Changing Practices:

Supporting the Introduction of Inquiry-Based Learning in a Suburban *Gaelscoil.*

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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.

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List of Abbreviations

ASTI	Association of Secondary Teachers, Ireland
ATECI	Association of Teachers' / Education Centres in Ireland
CBA	Classroom Based Assessment
CPD	Continuous Professional Development or Continuing Professional Development
DCU	Dublin City University
DES	Department of Education and Skills formerly Department of Education and Science
EPV	Extra Personal Vacation (days)
EU	European Union
GME	*Gàidhlig*-Medium Education
HRA	Haddington Road Agreement
IBL	Inquiry Based Learning
IBSE	Inquiry Based Science Education
ICT	Information and Communications Technology
INOTE	Irish National Organisation for Teachers of English
INTO	Irish National Teachers Association
ISE	Inspiring Science Education
ISTA	Irish Science Teachers Association
ITE	Initial Teacher Education
JCT	Junior Cycle for Teachers
JLSS	Junior Level Support Service
LRA	Lansdowne Road Agreement
NAPD	National Association of Principals and Deputy Principals
NBSS	National Behaviour Support Service
NCCA	National Council for Curriculum and Assessment
NGSS	Next Generation Science Standards
NIPT	National Induction Programme for Teachers
NRC	National Research Council
NSES	National Science Education Standards
PCK	Pedagogical Content Knowledge
PDST	Professional Development Service for Teachers
PGDE	Post-Graduate Diploma in Education
PME	Professional Masters in Education
PSSA	Public Service Stability Agreement
SEC	State Examinations Commission
SESS	Special Education Support Service
SLSS	Senior Level Support Service
TES	Teacher Education Section (of Department of Education and Skills)
TIMSS	Trends in International Mathematics and Science Study
TUI	Teachers Union of Ireland
VLE	Virtual Learning Environment

Abstract

This dissertation outlines my journey in preparing for, and implementing, the new Junior Cycle science curriculum, and how that implementation has in turn shaped my new understanding of inquiry-based learning in Irish-language science classrooms. The research underpinning this dissertation is influenced by the metaphor of the research as *bricolage*, and was carried out using an action research methodology, self-study and qualitative interviews. Each strand of the research is undertaken using the approach that most suited that aspect of the research.

I describe my initial attempts to support the use of inquiry-based learning amongst science teachers in all *Gaelscoileanna* nationally, as I organised and presented a series of webinars on that topic *as Gaeilge*.

I explain how the reflection process in this initial work led me to investigate my own teaching practice, to determine the extent to which I can claim that I am using inquiry-based methodologies in my classroom, and depict how this process contributed to a refinement in my understanding of inquiry-based learning.

I continue by describing and explaining how this reflexive process, in conjunction with the collaborative work undertaken by me and the other science teachers in my school, further informed and influenced my new understanding of inquiry-based learning.

The dissertation concludes with an investigation into how the teachers' interpretation of the new Junior Cycle science specification, with its emphasis on the use of inquiry, and the process of co-creating the science curriculum we implemented for our students, shaped their understanding of inquiry. This, in turn, helped me clarify my understanding of our roles as science teachers, and gain a new perspective on the nature of science education.

Chapter 1: Introduction

1.1 Introduction

This dissertation describes my journey as I undertook research into my professional life as part of a PhD in education in Dublin City University (DCU). This chapter outlines the nature and aims of the research, my rationale for undertaking the research, and the questions the research sought to answer. An overview of the dissertation is also provided.

I graduated with a BSc in Science Education from Dublin City University (DCU) in 2010, a programme which consists of a science degree with a concurrent teacher training component. My primary degree placed a heavy emphasis on inquiry-based learning (IBL), and I entered the teaching profession with an understanding of the benefits of implementing IBL in the classroom, and how that might be achieved. During the degree, I also developed an interest in how technology might be used in the classroom to facilitate teaching and learning, and my school was supportive in my attempts to investigate the possibilities of using emerging technologies in my practice.

I am from a *Gaeltacht* area of Ireland, a part of the country in which Irish is still, notionally at least, the predominant language. I am therefore a fluent Irish speaker. I undertook my primary and post-primary education through Irish, and was keen to enter the Irish-medium education sector after graduation. I was fortunate in carrying out one of my periods of teaching practice placement in a suburban *Gaelscoil*[1] in Dublin. I was even more fortunate to be offered a teaching position in that school after graduation, where I taught Junior Certificate science, Transition Year science, and Leaving Certificate chemistry, physics and applied mathematics through Irish until September 2018. This allowed me to experience the great efforts that educators are undertaking not only to provide an education in a minority language, but to promote the Irish culture, develop an

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[1] On a minor technicality, a *Gaelscoil* is an Irish-language immersion primary school located outside a *Gaeltacht* area; a *Gaelcholáiste* is the post-primary equivalent. They are most often found in larger urban areas. A school located inside a *Gaeltacht* area, which tend to be rural areas, is more properly known as a *Gaeltacht* school. However, for the sake of clarity, I will use the term *Gaelscoil* to refer to any school in which the language of communication is Irish. *Gaelscoil* is the singular term, the plural is *Gaelscoileanna*.

appreciation for its music and its literature and foster a love of the language that forms a central part of that culture. I have also witnessed, and experienced, the difficulties that are inherent in doing so. Recent decades have seen a dramatic increase in the number of students undertaking their education in Irish-medium schools, especially in the large urban centres. Although this is heartening, from a language revitalisation aspect, it has lead to difficulties which will be further discussed throughout the dissertation.

In 2011 I enrolled as a part-time student in DCU on the MSc in Education and Training Management (eLearning) which further broadened my appreciation of how effective technology could be in schools. My school allowed me to set up Moodle[2] to share notes with my students, and I invited other teachers who displayed an interest to experiment with me. I toyed with embedding videos into the Moodle courses, and attempted some online assessment techniques. In my Masters dissertation, I implemented a 'flipped classroom' with one of my mathematics classes, creating videos in Irish to explain the material, as there were no video resources available in Irish.

My experiences over the course of the two years illuminated not only the opportunities that technology can provide in education, but also some of the difficulties that are faced by teachers as they attempt to implement technology in their own practice. The previous paragraph may convey a sense that everything was a success, and that I was moving towards the integration of technology into every one of my classes, as well as somehow being the instigator of a school-wide shift encouraging all teachers to adopt technology in their practice. This is not the case. Moodle did not last long in my school, nor did the flipped classroom experiment. As interesting, and potentially profound, as these technological and pedagogical advances may have been, technical difficulties, lack of resources, and simple lack of interest from students and teachers all contributed to a lack of use. However, we continue to experiment.

[2] Moodle is a Virtual Learning Environment (VLE), built on constructivist principles. Further information can be found on moodle.org

Throughout the Masters degree and in the years since, I have attended conferences[3] and TeachMeet[4] events themed around science education, and technology in education. I read books and articles about teachers doing wonderful things with technology in their classrooms or implementing new teaching methodologies with great outcomes. However, I began to feel a vague sense of despair colour my excitement. Am I behind the curve here? Am I stuck in a rut? How do these people do all these great things successfully? What am I doing wrong? Am I wasting my time, and my students time, by even trying? The doubts began to set in, and indeed, they re-surface from time to time.

Successfully completing the MSc in 2013 gave me confidence in my own abilities. I had the confidence to try new things in my own teaching and if they didn't work, I wasn't going to worry about it. They can be tried again at some point, or a better alternative might present itself. I came to realise that all the positive stories that I was hearing and reading about were just that – the positive stories. Nobody was going to stand up at a conference or TeachMeet and talk about something they tried that was a complete failure.

In Spring 2014 I was asked to take part in the EU Inspiring Science Education (ISE) project, with which the International Centre for Innovation and Workplace Learning at DCU was involved. As a practicing science teacher, with an interest in implementing technology into my teaching, my supervisor Dr. Yvonne Crotty, who was one of DCU's lead researchers on the project, felt that I would be ideally suited to take part. The fact that I was teaching through Irish would add an extra dimension; if I could translate the materials provided by the project into Irish, and deliver the content to other teachers teaching in *Gaelscoileanna*, my supervisor felt an evaluation of the delivery of CPD via webinar to science teachers in *Gaelscoileanna* could form the basis of interesting PhD research.

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[3] The two largest technology in education conferences in Ireland, primarily aimed at teachers, are the Computers in Education Society of Ireland (CESI) conference and the ICT in Education (ICTedu) conference.

[4] A TeachMeet is an informal meeting lasting usually two or three hours. Presentations can be on any education-related topic, and last either two or seven minutes. Although they can be organised as stand-alone events, they have more commonly found to be run as satellite events at teaching-related conferences such as the CESI conference, the ICTedu conference and BETT. More information can be found at en.wikipedia.org/wiki/TeachMeet.

1.2 ISE Project

The Rocard Report (2007) is seen by many science education researchers as the primary call to action in Europe for the introduction of inquiry-based learning (IBL) into science classrooms. Since its publication, a plethora of EU funded research projects have been carried out with the aim of encouraging more teachers to implement this teaching methodology.

