the 3rd and 4th class guidelines. This also enables us to avoid a concept where we lack confidence, as outlined above. We will now focus on air resistance, which links to the 3rd and 4th class learning objectives for forces as shown in the table below. (Meeting Notes April 28th)
- The unit is designed to use paper spinners as an introductory teacher-directed inquiry -based lesson, allowing the children to develop their skills of prediction. This will lead to a child-led investigation whereby the children investigate a question they have about the spinners. Following this the children will use the knowledge they have gained to investigate what makes the 'best' parachute.
- The unit addresses the research theme as it outlines activities that will provide all children with the opportunity to work scientifically through the development of both science content knowledge and scientific skills such as predicting, observing, analysing and questioning.

5. Relationship of the lesson/unit to the curriculum

- How the learning in the lesson relates to the objectives for the class level.
- How the learning in the unit relates to prior objectives and future objectives.

Prior learning objectives that lesson builds on: (1st and 2nd classes)	Learning objectives for this lesson: (3rd and 4th classes)	Later objectives for which this lesson is a foundation: (5th and 6th classes)
<p>Content Objectives for Forces: Become aware of how moving air can make things move. Explore how objects may be moved by pushing and pulling. Investigate how forces act on objects - e.g. floating and sinking.</p>	<p>Content Objectives for Forces: Explore how some moving objects may be slowed down. Explore the effect of friction on movement. Investigate falling objects.</p>	<p>Content Objectives for Forces: Explore the effect of friction on movement and how it may be used to slow or stop moving objects. Come to appreciate that gravity is a force.</p>

Skills Objectives:

Observing: use the senses to observe objects and events in the environment. Observe similarities and differences.

Predicting: suggest outcomes of an investigation based on observations.

Investigating and experimenting: carry out simple investigations where the problem, materials and method are suggested by the teacher.

Analysing: Begin to look for and recognise patterns and relationships in observations. Draw conclusions from simple investigations.

Recording and communicating: describe and discuss observations orally using an increasing vocabulary. Represent findings using pictures, models and other methods.

Skills Objectives:

Observing: observe and describe processes in the immediate environment.

Predicting: offer suggestions (hypotheses) based on observations about the likely result of the investigation. *Give a reason for your idea, maybe ground it in your experience etc.*

Investigating and experimenting: design, plan and carry out simple investigations. Realise that an experiment is unfair if relevant variables are not controlled.

Analysing: Look for and recognise patterns and relationships in observations. Interpret information and offer explanations. Draw conclusions from suitable aspects of the evidence collected.

Recording and communicating: record and present findings and conclusions using a variety of methods.

Skills Objectives:

Observing: observe and describe processes in the immediate environment. Recognise and describe patterns and sequences in observations.

Predicting: offer suggestions (hypotheses) based on a number of observations and data available about the likely result of the investigation. Make inferences based on suggestions and observations. Propose ideas or simple theories that may be tested by experimentation.

Investigating and experimenting: design, plan and carry out simple investigations. Realise that an experiment is unfair if relevant variables are not controlled.

Appreciate the importance of repeating tests and experiments.

Analysing: Look for and recognise patterns and relationships in observations. Use observed patterns to make predictions. Interpret information and offer explanations. Draw conclusions from suitable

		<p>aspects of the evidence collected.</p> <p>Recording and communicating: record and present findings and conclusions using a variety of methods.</p>
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6. Unit Plan

The lesson sequence of the unit of work, with the task and learning goal of each lesson. The asterisk (*) shows the research lesson

Lesson	Learning goal(s) and tasks
1 *	<p>Refer to Plan Step 2: Examine the Unit Plan</p> <p>Lesson Goal: Children will work as scientists to observe how a paper spinner behaves when it falls and investigate different ways it can fall.</p> <p>Task: Ask the children to predict what they think will happen if they drop the spinner. Encourage the children to drop the spinner and observe what happens. Children record and share their experiences with the group. Repeat this process but change the manner in which the spinner is dropped</p>
2	<p>Lesson Goal: Children will work as scientists to further investigate a falling object - the paper spinner.</p> <p>Task: Children will investigate questions they developed about the paper spinner during the previous lesson</p>
3	<p>Lesson Goal: Children will work as scientists to explore the 'best' material for making a parachute dome.</p>

	<p>Task: Children will investigate which material is the best for making a parachute - i.e. which material is the slowest to fall to the ground.</p>
4	<p>Lesson Goal: Children will work as scientists to explore what difference the length of string has on how quickly a parachute falls.</p> <p>Task: Children will vary the length of a string on a parachute and investigate what impact this has on the speed at which it falls.</p>

7. Goals of the Research Lesson

Refer to [Plan | Step 3: Identify and Examine the Lesson](#)

- Children will predict what might happen when they drop a paper spinner to the ground and give a reason for their predictions.
- Children will observe what happens when they drop a paper spinner and record their observations.
- Children will predict and observe how changing properties (e.g. starting height, starting position, size) of the paper spinner will affect the manner in which it falls.
- Children will attempt to explain their results.
- Children will recognise that air causes the paper spinner to slow down as it falls.