The Inspiring Science Education (ISE) project was initiated as a way of "providing the tools to make science education more challenging, more playful and above all more imaginative and inspiring for today's students" (inspiring-science-education.net). With partners across 15 countries, and with the aim of involving more than 5,000 schools, the purpose of the project was to combine a specific model of IBL with 'eTools' such as online simulations and virtual laboratories to make it easier for teachers to engage in teaching using inquiry.

This project, which began in 2013, was timely in that it coincided with a period of large-scale change in junior post-primary education in Ireland. In 2012 (Department of Education and Skills (DES), 2012), then Minister for Education, Ruairi Quinn, announced that the existing Junior Certificate programme would be completely reformed, and replaced with a new Junior Cycle. The particular differences between the Junior Certificate and Junior Cycle will be discussed in further depth as the dissertation progresses, but as science teachers, the primary difference between the 'old' course and the 'new' course revolved around *how* we were to teach science in our classrooms. Although the previous syllabus, introduced in 2003 (DES, 2008), placed an emphasis on students conducting inquiry investigations, it was found by researchers in Ireland such as Eivers, Shiel and Cheevers (2006) that few teachers were actually teaching the course in this way. The 'new' Junior Cycle places an even greater emphasis on teachers allowing the students to have independence in the way they approach practical work. Similarly, the aims of the Junior Cycle include students learning 'key skills', which include numeracy, scientific literacy and digital skills, though they are not described in those exact terms.

The ISE project, therefore, coincided with a time in which teachers were being asked to change their teaching practices to be more in line with what is perceived as international best practice. Not only were we being asked to become more inquiry-focussed, but we were also expected to use technology more frequently in our teaching. The confluence of a change in teaching methodologies and use of ICT in our teaching seems fortuitous, given the nature of the ISE project.

In addition, as a teacher who teaches in an Irish-medium immersion school, the lack of provision of resources and training in Irish is acutely felt. This inequality not only refers to the provision of textbooks and other teaching resources, but also includes the Continuous Professional Development (CPD) opportunities available to teachers who teach through Irish. Not only are CPD opportunities organised by the Professional Development Service for Teachers (PDST) and other teacher training organisations provided through the English language only, I also include EU projects such as the ISE project. Part of the initial rationale for this my involvement in the ISE project was to address this lack of provision for teachers teaching through the medium of Irish.

1.3 Research Focus

The research initially began as part of an EU-funded project, the Inspiring Science Education (ISE) project, which aimed to disseminate new teaching methodologies to science teachers across Europe and help them avail of online tools to facilitate this change. The various university partners across Europe had differing approaches to how it would be carried out. In Ireland, DCU recruited approximately 20 teachers and delivered a series of webinars to these teachers. These webinars would outline the project, explain what IBL was, how IBL could be implemented in the participating teachers' classrooms, and provide online tools to facilitate that implementation. The cycle of recruitment and webinar delivery would then be repeated several times.

My role in the project, which formed the initial basis for this research, was to translate any project materials that were to be shared with the participants into Irish, and to organise a similar series of webinars *as Gaeilge*[5] for teachers who teach science through Irish. In addition, there was little point in encouraging teachers around the country to adopt IBL in their classrooms if I was the only teacher doing so in my own school, and I invited the other teachers in my school to take part in the ISE project. The initial research question at the time therefore read: "how can webinars be used to facilitate the implementation of IBL in science classrooms in *Gaelscoileanna*?".

However, upon delivering the first series of webinars to teachers in *Gaelscoileanna*, I encountered several problems. Feeling uncomfortable with delivering this CPD to teachers, without being certain that I was acting in the way I professed, I realised that I needed to examine my own practice. In addition, as the ISE project progressed, the ISE Lesson Authoring Tool was created. This was a web-based lesson planning tool, designed to facilitate the planning of inquiry-based lessons. Directions and guidance could be provided to students, interactive online simulations could be embedded into the lessons, and student progress could be tracked through the lesson. I, along with the other teachers in my school, made use of these technological tools to further facilitate our implementation of IBL in our classrooms. The research therefore broadened in scope to

[5] In Irish

include these aspects, and the research question shifted to incorporate these changes, becoming "how can I use technology to facilitate the implementation of IBL in science classrooms in *Gaelscoileanna*?".

Difficulties in recruiting teachers to take part in the series of webinars was the principal reason to move the focus of the research away from the webinar aspect, and to narrow the research to my own practice, and the practice of the other teachers in my school. We cooperated in planning for the new Junior Cycle course, and attended CPD both on the topics of inquiry-based learning, and on the new Junior Cycle Science Specification (DES, 2015). We then implemented our understanding of the new course for our students. Having taught the new course for two years, coming to the end of this research, I was interested to see to what extent teachers felt their classroom practices had changed, to what extent they felt they understood inquiry-based learning, and how this impacted my understanding of what IBL was, given the previous work I had done on investigating my own practice. The primary focus of the research, and therefore the title, changed to "Changing Practices: Supporting the introduction of inquiry-based learning in a suburban *Gaelscoil".*

To facilitate a visualisation of when the various strands of the research took place in relation to one another, and the introduction of the new Junior Cycle Science Specification, an approximate timeline of the research is provided in Appendix A.

1.4 Research Questions

As the research progressed and the focus of the research changed, so too did the research questions. Initially primary concerned with how webinars can be used to facilitate CPD for teachers who teach through the Irish language, then incorporating aspects of how technology can be used to support learning in science classrooms, the final research questions are somewhat different, although they retain some of the sense of the initial research questions. This research can be seen to answer three questions:

I. How can I improve the provision of CPD for science teachers who teach *as Gaeilge*?

II. Can I claim to be using inquiry in my practice?

III. In a time of curriculum reform, how do science teachers in my school view their practice?

Question I is a clear action research question, as it focusses on my attempt at improving a situation. It was the foundation of the research, my use of the ISE webinars to provide CPD to other science teachers in *Gaelscoileanna* around the country on the topic of inquiry-based learning.

Question II will be answered by a self-study of my own practice, to determine whether I am teaching by inquiry, when I think that's what I'm doing.

Question III is slightly more vague, for a reason. I'm interested in determining the extent to which teachers feel their practice changes as the curriculum changes and the extent to which they feel they understand new teaching methodologies they are being asked to use.

The three principal research questions underpinning this dissertation are, however, interrelated, and to facilitate their investigation, are subdivided into a number of sub-questions. These sub-questions arose organically, in much the same manner as McNiff's "spiral of spirals" (McNiff with Whitehead, 2002, p. 57) as the research progressed. Due to the changing focus of the research, these questions were added to and changed as the research progressed. Each sub-question will be addressed individually in each chapter, as appropriate, and will be woven together in Chapter Eight to address the main research questions above. The questions and sub-questions addressed in subsequent chapters are therefore:

Chapter Four: How can I improve the provision of CPD for science teachers who teach *as Gaeilge*?

i. How can technology be used to support the introduction of inquiry-based learning in Irish-language science classrooms?
ii. Do teachers who teach through the medium of Irish attach importance to undertaking their CPD *as Gaeilge*?
iii. What are the benefits and drawbacks to providing CPD opportunities via webinar, rather than face-to-face?

Chapter Five: Can I claim to be using inquiry in my practice?

iv. What does inquiry in the classroom look like in my practice?
v. Do our assessment approaches support the introduction of inquiry?

Chapter Seven: In a time of curriculum reform, how do science teachers in my school view their practice?

vi. With the introduction of the Junior Cycle, have the science teachers seen a change in their practice?
vii. What do the teachers think inquiry-based learning is?
viii. Have the teachers seen any effect on the students – either in their interest or learning?

However, given the nature of the *bricolage* used to construct this research, the main research questions and the sub-questions are interrelated. In Chapter Eight, I attempt to weave together the lessons from the previous chapters. To illustrate the relationship between the research questions and the sub-questions listed above, a graphical representation is provided in Figure 1.1 on the following page.

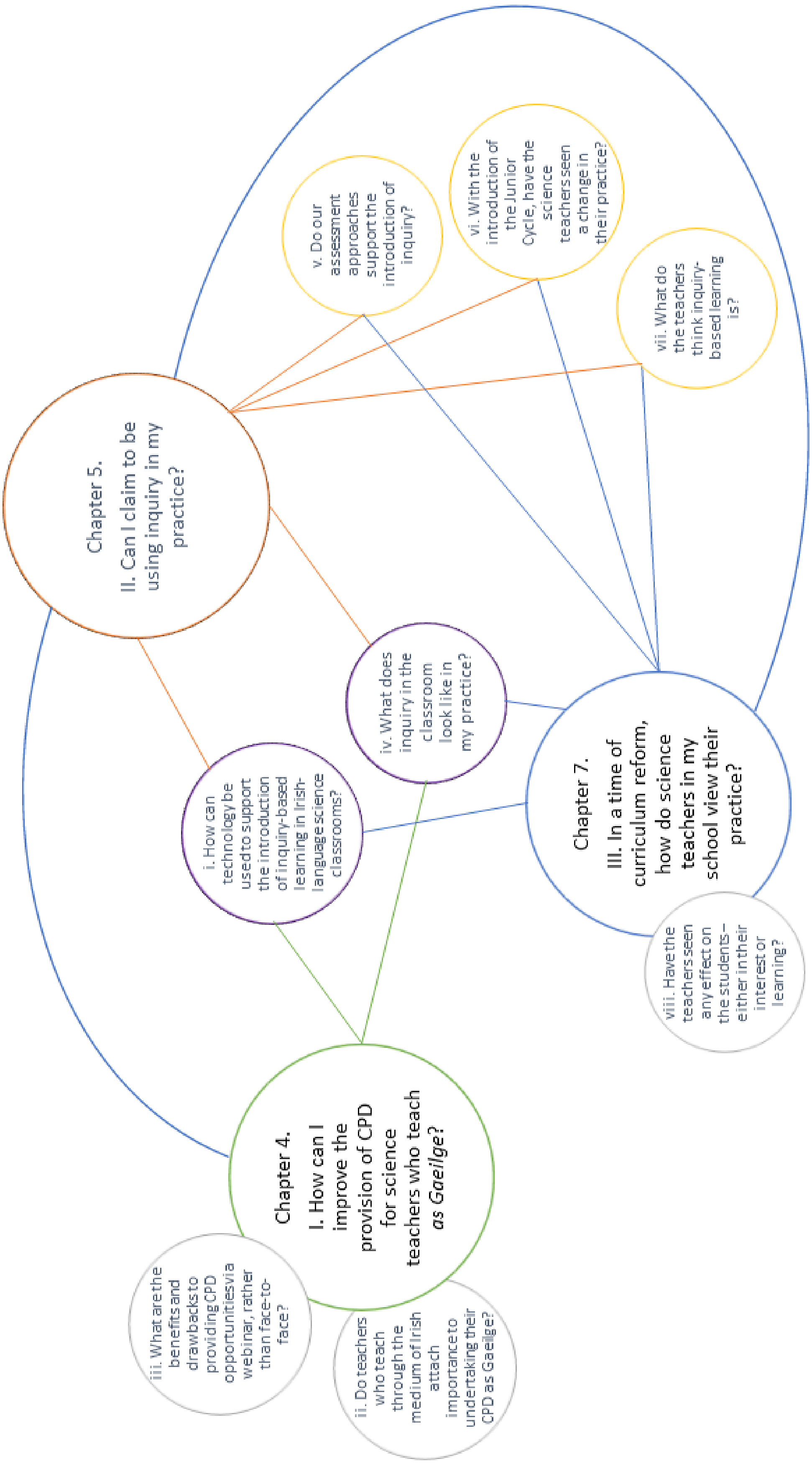

Figure 1.1: Graphical Representation of the Relationships between Research Questions

It should be noted that the lines connecting the various research questions do not denote a specific direction. For example, in addition to the three sub-questions listed on page 9, my experience of delivering CPD to science teachers to answer question I: 'How can I improve the provision of CPD for science teachers who teach as Gaeilge?' was affected by my own understanding, or lack thereof, of inquiry-based learning, as investigated in question V: 'Can I claim to be using inquiry in my practice?'. I similarly would have struggled, had I been asked during the CPD webinars to give concrete examples of inquiry from my classroom, which is inquired into in sub-question iv: 'What does inquiry in the classroom look like in my practice?'. In return, this experience forced me to examine my practice, to identify my practices that could be classed as inquiry, and to form an understanding of inquiry for myself, in order to answer question V: 'Can I claim to be using inquiry in my practice?'. This understanding would, of course, be shaped by the shared experiences of planning, collaborating and undertaking CPD with my colleagues, and therefore my responses to this question is shaped by question III: 'In a time of curriculum reform, how do science teachers in my school view their practice?', as well as by the sub-questions that specifically relate to that question, and Chapter Seven. Additional links between the research questions and sub-questions will be explored further in Chapter Eight.

1.5 Overview of the Dissertation

This dissertation investigates teaching practices of secondary school science teachers during a time of curriculum change. Chapter Two provides further background to the current curriculum reform, and outlines some of the literature in several of the main themes upon which this research is based. The chapter begins with a brief discussion on Irish-language immersion education, the historical factors behind it, and the challenges it faces. Continuous professional development for teachers is similarly discussed, how CPD is provided for in Ireland, and what effective CPD looks like. Finally, I provide a discussion on inquiry-based learning, explaining what it is, how it can be implemented in a classroom and how it may or may not benefit students.

The *bricolage* undertaken to construct this dissertation combines research carried out with science teachers in schools across Ireland, an investigation of my own teaching practices, and research carried out with science teachers in my school. Chapter Three outlines the bricolage used to tie the different aspects of the research together, the methodologies used in carrying out the strands of the research, my reasoning for choosing these methodologies, and the approaches I utilised in undertaking the research.

Chapter Four describes the work carried out designing and delivering a series of webinars to science teachers in other *Gaelscoileanna* to explain the basics of inquiry-based learning and how these teachers might find ways of implementing IBL in their classrooms. This work builds on the ISE project, and describes the delivery of the webinars as a series of action research cycles.

Chapter Five provides a description of how the action research carried out in Chapter Four led me to reflect on my own practice, and to investigate my own teaching practices, to determine whether my teaching can be described as IBL. Although I do not claim that all my teaching activities would contain aspects of inquiry, my investigation sought to determine whether those lessons I had envisaged as being inquiry lessons did, in truth, contain aspects of inquiry.

Chapter Six serves as a prologue to Chapter Seven, and describes the adoption of technology to facilitate the integration of inquiry-based learning in science lessons in my school. I describe how our collective participation in the ISE project, in particular our use of the ISE Lesson Authoring Tool, was perceived by the teachers.

In Chapter Seven, I use qualitative interviews to ask teachers to describe their attitudes towards, and experiences of, the change in curriculum surrounding the new Junior Cycle, as well as their understanding of IBL, and outline their responses in describing how they are using inquiry in their lessons.

The concluding chapter, Chapter Eight, summarises the findings of the research. I discuss how this research may contribute to a knowledge base for science teaching in *Gaelscoileanna* in particular, and science teaching in general. I also outline areas for further research or action.

Chapter 2: Background & Literature

The separate strands of this dissertation contain common aspects, namely the focus on science teaching in an Irish-language immersion education setting, and continuous professional development for science teachers, specifically relating to inquiry-based learning in science education.

Given the traditional layout of a PhD dissertation, it might be assumed that the literature review took place at the beginning of the research process, and that the subsequent chapters followed chronologically. However, this is not the case in this dissertation. Much of the literature discussed in Section 2.3, and subsequently referred to in Chapter Four, was not read until after the first cycle of webinars took place. Similarly, although a broad review had been conducted, much of the literature reviewed in Section 2.4, and upon which the discussion in Chapter Five is based, was not encountered and fully digested until the process of investigating my own practice was taking place. Where additional research resulted in unexpected ideas or events emerging in the course of practice, literature related to these developments will be woven into the relevant chapters throughout the dissertation.

In this chapter, I will provide an overview of the literature related to three themes which include science teaching in an Irish-language immersion education setting, continuous professional development for science teachers and inquiry-based learning in science education.

2.1 Irish Language Immersion Education

This section briefly outlines some of the factors that led to the development of the Irish-language immersion sector in Irish education, some of the challenges it faces, and how it compares to other minority languages.

2.1.1 Historical Factors

In Ireland, the constitution describes Irish "as the national language is the first official language", with the English language being the second national language (Bunreacht na hÉireann, 1937). The use of Irish in everyday life has declined since the 16th century, with Irish only surviving as the *lingua franca* in some small parts of the country, mainly along the western seaboard. These areas are known as *Gaeltacht* areas. According to the latest census figures (Central Statistics Office, 2017) 2% of the population lives in *Gaeltacht* areas. These census figures also show that nationally, almost 40% of the population profess being able to speak Irish, a decrease since the previous census in 2011, when the figure was slightly above 41%. This is despite the Irish language being a compulsory subject throughout the education system, until the student completes the Leaving Certificate.

In recent years, however, the language has become more popular in the major urban centres, and an increasing number of parents are opting to have their children educated in immersion schools, in which the language of instruction, and all interaction, is through the medium of the Irish language. These schools are known by the Irish term *Gaelscoileanna.* It should be noted that these schools are not simply providing an education in the Irish language. The aim of the *Gaelscoil* is for the student to develop a fluency in the Irish language, which requires the student to be completely immersed in the language. Therefore, they tend to be quite strict in terms of the language spoken by students and members of staff.

There are, based on the 2013-2014 statistics, 45 second-level *Gaelscoileanna* in the Republic of Ireland out of a total of 723 second-level schools. In 1972, there was only five secondary *Gaelscoileanna* outside the *Gaeltacht* areas, but by September 2013 this had increased to thirty-six, an increase of over 700% (Gaelscoileanna, 2015). In addition, two new second-level *Gaelscoileanna* opened their doors to students in the 2014-2015 school year, both in the greater Dublin area.