8. Research Lesson Plan

Learning task and activities, anticipated student responses, key questions or comparisons that will build insights	Teacher Support	Assessment (Points to Notice)
<p>Refer to Plan Step 4: Design the Flow of Instruction</p> <p>Introduction Children recall how they made the paper spinner, what features does it have? Does it remind them of anything they've seen before? (Perhaps Think Pair Share?)</p>	<p>Talk to your partner about how you made the spinner. Could you describe what it looks like to someone who can't see it? Does it remind you of anything you've seen before?</p>	<p>Looking for active and purposeful conversation - can the children describe their spinner through words/actions as appropriate to individual learners.</p>
<p>Posing the Task</p> <p>Tell the children that today they are going to work as scientists. Scientists think about things and ask questions about what they see around them. They often carry out experiments. Today we are going to be like</p>	<ul style="list-style-type: none"> • <i>What do you think will happen if you drop the spinner and the wings are at the top? Do you have a reason for thinking this?</i> 	<p>Give each pair (individual child) a pre-made sheet with a table where they record their prediction and</p>

<p>scientists as we work with the paper spinners. We are going to investigate, like scientists, what happens to the spinner when we drop it in different ways. Before we carry out different experiments we are going to talk about what we think might happen. We will give a reason for our answers so that it's not just a wild guess. Scientists call this making a prediction.</p> <p>Pairs follow a Predict, Observe, Explain approach for each of the scenarios outlined in the Teacher Support section.</p>	<ul style="list-style-type: none"> • <i>What do you think will happen if you drop the spinner and the wings are at the bottom? Give a reason for your thinking.</i> • <i>What do you predict will happen if you drop the spinner on its side? (Horizontally) Give a reason.</i> • <i>Do you think throwing the spinner at the start will change how it falls? Give a reason.</i> • <i>I wonder what would happen if we changed the size of the spinner and made it smaller? Do you think it would fall in the same way or would one spinner fall faster than the other?</i> • <i>How will we drop the big and small spinners in a fair way? (Perhaps refer to a race in P.E. etc. How do we make sure it's fair?)</i> 	<p>observations and explanations either pictorially or in written format.</p>
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<p><i>Anticipated Student Responses</i></p> <p><u>Wings at the top:</u> It will fall straight to the ground because when you drop things they fall.</p> <p><u>Wings at the bottom:</u> I think it might spin a bit but not as smoothly as when it was upright because when it's upright the weight underneath gives it balance to spin whereas upside down it won't have as much balance.</p> <p><u>Dropping sideways:</u> I don't think it will spin to the ground because it's all edges that are going down - there's nowhere for the air to support it.</p> <p><u>Different sizes:</u> The bigger one might fall faster because it's heavier. The bigger one might fall slower because there's more air pushing up on it. They might fall at the same speed because the size of the spinner doesn't matter.</p>	<p>Remember to give a reason for your idea so that you are making a prediction, just like a scientist.</p>	<p>Assess whether or not the children can offer a suggestion of what might happen and give a reason why.</p>
<p><i>Interpreting and explaining our results. Comparing and Discussing, including Teacher Key Questions</i></p> <p>Ask the children to recap on the results of each investigation.</p> <p>Refer back to the children's predictions and what they observed. Were there differences between what you thought would happen and what did happen?</p> <p>Try to identify any patterns in the way the spinners fell.</p> <p>Encouraging the children to relate what they've seen to everyday life.</p> <p>Have two sheets of paper ready as a prompt if necessary - scrunch one in a ball and leave one flat and drop at the same time. Children predict in advance what may happen and</p>	<ul style="list-style-type: none"> • What did you learn from carrying out this test? • Can you explain what happened? • Does the way the paper spinner falls remind you of anything you've seen before? • Does it remind you of the way a leaf falls to the ground in autumn? A paper 	<p>Assess whether or not the children can interpret that air is a slowing down force. Assess whether or not the children can relate their findings to everyday life.</p>

why.	plane, a drone etc?	
<p>Summing Up</p> <p>Reemphasise how the children were working as scientists today - asking questions, predicting, investigating, recording results - all things that real scientists do.</p> <p>Ask the children if they have any further questions about paper spinners that they would like to investigate.</p>	<p><i>Can you think of any other questions you have about paper spinners?</i></p> <p><i>Prompts if necessary:</i></p> <p><i>Could you change the type of paper the spinner is made out of e.g. to card?</i></p> <p><i>Could you change the size of the paper clip/ the amount of <u>blu</u> tack?</i></p> <p><i>Could you change the shape of the wings?</i></p> <p><i>Is the one that hits the ground first the one that spins the most number of times?</i></p>	<p>Teachers record if pairs can think of a question(s) to ask.</p>

9. Points of Evaluation (Assessment)

Prompts to focus observation and data collection.