Nonetheless, recent decades have seen a growth in the number of students attending Irish-language immersion education. Indeed, *Gaelscoileanna* are often oversubscribed in many of the larger urban areas, with Darmody and Daly (2015, p. 55) reporting that 66% of *Gaelscoileanna* outside *Gaeltacht* areas report having more applicants than places. In order to cater to this increased demand, in addition to the Irish-only schools, 22 English-language post-primary schools in Ireland have Irish-language streams, in which some students are taught some, or all, of their subjects through the Irish language. However, these units are often seen as less desirable, and less effective, than stand-alone Irish-language schools, due to the students being in contact with English-speakers on a constant basis (Darmody & Daly, 2015).

2.1.2 Benefits of Immersion Education & Bilingualism

One of the common misconceptions about immersion education is that the acquisition of the second language will decrease student proficiency in their first language. However, this has been shown not to be the case (Cummins, 1998). The English language enjoys widespread support outside the education system, and indeed many of the students attending immersion education programmes in Irish would not have Irish-speaking parents at home, and would not have the opportunity to practice their Irish-language skills outside of the school setting. In this case, the Irish language is being added to their existing language without producing any negative effect on the first language, a process known as additive bilingualism (Huguet, Vila & Llurda, 2000; Cummins, 2017). Indeed, improvement in one language benefits the other. Studies have shown that bilingualism, and especially early-age bilingualism, has benefits that exceed the acquisition of the target language. Research carried out by Ó Duibhir et al. (2017) has shown "cognitive, cultural and psychological advantages" to additive bilingualism.

2.1.3 Challenges facing Immersion Education in Ireland

This rise in the number of *Gaelscoileanna* has led to a shortage in qualified teachers who also possess the necessary language skills to teach through Irish (Mac Donnacha et al., 2005; Ó Duibhir et al., 2017). Often, the management of second-level Irish medium schools are "left with no option but to employ teachers who do not possess the relevant competency in Irish" (Mac Donnacha et al., 2005, p. 10). In the intervening years since Mac Donnacha et al. (2005), the situation has not improved. Indeed, with increasing numbers of *Gaelscoileanna* opening, and existing *Gaelscoileanna* catering to increased numbers of students, the situation has only been exacerbated (Ó Grádaigh, 2015). In a study of a teacher training course in NUI Galway, the only teacher training course offered through Irish, Ó Grádaigh (2015) noted that the shortfall in qualified teachers with the requisite language skills is especially evident in certain subject areas, the sciences being especially affected.

2.1.4 Immersion Education in Other Contexts

In this section, I highlight three regions where a minority language is present. In each case, steps are being taken to revitalise the language through the education system. I am careful, however, to distinguish between immersion education, which takes place in a major language, for example education through English in international schools, which has the purpose of student acquisition of a second major international language, and immersion education in a minority language, usually with the aim of revitalising the language. Although I limit the review to three examples, Wales, Scotland and Catalonia, efforts to promote minority languages take place in a number of other situations, such as the Maori language in New Zealand, Frisian in the Netherlands, and Navajo and Hawaiian in the USA.

2.1.4.1 Wales

Approximately 30% of the population of Wales claim to be able to speak the Welsh language, according to the most recent census (Office for National Statistics, 2012), although this is a decrease on the previous census figures. Welsh language is a compulsory subject for all students up to the age of 16. Welsh-immersion education is available, and the number of Welsh-medium schools is increasing. In addition, bilingual education is more becoming widely available, with schools beginning to offer some subjects through the Welsh language.

2.1.4.2 Scotland

The current state of the *Gàidhlig*[6] language in Scotland is even more precarious than Irish in Ireland. Less than 2% of the population claim to be able to speak the language, and general attitudes to the language are negative. *Gàidhlig* is not a compulsory subject in school. However, since the 1980s, efforts have been made to increase the number of speakers of the language by increasing access to *Gàidhlig*-medium education (GME) (Darmody & Daly, 2015). A number of GME units have opened in English-language schools, and a small number of *Gàidhlig*-only primary schools exist (Ó Duibhir et al., 2015). Similar to the situation faced in Ireland, the greatest challenge facing *Gàidhlig*-immersion education is the lack of teachers with the required language skills, a situation which is being addressed by the provision of concurrent *Gàidhlig* and Primary Education degrees, enabling graduates to teach in *Gàidhlig*-immersion schools (University of Edinburgh, 2018).

2.1.4.3 Catalonia

The experience of the Catalan language is possibly one of the most interesting in Europe. Although a minority language in Spain, it is a majority language in the autonomous region of Catalonia. Mercator (2013 cited in Darmody & Daly, 2015) describes how its use was forbidden by the Franco dictatorship until 1975. However, following the restoration of democracy, Catalan was again officially recognised as an official language. Since 1978, Catalan has been the medium of instruction at all levels of education in Catalonia, resulting in an increase in language users (Huguet et al., 2000). All teachers in the Catalan education system must be fluent in both Spanish and Catalan, and teacher training ensures that prospective teachers have the necessary skills to do so (Darmody & Daly, 2015).

2.1.5 Discussion

Irish-immersion education outside of *Gaeltacht* areas, in the form of *Gaelscoileanna,* has become increasingly popular over the past decades. From a language revitalisation viewpoint, this is a welcome development. More students are being educated in the Irish

[6] Sometimes referred to as Gaelic, or Scots Gaelic.

language, developing a fluency in the language, as well as an appreciation of the rich cultural heritage, of which the language forms a central part. However, this expansion in the Irish-medium sector has lead to increasing shortages of teachers who are both qualified to teach at post-primary level, especially in the sciences, and have the necessary language skills to not only teach effectively, but also converse socially and discuss scientific concepts with the students. This highlights a need for teachers to have the opportunity to develop their language skills in their subject areas, by taking part in CPD opportunities specific to both their subject area, and in the Irish language. This would enable them to practice the language and terminology they would be using in the classroom in a setting in which they would feel more comfortable making mistakes; amongst their peers, rather than in front of their students.

However, from the perspective of the research underpinning this dissertation, the fact that the *Gaelscoil* movement is still a relatively small proportion of the post-primary education system is a factor. Given the comparatively small number of teachers who teach exclusively through Irish, and the fact that they are geographically disparate, it is unlikely to be feasible to organise traditional CPD workshops through Irish outside of Dublin, as the distance teachers would have to travel to attend such workshops would be too great, a concern supported by Ó Duibhir et al. (2015). This tallies with the experiences of *Gàidhlig*-medium educators in Scotland, where it is felt that the geographic spread of teachers across the country makes regular face-to-face CPD events difficult (Milligan et al., 2012, p. 45). Indeed, even within the Dublin area, it may be assumed that the numbers attending any such workshops would be too low to make such CPD events economical. This may be one important factor in the lack of CPD provision *as Gaeilge* for teachers in *Gaelscoileanna.* However, part of this research aims to overcome this barrier by utilising webinars as a technology to connect teachers.

2.2 Continuous Professional Development

This section discusses the concept of Continuous Professional Development (CPD) and offers definitions of CPD. It also provides some description of the purposes of CPD, suggests the current view of what makes for effective CPD and gives an account of CPD for teachers in Ireland.

2.2.1 What is Continuous Professional Development?

Continuous Professional Development (CPD)[7] may be seen as a process of lifelong learning, undertaken by professionals in all sectors, to continuously upskill and remain abreast of current developments in their profession. Fullan and Stiegelbauer (1991 in Capps, Crawford & Constas, 2012, p. 295) define Professional Development (PD) as the "sum total of formal and informal learning experiences throughout one's career from preservice teacher education to retirement". Immediately, it can be seen that there are two principal forms of teacher CPD, namely formal CPD programs, which have an explicit aim, and informal experiences in which learning may occur.

Griffin (1983 in Gaines, Osman, Maddocks, Warner, Freeman & Schallert, 2019, p. 54) explains that the aim of formal teacher CPD is to "alter the professional practices, beliefs, and understanding of school persons toward an articulated end" namely improving student achievement. Similarly, Guskey (2002) defines teacher CPD as "systematic efforts to bring about change in the classroom practice of teachers, in their attitudes and beliefs, and in the learning outcomes of students". By omitting the informal aspect of CPD from their definitions, both Griffin (1983) and Guskey (2002) discount possible learning experiences, where teacher learning can occur in more ways than simply attending organised CPD events with specific aims and objectives.

However, Desimone (2009, p. 182) gives what I believe to be a fuller description of teacher CPD, describing it as:

[7] The terms continuous professional development and continuing professional development are both used interchangeably; although particularly in the United States, it is simply referred to as professional development. I will use continuous professional development.

> a vast range of activities and interactions that may increase their knowledge and skills and improve their teaching practice, as well as contribute to their personal, social, and emotional growth as teachers. These experiences can range from formal, structured topic-specific seminars given on in-service days, to everyday, informal "hallway" discussions with other teachers about instruction techniques, embedded in teachers' everyday work lives.

What is important here is not only Desimone's acknowledgement of both the formal and informal experiences that may contribute to a teacher's learning, but that teacher professional development should not simply be viewed as activities that improve a teacher's teaching skills, and thereby improve the teacher's practice. In addition to this aspect of a teacher's directly applicable skills and beliefs is the inclusion of their "personal, social and emotional growth" (Desimone, 2009, p. 182) as aims in teacher development. Although this is a valid and important aspect of teacher development, for the purposes of this dissertation I will focus on the aspects of teacher CPD which are directly related to teaching and learning.

2.2.2 What makes effective CPD?

Continuous professional development can be considered "effective if they are able to create lasting change among the participants and those in their realm of influence" (Marshall, Smart & Alston, 2017, p. 780). Guskey (2002) claims that there are two principal reasons for CPD to fail. Ineffective CPD takes place when it fails to take into account (i) teachers' motivation to attend CPD and (ii) the process by which teachers learn during CPD. These reasons will be discussed in turn in the following sub-sections.

2.2.2.1 Formal CPD: Teacher Knowledge & Skills

Teachers can be motivated by a variety of reasons to undertake CPD. They may be contractually obliged, a situation in which teachers in Ireland may find themselves in the near future (Teaching Council, 2011). However, for most teachers, they simply want to become better teachers (Guskey, 2002). For these teachers, becoming a better teacher means improving student outcomes.

To successfully educate students, and develop their conceptual understanding, teachers "must have rich and flexible knowledge of the subjects they teach" (Borko, 2004, p. 5).

Part of the aims of CPD can be to keep teachers abreast of recent developments in their own subject areas. For example, Guskey (2000, p. 16) outlines how the knowledge base of education, including teaching and learning processes, are developing constantly, and that teachers should be kept aware of these developments, to "continually refine their conceptual and craft skills".

In attending CPD, Fullan and Miles (1992, p. 752) state that teachers are looking for "specific, concrete, and practical ideas that directly relate to the day-to-day operation of their classrooms". Many teachers are not seeking workshops on theoretical, abstract topics, but CPD events that will directly impact on their teaching practice. Similarly, Putnam and Borko (2000, p. 6) report that teachers complain that "learning experiences outside the classroom are too removed from the day-to-day work of teaching to have a meaningful impact".

In this vein, CPD addresses skills shortages that teachers might have, or seek to introduce new methods in how teachers teach. This is especially evident when a period of curriculum reform is taking place, of which the Junior Cycle reform in Ireland is the example under study in this research. As noted by Guskey (2000, p. 4), CPD is an "absolutely necessary ingredient in all educational improvement efforts".

2.2.2.2 How teachers learn

Cordingley et al. (2015) in a meta-meta-analysis carried out on the effectiveness of CPD for teachers, reported several characteristics of effective CPD programmes. Although the authors note that undertaking a review of reviews produces somewhat abstract results, the conclusions formed by the authors are nonetheless pertinent. They found that the most effective CPD programmes include the following characteristic:

- Are carefully designed and aligned with a strong focus on student outcomes.
- Prolonged CPD programmes are generally more effective than shorter ones. For "significant organisational and cultural change" (p. 4), at least two terms were required. However, shorter timescales (e.g. one day) were found to be highly effective for narrowly defined specific aspects of teaching.
- Follow-up is important. However, less important than the amount or nature of the follow-up was its frequency. Studies in which the consolidation or support

sessions followed a regular rhythm, such as monthly, reported higher student outcomes.

- Content must be relevant to participants, and their day-to-day experiences.
- Differences between participants and their starting positions should be recognised, and opportunities for peer learning and support are important.
- Pedagogy and subject knowledge are equally important; conversely CPD that focusses on generic pedagogic strategies is insufficient.

Desimone (2009, p. 184) similarly described the components of effective CPD. These five characteristics are important to increasing teacher knowledge and skills, and lead to increasing student outcomes. They are as follows:

- Content focus: the CPD program should focus on subject matter content, and how the students can learn that content.
- Active learning: including opportunities for participating teachers to engage in active learning can increase the effectiveness of the CPD
- Coherence: that the learning is consistent with teachers' knowledge and beliefs, and is aligned with school policies and curricula.
- Duration: both number of contact hours and the time span over which the CPD is spread are important
- Collective participation: when teachers engage in CPD, that they do so with other teachers from their school and subject department.

Based upon these five common characteristics, Desimone outlined a framework for studying how teacher CPD influences teacher learning, and thereby affects student outcomes. Figure 2.1 illustrates how an effective CPD program can lead to an increase in teacher knowledge and skills, as well as changing their beliefs. In turn, this leads to a change in classroom practices, increasing student achievement.

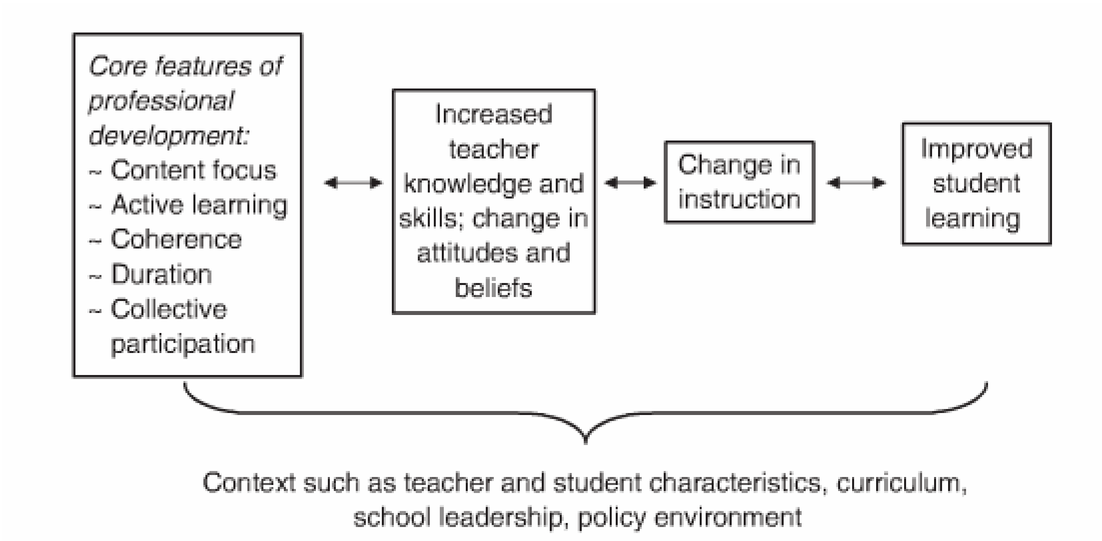

Figure 2.1: Conceptual Framework for Studying CPD (Desimone, 2009, p. 185)

As Guskey (2002) noted, and as Desimone (2009) illustrated with her CPD framework discussed earlier, many CPD programmes are designed to first bring about a change in teacher beliefs and attitudes, which in turn would bring about a change in behaviour, thereby increasing student outcomes. This is a model Guskey disagreed with, however, and proposed an alternative model, in which the change in teacher beliefs and attitudes occurs *after* experiencing an increase in student outcomes.

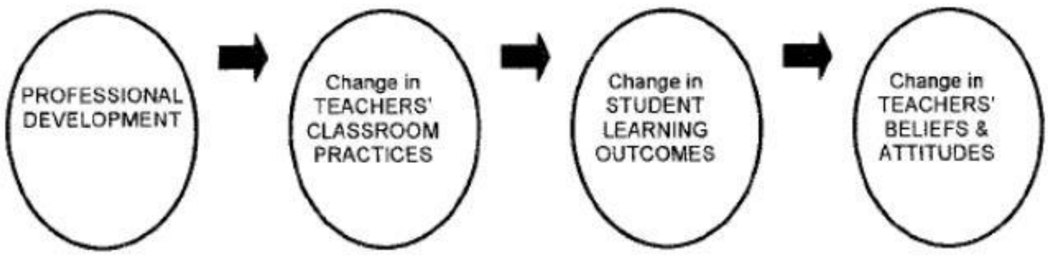

Figure 2.2: Guskey's Model of Teacher Change (Guskey, 2002, p. 383)

As can be seen from Guskey's model in Figure 2.2, the assertion is that the aim of the CPD programme should be to bring about a change in the teachers' behaviour first. If the teacher could be encouraged to implement a change, and see the benefits of the change in terms of the students' achievement, then the teacher would thereby become convinced of the effectiveness of the change in classroom practice. The beliefs and attitudes of the teacher would be changed by the evidence of successful implementation of the new strategies or methodologies, rather than by the CPD itself.

2.2.2.3 Other modes of CPD

A wide range of activities can be undertaken by teachers which can be described as CPD, although often these are not recognised as ‘valid methods’ of undertaking CPD. These activities comprise the informal aspect of CPD, as Desimone (2009) included in her definition, although the level of formality can vary. Putnam and Borko (2000), for example, describe the teacher’s own classroom as a location in which powerful teacher learning can take place, through either self- or observer examination of the teacher’s practice, a practice endorsed by others (Guskey, 2000; Loucks-Horsley, Harding, Arbuckle, Murray, Dubea & Williams, 1987; Sparks & Loucks-Horsley, 1989). Guskey (2000) also promotes teachers’ engagement in inquiry or action research as an effective method of enhancing teacher learning, which would include the undertaking of the research upon which this dissertation is based. Similarly, Guskey (2000) and Loucks-Horsley, Styles and Hewson (1996) suggests that if the teacher becomes involved in a development or improvement process, such as assisting with the school development plan, choosing textbooks, or reviewing curricula, that this often leads to the participant learning new knowledge or skills, thereby fulfilling the role of CPD.