Refer to [Plan | Step 5: Focus the Data Collection](#)

Teachers will observe two children during the lesson and take notes on an observation log.

- Listen as two children predict what might happen when they drop a paper spinner to the ground.
- Record if the children can make a prediction, i.e. give a reason for their thinking.
- Listen to and record some of the language the children use as they describe what they see.
- Listen as the children attempt to explain their results and record the same.
- Listen to the children in order to analyse whether or not they recognise that air causes the paper spinner to slow down as it falls.
- Listen as the children discuss what other questions they could investigate using their paper spinners and record some of their thinking.

10. Board Plan

Refer to [Plan | Step 6: Teach a Mock-up Lesson](#)

Some Participant Responses from the Mock Lesson:

Position	Prediction	Reason
Wings at the Top	<p>It would fall on the floor - relating prediction to pen dropped onto floor, it went straight down.</p> <p>Don't know if it would go straight or if it would go in a curve.</p> <p>Go down like a kite, moves in different directions, doesn't go straight down.</p>	

	<p>The heavy bit will turn it and the heavy bit (head of the hammer) will go down first.</p> <p>The weight is quite heavy so that would pull it down first.</p> <p>Paper doesn't tend to fall straight it will go off to the side like if you drop a sheet of paper.</p>	
Wings at the Bottom	<p>Flip around to the heavy end. Fall flat Flip and spin Crash landing</p>	<p>Weight and gravity pulling it down. Shape – narrow at one end and not at the other end. Might go sideways and down The two flat pieces will cause it to drop to the ground.</p>
Spinner on its side	<p>The weight will go to the bottom and the same as last time. It will happen more quickly.</p>	<p>Doesn't have as much rotation Knowledge from test one is informing our thinking.</p>
Throw the spinner into the air	<p>Hard to throw Javelin throw Will stop suddenly and then return to its normal form. The wings will stop it going far.</p>	<p>Weight will pull it down quicker. Not pointy</p>
Larger v smaller spinner	<p>Smaller will be faster - propellers are smaller and won't have as much</p>	

	<p>“up-force” (air force) or resistance, smaller diameter for resistance.</p> <p>Fall at the same time - relating current information to past experiences - remembering a previous experiment with tennis balls (of different temperatures) being dropped.</p> <p>Mention of ratio - they will fall at the same time because the proportions are the same.</p>	
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11. End of Cycle Reflection

What Did We Learn? (to be filled out after the post-lesson discussion)

Refer to [Reflect | Step 4: Consolidate Your Learning](#)

- *The lesson is too long - could be split into two lessons - dropping one spinner with wings on top, wings on the bottom and wings on the side and throwing the spinner all as one lesson. Comparing the large and small spinners in the next lesson along with discussion of what other questions the children could investigate.*
- *We noted progression in the children’s ability to predict - some of them found this challenging in the beginning, especially giving a reason for their thinking, but they used their previous experience of dropping the spinner when making each new prediction as the lesson went on.*
- *The children were very quiet and did not talk very much to their partners - was this a result of the Covid-19 social distancing requirements? Next time we would hope to reduce the amount of writing time and increase the amount of discussion in pairs/groups.*

APPENDIX Q TEACHING LEARNING PLAN LS2

Team Members

[REDACTED]

Lesson Date:

27/6/2022

Person responsible for teaching lesson:

[REDACTED]

Class:

5th

1. Title of Lesson

Refer to [Plan | Step 3: Identify and Examine the Lesson](#)

Developing a model that recreates shadows formed by our bodies outside.

2. Research Theme

The long-term goals for our students and how we will get there (theory of action)

Refer to [Study | Step 2: Develop a Research Theme](#)

All children will have the opportunity to work scientifically.

3. Background and Research on the Content

- Why we chose to focus on this topic - for example, what is difficult for our students, what we noticed about student learning
- What resources we studied, and what we learned about the content and about student thinking

Refer to [Plan | Step 1: Take Stock](#)

- We discovered that children's knowledge and our understanding of light were not always compatible. A direct consequence of lack of confidence in our own knowledge of light impacts on our ability to teach the concept. From previous

teaching experience we found that it was difficult to assess the children's knowledge and understanding after the lesson as the criteria were vague and ambiguous. We would like to develop our own scientific content knowledge in this area of the curriculum.

- As a group we identified resources which may be suitable for us to study, focusing on light. We looked at concept cartoons, our in school science journal for potential questions, "There's more to light than meets the eye" article in Primary Science Review and Smithsonian videos about light and shadows. We also referred to the Primary Science Curriculum, noting that the children may have missed some curriculum objectives due to covid and remote learning. We were not confident that all children would have achieved the objectives when working from home.
- We spent time engaging with the resources available to enhance our own understanding and simulate what the children might discover. In this way we were able to preempt the questions the children might ask. We were able to bolster our own confidence and test out materials (light strength on torches etc) prior to discussing the lesson goals and targets that we would hope to achieve. We benefited from a group member's background in science in order to better understand certain concepts.
- We could encourage them to relate ideas to lived experience and aim to reduce the fear of being wrong.