As described, much teacher learning can also take place in more informal situations. Teacher conversation in informal settings is one such example, the “informal ‘hallway’ discussion” that is a part of many teachers’ daily practice (Desimone, 2009, p. 182). Often, it is during the coffee or lunch breaks at formal CPD events at which some of the most fruitful conversations take place. As Borko (2004, p. 7) describes: “Teachers generally welcome the opportunity to discuss ideas and materials related to their work, and conversations in professional development settings are easily fostered”. This teacher conversation can be formalised in certain situations, and a teacher learning community established to support the learning taking place within the school community. However, deliberately creating such a teacher learning community can be “difficult and time-consuming work” (Borko, 2004, p. 7).

2.2.3 Teacher CPD in Ireland

The Teaching Council's Framework on Teacher CPD "*Cosán*[8]" (Teaching Council, 2016) refers to the 2011 Teaching Council "Policy on the Continuum of Teacher Education" (Teaching Council, 2011, p. 19) when providing a definition of teacher CPD:

> Continuing professional development (CPD) refers to life-long teacher learning and comprises the full range of educational experiences designed to enrich teachers' professional knowledge, understanding and capabilities throughout their careers.

The Teaching Council (2016) views CPD as being critical in ensuring that teachers remain capable of dealing with an increasing number of challenges within the profession, including "expanding fields of knowledge, diverse student populations, higher social expectations of schools and new types of responsibilities" (p. 5).

Despite the recognised importance of professional development, there is no formal requirement for teachers in Ireland to engage with CPD on a regular basis. This fact is recognised by the Teaching Council, who simultaneously acknowledge that teachers in Ireland "are already committed to their professional learning" (ibid.). However, to formalise the necessity for ongoing CPD, the Teaching Council has announced its intention to work towards a position "where renewal of registration with the Teaching Council will be subject to the receipt of satisfactory evidence in relation to engagement in CPD" (Teaching Council, 2011, p. 19). I will now explore the provision of CPD in Ireland in the years leading up to the roll-out of the new Junior Cycle, and any changes in this provision.

2.2.3.1 CPD for Teachers

The Teaching Council (2011, p. 19) recognises CPD as "a Right and Responsibility" of all teachers, but in Ireland there has, until recently, been no formal requirement for teachers to engage in CPD. Until the rollout of the new Junior Cycle in 2015, teacher-specific CPD for practicing teachers was provided through two principal routes; courses available

[8] 'Cosán' is the Irish word for a path, or pathway.

during the school holidays, and evening workshops organised during term-time. This omits, of course, third-level courses which may be organised on a part-time basis, with evening and/or weekend lectures. Although some postgraduate courses are aimed at teachers professional development, this level of engagement with education is beyond the scope of this research.

Since 1965, primary school teachers in Ireland have been entitled to Extra Personal Vacation (EPV) Days as time in lieu for attendance at CPD courses during the school holidays (DES, 1965). Many primary school teachers avail of the summer courses provided by a number of organisations, which can entitle them to up to five EPV days during the school year. These courses are provided by the primary teachers' union, the Irish National Teachers' Organisation (INTO) and the Professional Development Service for Teachers (PDST), as well as several private companies. Some of these courses are run on a face-to-face basis, while others are run in an online setting. The courses are available for any teacher to undertake, although no provision for EPV days is available for teachers in second-level schools.

Apart from postgraduate courses, CPD for post-primary teachers in Ireland is generally provided by the Professional Development Service for Teachers (PDST), a DES-funded body which has overall responsibility for "professional development and support for teachers and schools" (PDST, 2015) in Ireland. Although the PDST offers in-school CPD workshops on various topics should a school request it, one of its main functions is the provision of in-service workshops in conjunction with the various Education Centres, both during school time and in the evenings.

Education Centres, of which 21 are full-time and 9 are part-time, are statutory bodies whose principal activities include the delivery of national CPD programmes on behalf of the DES (www.ateci.ie). Some of these workshops are organised by the PDST, usually with one two-hour subject-specific workshop organised for each subject per term. Workshops delivered in the Education Centres also include stand-alone workshops on other topics, and short course programmes of perhaps 8 to 10 workshops, organised by the Education Centre themselves, or in conjunction with organisations such as the Junior Cycle for Teachers (JCT), the National Induction Programme for Teachers (NIPT), the Special

Education Support Service (SESS) and the National Behaviour Support Service (NBSS). These workshops address all aspects of teaching and learning, including but not limited to Leadership, ICT in Education, Literacy and Numeracy.

Additionally, CPD courses and events are organised by subject-specific associations, such as the Irish Science Teachers Association (ISTA) and the Irish National Organisation for Teachers of English (INOTE). Given the geographical spread of the Education Centres, most teachers in the country would be within a one-hour drive of their nearest centre, providing the opportunity to attend mid-week evening workshops as they desire. Except for CPD events that deal with the teaching of Irish as a subject in school, all of the workshops take place through English (PDST, 2015)[9].

2.2.3.2 CPD for the Junior Cycle

Since the introduction of the Junior Cycle, with the rollout of the first of the new specifications in English, in 2015, the JCT has implemented a programme of national CPD in every secondary school in the country. It should be noted here that one of the second-level teacher unions, the Association of Secondary Teachers, Ireland (ASTI), was engaged in industrial action at the time (ASTI, 2014), and did not engage with this CPD, or any aspect of the new Junior Cycle, until the 2017-2018 school year (ASTI, 2017).

This CPD consisted of several aspects. Before the implementation of a new subject specification, 3 days of subject-specific training would be provided to subject teachers. In this case, individual teachers were released from teaching to attend day-long workshops, which took place in local education centres. Given that the workshops took place during school time, not all teachers could be released from school on the same day, and therefore teaching staff from more than one school attended these workshops at the same time. What is most pertinent to this research is that this is the first time that Irish-language CPD was offered to teachers who did not teach Irish as a subject, but rather taught their subject through the Irish language.

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[9] I should note at this point that there is one organisation, COGG, who do provide a CPD course in Irish, for teachers entering the Irish-medium education sector. This week-long course takes place every August, and predominantly focusses on learning the Irish language, with one day devoted to subject-specific content matter and language.

In addition, the JCT provide two days per year of whole-school CPD, for the entire teaching staff of the school. These whole-school CPD days take place during school days, but the school is closed to students. On one of these days each year, the whole school teaching staff receive the same training, with a different topic being covered each year, for example the first of these whole-school days consisted of a general overview of the new Junior Cycle framework; another year the topic explored promoting student wellbeing; and a third CPD topic covered formative assessment techniques.

The second type of full-day whole-school training is termed a “cluster day”. On cluster days, the subject teachers from three or four neighbouring schools meet together in one location to discuss the specification for their subject, teaching methodologies and resources. Training is provided on various topics, and teachers can participate in activities that would be suitable for students, so that they may experience these activities as the students would, which Borko (2004, p. 5) and Desimone (2009, p. 184) describe as a particularly effective approach. It has not been made clear to school if these whole-school CPD days provided by the JCT will continue indefinitely. It is assumed that it will be an annual event until all subjects have introduced a new specification in line with the Junior Cycle, and perhaps until all subjects have had one student cohort undertake the Junior Cycle examination.

Until the implementation of these whole-school CPD days, during which the CPD is being provided to *Gaelscoileanna* and *Gaeltacht* schools in Irish, no CPD in Irish was available to those teachers who taught in the Irish language. To this date, any workshops organised by organisations such as the Education Centres, PDST, NIPT, and SESS, are organised in the English language only.

2.2.3.3 CPD as part of ‘Croke Park Hours’

The implementation of the Junior Cycle took place against a backdrop of extreme austerity in the education sector in Ireland, across the public sector in general, and the country as a whole. One of the public sector agreements between the Government and the trade unions with a view to reducing the national budget deficit was signed in Croke

Park, the national stadium of the Gaelic Athletic Association (GAA). To this day, the ‘Public Service Agreement 2010-2014’ is known as the ‘Croke Park Agreement’[10] (DES, 2010).

One of the ‘efficiencies’ agreed as part of the Croke Park Agreement was that every member of the public service would work an additional number of hours per year. In the case of second-level teachers, this equated to 33 hours, or one hour per week during term-time, and these hours came to be known colloquially as ‘Croke Park Hours’. The hours were not added to the teachers’ teaching load but were to be used to facilitate school planning and other after-school meetings, such as parent-teacher meetings. These additional hours could also be used to facilitate CPD, although originally this CPD had to be carried out on a whole-school basis. Given that, in a post-primary school, teachers from various subject departments would all have their unique CPD needs, it became increasingly difficult for schools to organise effective CPD that could be provided for all staff at the same time. Guskey (2000) outlines why this model of CPD can be ineffective, as it allows for little choice and does not account for the needs of the teachers. These needs depend on several factors, such as experience, subject area and skill level.