4. Rationale for the Design of Instruction

- What we learned from studying our own curriculum and other resources
- Why the unit and lesson are designed as they are - for example, why we chose this particular task, representations, contexts, lesson sequence, etc.
- How the unit and lesson design address the research theme

Refer to [Plan | Step 7: Finalize the Teaching-Learning Plan](#)

- We weren't aware of the trajectory of learning from Infants to 6th class with regard to light and questioned whether we would have considered the whole curriculum aside from partaking in Lesson Study. We tend to just focus on the class level we are teaching at, rather than considering the progression of a strand from Infants to 6th class. We noted that the children may have missed some curriculum objectives due to covid and remote learning. We were not confident that all children would have achieved the objectives when working from home.
- As our focus is on 5th class we are choosing to investigate light and shadows as per the 3rd and 4th class guidelines due to missed learning during covid closures.

- The unit is designed to allow children to investigate light and shadows through teacher designed tasks and culminates in the children creating a model to represent shadows created outside.
- The unit addresses the research theme as it outlines activities that will provide all children with the opportunity to work scientifically through the development of both science content knowledge and scientific skills such as predicting, observing, analysing and questioning.

5. Relationship of the lesson/unit to the curriculum

- How the learning in the lesson relates to the objectives for the class level.
- How the learning in the unit relates to prior objectives and future objectives.

Prior learning objectives that lesson builds on: (1st and 2nd classes)	Prior learning objectives that lesson builds on: (3rd and 4th classes)	Learning objectives for this lesson: : (5th and 6th classes)
<p>Content Objectives for Light: Recognise that light comes from different sources. Recognise that light is needed in order to see. Investigate the relationship between light and materials e.g. transparent, opaque, shadows. Recognise that the sun gives us light and heat, without which we could not survive. Become aware of the dangers of directly looking at the sun.</p>	<p>Content Objectives for Light: Learn that light is a form of energy. Recognise that light comes from different natural and artificial sources. Investigate that light can be broken up into many different colours - use prism to create spectrum. Investigate the relationship between light and materials e.g. transparent, opaque, translucent, shadows. Investigate how mirrors and other shiny surfaces are good reflectors of</p>	<p>Content Objectives for Light: Learn that light is a form of energy. Know that light travels from a source. Investigate the splitting and mixing of light. Investigate the refraction of light. Investigate how mirrors and other shiny surfaces are good reflectors of light. Explore how objects may be magnified using simple lens or magnifier. Appreciate the importance of sight. Understand the role of sunlight in photosynthesis and</p>

	<p>light. Recognise that the sun gives us light and heat, without which we could not survive. Become aware of the dangers of directly looking at the sun.</p>	<p>appreciate that the sun gives us light and heat without which people and animals could not survive. Be aware of the dangers of excessive sunlight.</p>
<p>Skills Objectives: Observing: use the senses to observe objects and events in the environment. Observe similarities and differences. Predicting: suggest outcomes of an investigation based on observations. Investigating and experimenting: carry out simple investigations where the problem, materials and method are suggested by the teacher. Analysing: Begin to look for and recognise patterns and relationships in observations. Draw conclusions from simple investigations. Recording and communicating: describe and discuss observations orally using</p>	<p>Skills Objectives: Observing: observe and describe processes in the immediate environment. Predicting: offer suggestions (hypotheses) based on observations about the likely result of the investigation. <i>Give a reason for your idea, maybe ground it in your experience etc.</i> Investigating and experimenting: design, plan and carry out simple investigations. Realise that an experiment is unfair if relevant variables are not controlled. Analysing: Look for and recognise patterns and relationships in observations. Interpret information and offer explanations. Draw conclusions from suitable aspects of the evidence collected.</p>	<p>Skills Objectives: Observing: observe and describe processes in the immediate environment. Recognise and describe patterns and sequences in observations. Predicting: offer suggestions (hypotheses) based on a number of observations and data available about the likely result of the investigation. Make inferences based on suggestions and observations. Propose ideas or simple theories that may be tested by experimentation. Investigating and experimenting: design, plan and carry out simple investigations. Realise that an experiment is unfair if relevant variables are not controlled. Appreciate the</p>

<p>an increasing vocabulary. Represent findings using pictures, models and other methods.</p>	<p>Recording and communicating: record and present findings and conclusions using a variety of methods.</p>	<p>importance of repeating tests and experiments. Analysing: Look for and recognise patterns and relationships in observations. Use observed patterns to make predictions. Interpret information and offer explanations. Draw conclusions from suitable aspects of the evidence collected. Recording and communicating: record and present findings and conclusions using a variety of methods.</p>
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6. Unit Plan

The lesson sequence of the unit of work, with the task and learning goal of each lesson. The asterisk (*) shows the research lesson

Lesson	Learning goal(s) and tasks
1	<p>Refer to Plan Step 2: Examine the Unit Plan</p> <p>Lesson Goal: Children will work as scientists to observe the relationship between light and materials.</p> <p>Task: Ask the children to predict what they think will happen if they shine a light on individual objects. Children analyse their results to determine which objects are transparent, translucent or opaque.</p>

2	<p>Lesson Goal: Children will work as scientists to investigate the relationship between distance from the light source and the type of and nature of shadow created.</p> <p>Task: Children will investigate moving the light source or object and analysing the effect on the shadow produced.</p>
3	<p>Lesson Goal: Children will work as scientists to observe what happens to their shadow at different intervals on a sunny day.</p> <p>Task: Record the position, length and shape of their shadow at different times of the day.</p>
4*	<p>Lesson Goal: Children will develop a model to recreate the shadows formed at different times of the day.</p> <p>Task: Children will communicate their understanding of the relationship between the shadows formed and the light source.</p>

7. Goals of the Research Lesson

Refer to [Plan | Step 3: Identify and Examine the Lesson](#)

- Children will analyse the photos and/or drawings from Lesson 3 (shadows their bodies created outside at different times on a sunny day), noting differences in position and length.
- Children will create a model to depict what happened outside in Lesson 3.
- Children will manipulate light sources (torches/iPads) to mimic the results of Lesson 3.
- Children will attempt to explain and communicate the relationship between the shadows formed and the light source.
- Children will recognise that although it appears that the sun moves it's the rotation of the earth that determines the shape, size and nature of the shadow.

8. Research Lesson Plan

Learning task and activities, anticipated student responses, key questions or comparisons that will build insights	Teacher Support	Assessment (Points to Notice)
<p>Refer to Plan Step 4: Design the Flow of Instruction</p> <p>Introduction Children will review their drawings/photos from Lesson 3. Children will note differences in position and length of shadows created at different times of the day.</p>	<p>Talk to your partner about your shadow photos and drawings. What do you see? Did they stay the same? Do you notice any differences? Can you think of any reasons for the results you found? Compare your pictures with a group near you.</p>	<p>Look for active and purposeful conversation. Most students should identify a difference between shadow positions and length. Some students may infer a relationship between the shadow created and the position of the sun.</p>

<p>Posing the Task</p> <p>Tell the children that today they are going to work as scientists. Scientists sometimes use models to recreate things they've seen in their environment. A model is a smaller version of something bigger, for example Lego models. Today we are going to be like scientists as we create a model to represent how we created shadows outside.</p> <p>Provide the children with the materials they will need (whiteboards, markers, torches, iPads, lego characters, blutack) and encourage them to create the model in pairs.</p>	<ul style="list-style-type: none"> • <i>We don't have the sun in our classroom. How can we recreate what we did in the yard while working here in the classroom?</i> • <i>Analyse what is in the picture. What do we need to represent the ground, the person and the sun? How will we make sure our person stays in the same place?</i> • 	<p>Observe the pairs making their model and recreating a shadow similar to their morning shadow on their photo or drawing.</p> <p>Assess whether children can create shadows representing specific times of the day.</p> <p>Can the children show the different shadows in one continuous sequence?</p>
<p>Anticipated Student Responses</p> <p><u>The sun is moving:</u> The sun moves across the sky during the day.</p> <p>Sun only appears to be moving through the sky but we're actually the ones moving.</p> <p><u>The clouds have something to do with the shadows:</u> the clouds determine the strength of the sun and therefore the position of the shadow.</p> <p><u>I have a shadow because my body is blocking the sun (opaque) from hitting the ground:</u></p> <p><u>My shadow is being reflected onto the ground:</u></p>	<p>Refer back to earlier lessons and prior knowledge as well as the photographs.</p>	<p>Assess whether or not the children can communicate why shadows are created and why they appear to change throughout the day.</p>

<p><i>Interpreting and explaining our results. Comparing and Discussing, including Teacher Key Questions</i> Ask the children to recap on the results of their simulation. Demonstrate their model to the class. Encourage the children to critically analyse each other's models.</p> <p>Encouraging the children to relate what they've seen to everyday life. (The sun isn't moving, we are!)</p>	<ul style="list-style-type: none"> • What did you learn from carrying out this test? • Can you explain what happened? • How accurate is our model to what's happening in real life? • Is the sun really moving across the sky? • What do you know about how the Earth travels in space? • How could we make our model more accurate? 	<p>Assess whether or not the children can communicate why shadows are created and why they appear to change throughout the day. Assess whether or not the children have the appropriate language to communicate their <u>understandings</u>. Assess through observation if the children can determine that the model should be moving and not the light source to accurately represent Earth's relationship to the sun.</p>
<p><i>Summing Up</i> Reemphasise how the children were working as scientists today - asking questions, analysing, creating models, investigating, recording results - all things that real scientists do. Ask the children if they have any further questions about light and shadows that they</p>	<p><i>Can you think of any other questions you have about light and shadows?</i> <i>Prompts if necessary: Could you change the light source? Could you make the room darker?</i></p>	<p>Teachers record if pairs can think of a question(s) to ask.</p>

<p>would like to investigate.</p>	<p><i>Could you change the model in any way to more accurately represent Earth and its relationship to the sun?</i></p>	
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9. Points of Evaluation (Assessment)

Prompts to focus observation and data collection.