For this reason, the rules regarding using Croke Park Hours for CPD were relaxed in the 2014-2015 academic year (DES, 2014). Teachers were now entitled to use 5 of the 33 Croke Park Hours for “planning and development work on other than a whole-school basis” including for subject department meetings and personal CPD, although anecdotally, some schools have been reticent about allowing teachers complete autonomy in choosing their CPD. Many schools, for instance, insisted that teachers prove their attendance at CPD events by furnishing the school with certificates of attendance from recognised CPD providers. Of course, this created difficulties for teachers who wanted to attend online CPD, such as webinars.

However, as time progressed schools were, and continue to be, encouraged to recognise the value in more informal CPD. The allocation of hours for planning and development

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[10] Since the ‘Croke Park Agreement’, three additional public sector agreements have come into effect, the 2013-2016 ‘Haddington Road Agreement’ (HRA), the 2015 ‘Lansdowne Road Agreement’ (LRA) which extended the HRA until 2018, and the 2018 ‘Public Service Stability Agreement’ (PSSA) which further continued most of the ‘efficiencies’ until 2020.

was increased to 10 hours in the 2017-2018 school year (DES, 2016a). As Circular 0045/2016 (DES, 2016a) states, regard will be given to “teacher professional judgement”. One unfortunate side-effect of this ’10 hours of CPD’, however, has been the increasing view amongst teachers of how they can fill up their hours, an outlook lamented by Guskey (2000, p. 15).

2.2.4 Webinar-Facilitated CPD Delivery

For decades, the promise of technology to revolutionise education has been a recurring theme, and has led to a wide variety of modes of online education and training. Asynchronous technologies have become the most widely used, and most studied, forms. These include the use of websites, wikis, and virtual learning environments, where media and activities can be uploaded for use by the student as and when it suits. With the increasing availability of high-speed broadband and the development of a variety of software, recent years have seen a rise in synchronous online learning, “using webcams and microphones to allow real-time viewing and interaction between participants, and between participants and tutors” (Yates, 2014, p. 246). These online, real-time sessions are variously called online conferences; online meetings; webcasts, a portmanteau of web and cast; and webinars, from web seminar. The use of webinar technology to facilitate CPD has clear benefits, although there are drawbacks to the use of webinars that may not be immediately apparent.

Allred and Smallidge (2010) highlight the obvious benefits of using webinars as a means of CPD, in allowing participants “to acquire information at a time and place that is convenient to their schedule”. However, this statement raises a possible contradiction. If a webinar is an example of synchronous communication, it follows that the time of a webinar might not be the most convenient for all participants (Olson & McCracken, 2015). This is highlighted in a systematic review of workplace eLearning (Booth, Carroll, Papaioannou, Sutton & Wong, 2009) which found that CPD which included the requirement to attend a large number of synchronous interactions “is contrary to the very features that made e-learning attractive in the first place” (p. 15).

However, given that webinars can be recorded for later access by participants, the inability by some to attend the live webinar can be overcome. This, in turn, provides additional benefits, such as the ability to view the webinar more than once, and the ability to start, pause, and rewind the recording as needed (Vaccani, Javidnia & Humphrey-Murto, 2016; Zoumenou, Sigman-Grant, Coleman, Malekian, Zee, Fountain & Marsh, 2015).

A further benefit of using webinar technology to facilitate CPD is the fact that geographic barriers to training are reduced, and costs associated with hosting a real-life physical training event are also avoided (Allred & Smallidge, 2010; Vaccani et al., 2016; Yates, 2014; Zoumenou et al., 2015). Participants avoid the costs of travel, and have the opportunity to attend the CPD at a remote location that suits them best. However, this, in turn, can lead to additional difficulties, particularly in relation to the use of technology by novices. Because each participant in the webinar is geographically separate from other participants, it can be difficult to diagnose and solve technical problems, either with the webinar platform itself, or with the participants own device (Ng, 2007; Yates, 2014; Zoumenou et al., 2015).

Although there has been much research carried out on eLearning, there have been very few peer-reviewed articles published on the use of synchronous webinars in education, and CPD in particular (Yates, 2014; Zoumenou et al., 2015). However, this research has shown that webinars can be equally effective as attending real-life lectures (Vaccani et al., 2016; Zureick, Burk-Rafael, Purkiss & Hortsch, 2018). However, the research also reports drawbacks when compared to real-life instructional settings. Most of the research highlights a “lack of interactivity with the speaker and other participants” (Allred & Smallidge, 2010, p. 12; also Olson & McCracken, 2015; Vaccani et al., 2016; Zoumenou et al., 2015). This can be affected by decisions made by the organisers of the webinar, such as muting participants’ microphones thereby limiting participants to text-based chat. As reported by Olson and McCracken (2015), this had the effect of a webinar feeling “like a conference call” (p. 8) for one group of students engaging with synchronous lectures.

The level of interaction between participants and presenter, and between participants is also highlighted by research carried out by Vaccani et al. (2016). This research was carried out on medical students, who had a compulsory module consisting of three lectures. Half the participants attended live lectures, and half viewed recordings of the lectures at their own convenience. In each case, the same lecturer and lecture slides were used. The webcast group were provided with a scheduled question and answer session at the end of the module. The results in this case tend to mirror those of other research studies. Although most students felt the webcasts were a better learning tool than the live lectures, only “35% preferred to have most of their lectures in the webcast format” (p. 4). The primary reasons cited by the respondents in this research related to the loss of personal interaction, both with the lecturer, and with their peers in a classroom setting.

Due to the lack of scholarly articles describing best practices for webinars, and in order to combat this possibility of “minimized peer interaction”, Zoumenou et al. (2015, p. 64) conducted a literature review on best practices for conducting webinars, and subsequently interviewed three webinar professionals to determine the steps that should be carried out to ensure that webinars are carried out in a professional manner, and to ensure engagement and interactivity amongst the participants. Although the complete findings of their article are too numerous to list at this point, they consider that the following steps should be included in any preparation for a webinar:

- Selecting an appropriate time
- Send reminders before the webinar
- Consider the size of the audience
- The presenter should learn how to use the technology in advance

Similarly, Zoumenou et al. (2015) list several aspects to consider during the webinar:

- Have the presenter sign in early to ensure the system is working correctly
- Keep participants engaged by asking questions during the webinar, allowing use of the smiley face, or raise a hand feature, or by using the text box
- Give something free to participants, and offer take away tips
- Approximately one hour is a good length of time for a webinar

And finally, the authors included some best practice suggestions for after a webinar:

- Provide an asynchronous option for those who could not attend at the time
- Seek feedback

2.2.5 Discussion

As discussed, CPD can be seen as both learning that occurs due to participation in formal programs and events, or informally, such as conversations with colleagues or learning in practice. This learning can lead to a change in teacher knowledge, beliefs and attitudes, often leading to a change in teaching practices (Desimone, 2009), although Guskey (2002) contends that a change in teaching practices is required first, and the revelation that the change in practice results in a change in student achievement subsequently leads to a change in beliefs and attitudes.

The introduction of the Junior Cycle has seen an increase in in-school CPD being provided for teachers, both on a whole-school basis, and on a subject-specific basis. This is in addition to the currently existing evening, weekend and summer courses and CPD events. As previously described, the original aim of this research was to provide CPD *as Gaeilge* to science teachers who teacher through the Irish language, as will be discussed in Chapter Four. This CPD would supplement the CPD being provided by the JCT in increasing the teachers' understanding of inquiry-based learning, thereby encouraging them to implement this methodology in the classroom. In addition, as described in Section 2.1.5, the fact that the CPD would be offered *as Gaeilge* would give teachers who might not be fluent in the language the opportunity to practice their language skills, to hear other teachers using the scientific terminology appropriately, and to further develop their fluency in order to more effectively engage in social and scientific discourse with their students. The participating teachers will be asked for their opinions as to the importance they attach to receiving this CPD *as Gaeilge*, rather than in English.

As described previously, *Gaelscoileanna* are spread across the entire country, with the largest concentration of second-level *Gaelscoileanna* in Dublin. This geographical spread means that the organisation of face-to-face workshops conducted through Irish for these teachers is not feasible. Webinars, however, as a form of synchronous online learning, provide the means for teachers to not only take part in CPD in the language in which they teach, but the webinar platform can also allow for the teachers to actively participate in the workshop, asking and answering questions; sharing their experiences; and generally participating in a community of practice with teachers with whom they share a common language and common difficulties. The teachers participating in the webinars will also be asked for their opinions regarding the provision of this CPD in a webinar setting, as opposed to a face-to-face setting.

In designing the series of webinars for teachers in Irish-medium schools, the literature indicates a number of characteristics shared by successful CPD events. For teacher CPD to be effective, it needs to address the principal purpose of teacher CPD; namely improving outcomes for the students of teachers who undertake the CPD. There are also several additional factors to consider, including: the CPD should address concrete topics that relate directly to the teaching practice of the teacher, rather than focussing on abstract concepts; the teachers should be active participants in the CPD sessions; the CPD events should be spread out in duration, rather than taking place in one long session; and there should be a consistent follow-up programme. Had this review of the literature taken place before the first series of webinars was delivered, more care would have been taken in the design of the webinars to address those aspects which would have made the CPD more successful. In addition, more focus would have been placed on incorporating the elements of best practice for webinar delivery described in the literature. This will be further discussed in Chapter Four.