Refer to [Plan | Step 5: Focus the Data Collection](#)

Teachers will observe two children during the lesson and take notes on an observation log.

- Listen as two children analyse the photos and/or drawings from Lesson 3.
- Record if the children can note differences in the shadows created at various times of the day.
- Observe the children creating a model which mimics Lesson 3.
- Listen to and record some of the language the children use as they describe what they see.
- Listen as the children attempt to explain their results and record same.
- Listen to the children in order to analyse whether or not they recognise that the Earth is moving, not the sun.

10. Board Plan

Refer to [Plan | Step 6: Teach a Mock-up Lesson](#)

Some Participant Responses from the Mock Lesson:

11. End of Cycle Reflection

What Did We Learn? (to be filled out after the post-lesson discussion)

Refer to [Reflect | Step 4: Consolidate Your Learning](#)

- *Lesson 4 was beneficial in terms of assessing the children's thinking and having an awareness of their prior knowledge.*
- *We noted progression in the children's ability to articulate their thinking about light and analyse their shadow photos in order to create a model - there was a variety of learning outcomes amongst the class.*
- *Very practical lesson and lots for the observers to note and record because the children were spending time doing as opposed to recording.*
- *Children had more language and were talking to each other more.*

APPENDIX R TEACHING LEARNING PLAN LS2

Team Members

[REDACTED]

Lesson Date:

Person responsible for teaching lesson:

Class:

27/3/2023

[REDACTED]

5th

1. Title of Lesson

Refer to [Plan | Step 3: Identify and Examine the Lesson](#)

Create and use different types of pulleys in order to determine which is most efficient for lifting.

2. Research Theme

The long-term goals for our students and how we will get there (theory of action)

Refer to [Study | Step 2: Develop a Research Theme](#)

All children will have the opportunity to work scientifically.

3. Background and Research on the Content

- Why we chose to focus on this topic - for example, what is difficult for our students, what we noticed about student learning
- What resources we studied, and what we learned about the content and about student thinking

Refer to [Plan | Step 1: Take Stock](#)

- A direct consequence of lack of confidence in our own knowledge of pulleys impacts on our ability to teach the concept. There's a collective acknowledgement as working professionals that there's an absence of subject content knowledge relating to pulleys and therefore due to lack of subject content knowledge we also

lack pedagogical content knowledge to teach about pulleys. We all found that we were actively avoiding the topic.

- We would like to develop our own scientific content knowledge and our pedagogical content knowledge in this area of the curriculum.
- As a group we identified a complete lack of resources which may be suitable for us to study, focusing on pulleys. There were no pulleys in the school at the beginning of this cycle.
- We looked at videos to develop our own knowledge of what pulleys are, how to teach them and how to use them. We looked at exemplars from the Discover Primary Science suite of resources. We compared and contrasted different pulleys to see which might suit our needs best within a classroom setting.
- We spent time engaging with the resources available to enhance our own understanding and simulate what the children might discover. We were able to bolster our own confidence and test out materials (rolling pin pulley, fixed pulley, moveable pulley and compound pulley) prior to discussing the lesson goals and targets that we would hope to achieve.
- We benefited from having both homemade and commercially bought pulleys.
- We want to continue investigating how to properly use force meters to get consistent results.

4. Rationale for the Design of Instruction

- What we learned from studying our own curriculum and other resources
- Why the unit and lesson are designed as they are - for example, why we chose this particular task, representations, contexts, lesson sequence, etc.
- How the unit and lesson design address the research theme

Refer to [Plan | Step 7: Finalize the Teaching-Learning Plan](#)

- We weren't aware of the trajectory of learning from Infants to 6th class with regard to pulleys. It is a topic we had avoided up to now because we didn't have the content knowledge or confidence.
- As our focus is on 5th class we are choosing to investigate pulleys as per the 3rd and 4th class guidelines due to lack of prior engagement.
- The unit is designed to allow children to investigate pulleys through teacher designed tasks and culminates in the children creating a model of a compound pulley.
- The unit addresses the research theme as it outlines activities that will provide all children with the opportunity to work scientifically through the development of both science content knowledge and scientific skills such as predicting, observing, analysing and questioning.

5. Relationship of the lesson/unit to the curriculum

- How the learning in the lesson relates to the objectives for the class level.
- How the learning in the unit relates to prior objectives and future objectives.

Prior learning objectives that lesson builds on: (1st and 2nd classes)	Prior learning objectives that lesson builds on: (3rd and 4th classes)	Learning objectives for this lesson: : (5th and 6th classes)
<p>Content Objectives for Forces: Explore how objects may be moved by pushing and pulling. Investigate how forces act on objects.</p>	<p>Content Objectives for Forces: Explore how objects may be moved:</p> <ul style="list-style-type: none"> • by pushing and pulling • by machines (e.g. rollers, wheels, pulleys) 	<p>Content Objectives for Forces: Identify and explore how objects and materials may be moved:</p> <ul style="list-style-type: none"> • by pushing and pulling • by machines (e.g. rollers, wheels, axles, gear wheels, chains and belts) • Come to appreciate that gravity is a force.
<p>Skills Objectives: Observing: use the senses to observe objects and events in the environment. Observe similarities and differences. Predicting: suggest outcomes of an investigation based on observations. Investigating and experimenting: carry out simple investigations where the problem,</p>	<p>Skills Objectives: Observing: observe and describe processes in the immediate environment. Predicting: offer suggestions (hypotheses) based on observations about the likely result of the investigation. <i>Give a reason for your idea, maybe ground it in your experience etc.</i> Investigating and experimenting: design, plan and carry out simple</p>	<p>Skills Objectives: Observing: observe and describe processes in the immediate environment. Recognise and describe patterns and sequences in observations. Predicting: offer suggestions (hypotheses) based on a number of observations and data available about the likely result of the investigation. Make inferences based on suggestions and</p>

<p>materials and method are suggested by the teacher.</p> <p>Analysing: Begin to look for and recognise patterns and relationships in observations. Draw conclusions from simple investigations.</p> <p>Recording and communicating: describe and discuss observations orally using an increasing vocabulary. Represent findings using pictures, models and other methods.</p>	<p>investigations. Realise that an experiment is unfair if relevant variables are not controlled.</p> <p>Analysing: Look for and recognise patterns and relationships in observations. Interpret information and offer explanations. Draw conclusions from suitable aspects of the evidence collected.</p> <p>Recording and communicating: record and present findings and conclusions using a variety of methods.</p>	<p>observations. Propose ideas or simple theories that may be tested by experimentation.</p> <p>Investigating and experimenting: design, plan and carry out simple investigations. Realise that an experiment is unfair if relevant variables are not controlled. Appreciate the importance of repeating tests and experiments.</p> <p>Analysing: Look for and recognise patterns and relationships in observations. Use observed patterns to make predictions. Interpret information and offer explanations. Draw conclusions from suitable aspects of the evidence collected.</p> <p>Recording and communicating: record and present findings and conclusions using a variety of methods.</p>
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6. Unit Plan

The lesson sequence of the unit of work, with the task and learning goal of each lesson. The asterisk (*) shows the research lesson

Lesson	Learning goal(s) and tasks
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<p>1</p>	<p>Refer to Plan Step 2: Examine the Unit Plan</p> <p>Lesson Goal: (Info lesson - videos of pulleys in the environment and concept cartoons) Children will work as scientists to observe pulleys in the environment and consider the purpose of a pulley.</p> <p>Task: Ask the children to examine learning artefacts (a photo, concept cartoon, video and virtual manipulatives) of pulleys and discuss their purpose with a partner.</p>
<p>2</p>	<p>Lesson Goal: (fixed pulleys) Children will work as scientists to explore a fixed pulley and its efficacy when lifting heavy loads.</p> <p>Task: Children will create fixed pulleys using a rolling pin, string and 1kg weight. They will investigate how pulleys work with gravity to help us lift things.</p>
<p>3</p>	<p>Lesson Goal: (fixed pulleys Vs movable pulleys) Children will work as scientists to explore a moveable pulley and compare and contrast it with a fixed pulley.</p> <p>Task: Children will use a commercial plastic fixed pulley to lift a 1kg weight. Children will be introduced to the concept of a moveable pulley in order to compare how they work with a fixed pulley.</p>
<p>4*</p>	<p>Lesson Goal: Fixed/Movable Vs Compound Children will work as scientists to create and use different types of pulleys in order to determine which is most efficient for lifting.</p> <p>Task: Children will compare fixed, moveable and compound pulley systems in order to analyse the efficacy of the compound pulley.</p>

7. Goals of the Research Lesson

Refer to [Plan | Step 3: Identify and Examine the Lesson](#)

- *Overall Aim: Children will work as scientists to create and use different types of pulleys in order to determine which is most efficient for lifting.*
- Children will create a compound pulley drawing on their understanding of a fixed and moveable pulley.
- Children will compare fixed, moveable and compound pulley systems in order to analyse the efficacy of the compound pulley.
- Children will attempt to explain and communicate the differences and similarities between the different types of pulleys.

8. Research Lesson Plan

Learning task and activities, anticipated student responses, key questions or comparisons that will build insights	Teacher Support	Assessment (Points to Notice)
<p>Refer to Plan Step 4: Design the Flow of Instruction</p> <p>Introduction</p> <ul style="list-style-type: none"> • Discuss what we have discovered about fixed/moveable pulleys so far. Which one was easier to use? Why? Did they make things easier to lift/hold? 	<p>Can you draw the two different types of pulleys that we've explored? Is there any way that a moveable pulley would be easier to use? Explain your thinking using a whiteboard.</p>	<p>Look for active and purposeful conversation. Observe the drawings created of fixed and moveable pulleys. Note any modifications suggested for moveable pulleys.</p>
<p>Posing the Task</p> <p>The children will be invited to reflect upon how they used the chair to improve the functionality of their moveable pulley in lesson 3.</p>	<ul style="list-style-type: none"> • <i>What was the purpose of the chair in making the moveable work better?</i> • <i>Has anyone ever</i> 	<p>Observe the groups making their compound pulleys.</p>

<p>Introduce the concept of a compound pulley by asking the children for the meaning of the word “compound”.</p> <p>Children will be asked to reflect upon their knowledge of fixed and moveable pulleys to attempt to create a compound pulley independently and without a visual clue.</p> <p>After 5 minutes the children will be invited to demonstrate their compound pulley to the other groups in the class. They will be asked to explain what they did and why they made those decisions.</p> <p>Children will be shown a diagram of a compound pulley so they can compare this to what they have created themselves.</p> <p>The children will be shown a concept cartoon and will determine/discuss the functionality of a compound pulley.</p> <p>Children will set up compound, fixed and moveable pulley systems to lift a 1kg weight to compare their efficacy.</p> <p>The children will fill in the “What I now know about pulleys” section of their worksheet.</p>	<p><i>heard of the word “compound” before?</i></p> <ul style="list-style-type: none"> • <i>Can you give me some examples of a compound word?</i> • <i>So when talking about a compound pulley, what do you think that means?</i> • <i>Could you use what you know already to make and demonstrate a compound pulley?</i> • <i>Can you explain to me what you have done? Why?</i> • <i>Did you find any differences between each pulley system?</i> • <i>Did you think one was better than the others?</i> 	<p>Assess whether children can create a compound pulley independently (no visual aid) or need a diagram for support.</p> <p>Assess if the children can determine the efficacy of a compound pulley.</p>
<p><i>Anticipated Student Responses</i></p> <p>A compound pulley is a fixed and a moveable pulley working together.</p> <p>A compound pulley makes things easier to lift.</p> <p>Some children might say that they don’t notice any difference.</p>		<p>See above</p>

<p>Summing Up Ask the children to recap on what they have learned about pulleys.</p> <p>Ask the children if they have any further questions about pulleys that they would like to investigate.</p> <p>Reemphasise how the children were working as scientists today - asking questions, analysing, creating models, investigating, recording results - all things that real scientists do.</p>	<ul style="list-style-type: none"> • What did you learn from investigating pulleys? • What different types of pulleys have you learned about? • Have you noticed the relationship between different types of pulleys and different types of forces? (gravity) • Is there anywhere in the school where a pulley would be useful? • Do you have any further questions about pulleys that you would like to investigate? 	<p>Teachers record if groups can think of a question(s) to ask.</p>
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9. Points of Evaluation (Assessment)

Prompts to focus observation and data collection.



Refer to *Plan | Step 5: Focus the Data Collection*

Teachers will observe two children during the lesson and take notes on an observation log.

- Look for active and purposeful conversation.
- Observe the drawings created of fixed and moveable pulleys.
- Note any modifications suggested for moveable pulleys.
- Observe the groups making their compound pulleys.
- Determine if children can create a compound pulley independently (no visual aid) or need a diagram for support.
- Determine if the children can describe the efficacy of a compound pulley.
- Record if groups can think of a question(s) to ask.

10. Board Plan

Refer to [Plan | Step 6: Teach a Mock-up Lesson](#)

11. End of Cycle Reflection

What Did We Learn? (to be filled out after the post-lesson discussion)

Refer to [Reflect | Step 4: Consolidate Your Learning](#)

- Lesson 4 was beneficial in terms of assessing the children's thinking and having an awareness of their prior knowledge.
- We noted progression in the children's ability to articulate their thinking about pulleys and determine that a compound pulley makes things easier to lift.
- Very practical lesson and lots for the observers to note and record because the children were spending time doing as opposed to recording.
- Children appeared to have appropriate language and were able to use that language to articulate their thinking.
- Scaffolding for all children but especially for children who struggle and may have additional needs.
- Giving the children the freedom to try things themselves allows us to see their thinking and prior conceptions.