2.3 Inquiry-Based Learning in Science Education.

For decades, the teaching of science at both primary and post-primary level has been the focus of much research and debate. Interest in science has been in decline for several decades (Osborne, Simon & Collins, 2003). This is especially evident in the transition from primary to post-primary education (Christidou, 2011; George, 2000). Krapp and Prenzel (2011, p. 35) posit that one reason for the decline in interest in science is “the quality and type of instruction”. The need for change in this regard was similarly reflected in both the Relevance of Science Education report (Matthews, 2007) and the Report and Recommendations of the Task Force on the Physical Sciences (Task Force on the Physical Sciences, 2002). Both of these reports documented, and commented upon, the decline in the uptake of physical science in the senior cycle of post-primary education in Ireland, which has been a cause for concern amongst policymakers and industry.

Since the 1960s, emphasis has been placed on the need to move away from traditional didactic models of ‘teaching science’ towards a more interactive model of ‘learning science’. The European Commission report commonly known as the Rocard Report (Rocard, Csermely, Jorde, Lenzen, Walberg-Henriksson & Hemmo, 2007), advocated the use of the teaching methodology known as Inquiry-Based Learning, or Inquiry Based Science Education in the teaching of science[11]. In the United States, the National Science Education Standards (NSES) published by the National Research Council (NRC, 1996), and the Next Generation Science Standards (NGSS) (NRC, 2013) describe the learning of science as “something students do, not something that is done to them” (ibid., p. 20), and advocated the introduction of inquiry-based learning (IBL) as a means of improving the learning of science.

Similarly, the 2003 science syllabus published by the Department of Education and Skills (DES, 2008) in Ireland, outlining the material to be covered in the Junior Certificate

[11] Alternative labels are applied to the particular methodology being discussed in this dissertation. Inquiry-Based Learning (IBL) is the label that will be used most commonly, (even if the common UK English spelling is Enquiry). When IBL specifically relates to the teaching of science, the term Inquiry Based Science Education (IBSE) is also a widespread label. IBL and IBSE, for the purposes of this dissertation are interchangeable, although to prevent confusion, I will limit myself to the label IBL.

science curriculum, placed an emphasis on the inquiry nature of science, and referred to the fact that the students should experience science as an investigative subject. In addition, the 2003 syllabus decreased the amount of material to be covered during the three-year course, thereby allowing more time for students to engage in active learning and hands-on investigation (DES, 2008; Eivers et al., 2006; National Council for Curriculum and Assessment (NCCA), 2006). Similarly, the new Junior Cycle Science Specification (DES, 2015) seeks to further mitigate the decline in student interest by changing how science is taught. A more inquiry-focussed approach is recommended, which “serves as a means to engage students in the ideas, concepts, processes and practices of authentic science” (Adler, Schwartz, Madjar & Zion, 2018, p. 823).

One of the European-funded projects inspired by the themes laid out in the Rocard Report (Rocard et al., 2007) is the Inspiring Science Education (ISE) Project. The aim of this project is to make science in school more "attractive and relevant" (inspiring-science-education.net) to students. The ISE project organises CPD for science teachers, instructing them on how to implement inquiry-based learning in their classrooms. However, the major difference between the ISE project and other EU projects with a focus on IBL methods is that the ISE project explicitly makes use of "interactive tools and digital resources" (ibid.) in conjunction with IBL methods to make the teaching and learning of science more interactive and practical.

The ISE project not only provides CPD to science teachers but also demonstrates best practice in IBL through the provision of ‘learning scenarios’ authored by the project in conjunction with participating schools throughout Europe. These learning scenarios can be used by the teachers undertaking CPD, and trialled in their own classrooms, to experience how a well-thought-out IBL lesson might progress. These learning scenarios, and the CPD provided by ISE project in Ireland, are all in the English language, as this is the working language of the project.

2.3.1 Junior Cycle Reform in Ireland - Science

Although much of the current impetus for reform of science teaching stems from international stimuli, Inquiry-Based Learning (IBL) has been promoted in Irish science teaching for many years. Although the Department of Education and Science (DES) revised Junior Certificate Science Syllabus (DES, 2008) does not explicitly use the word 'inquiry', the aims of the syllabus emphasised the importance of students gaining "practical experience of science"; developing a knowledge of the scientific method and "the concept of a valid experiment"; developing the skills associated with "the use of the scientific method in problem solving", "observation, measurement and the accurate recording of data" and "the formation of opinions and judgements based on evidence and experiment" (p. 4). The 2008 syllabus provides a description of Inquiry-Based Learning, for which a definition will be discussed in further detail in Section 2.3.2.

However, despite the changes brought about by the new syllabus, the National Council for Curriculum and Assessment (NCCA) stated in 2011 that "little has changed for students" (NCCA, 2011, p. 5). Although part of the aim of the 2008 syllabus had been to reduce the importance of the terminal examination after a three-year course of study at junior cycle in post-primary school, it was found that "the path through junior cycle is a path towards the examination" (NCCA, 2011, p. 5). This document, along with the succeeding document, outlined a shift away from terminal examination towards a "new school-based model of assessment" (NCCA, 2012, p. 3). Indeed, together these documents outlined a complete reformation of the junior cycle in post-primary education, with the name Junior Cycle replacing the previous Junior Certificate. As part of a phased roll-out of the new Junior Cycle, new subject specifications were being produced in turn, with English the first to be introduced in September 2014, and the introduction of Science and Business Studies in September 2015. However, following widespread resistance by teachers (ASTI, 2014; TUI, 2014) to the Junior Cycle, the implementation of the new Junior Cycle Science Curriculum Specification (DES, 2015) was delayed until September 2016 (Erduran & Dagher, 2014).

2.3.1.1 Curriculum Reform in Science

Research into the 2003 science syllabus found that many teachers had not changed their teaching strategies to accommodate the emphasis on inquiry in the classroom; nor had the expected increase in student understanding and interest occurred (Eivers et al., 2006; Matthews, 2007). In early 2013 the National Council for Curriculum and Assessment (NCCA), as part of the government drive to reform the entire junior cycle, launched a consultation process into how best to reform the teaching and learning of science at junior secondary school level. The NCCA published a background paper (NCCA, 2013) which would form the basis of this consultation process. This background paper stressed the need for increased emphasis on students' active participation in their own learning, including the need to learn not only scientific facts, but also an understanding of the "nature of science". The vision at the time of the new Junior Cycle award was one that would allow students to develop their scientific literacy and would therefore address how "inquiry-based teaching and learning should be promoted".

Following the consultation period, the NCCA published the draft Junior Cycle Science *Specification*[12] in September 2014 (NCCA, 2014). The *Specification* imagines the subject as consisting of five strands with one of those strands, the Nature of Science, "permeating all the strands". Essentially, this strand outlines how the students would learn the material being outlined in the *Specification*; there would be a "strong focus on inquiry", where the aim is to allow the students to:

> construct a coherent body of facts, learn how and where to access knowledge, and develop scientific habits of mind and reasoning skills to build a foundation for understanding the events and phenomena they encounter in everyday life. This makes the science classroom a dynamic and interactive space, in which students are active participants in their development. (NCCA, 2014, p. 13)

2.3.1.2 A Note on Terminology

The finalised version of the new Junior Cycle *Specification* was published in the Winter of 2015, and as teachers we had the remainder of the 2015-2016 school year to understand the new *Specification*, and plan its implementation for the first cohort of students who would undertake this course, beginning in September of 2016. There was, immediately, a stark difference between the old curriculum (DES, 2008) and the new specification (DES, 2015). This is possibly best outlined by Declan Kennedy (2018) in his article on the differences between a syllabus, specification and curriculum.

Using the definitions for these terms from various dictionaries, he contends that, while the document outlining the previous course (DES, 2008), as well as the Leaving Certificate

[12] Henceforth I will refer to the Junior Cycle Science Specification (DES, 2015) as the *Specification.*

Biology, Chemistry and Physics courses, could be described as specifications, given the level of detail they provide, the new *Specification* (DES 2015) cannot be described as such. It does not provide details such as "depth of treatment, examination specification, practicals and laboratory experiments and other advice for teachers and pupils" (Kennedy, 2018, p. 37), which, he contends, would be required of a document which purports itself to be a specification. The correct term for the document issued by the Department of Education, he concludes is therefore a syllabus, a document which "satisfies the criteria of "outline" or "summary" as used to describe a syllabus" (Kennedy, 2018, p. 37).

Nonetheless, in the case of either a syllabus or a specification, the document must be understood and interpreted by the teacher to develop the curriculum they implement with their students. Curriculum, in this sense and for my purposes, is most accurately described by the definition provided by Rowntree (1981, cited in Kennedy, 2018):

> The total structure of ideas and activities developed by an educational institution to meet the learning needs of students and to achieve desired educational aims. Some people use the term to refer simply to the content of what is taught. Others also include the teaching and learning methods involved, how students' attainment is assessed, and the underlying theory or philosophy of education.

Having previously been provided with a concrete outline of the course, including the required depth of treatment, description of practical work and assessment guidelines, it was clear that a 'national curriculum' had been achieved. All students would experience the same learning outcomes, and would be assessed equally. Although small differences might arise given the differences in teacher styles, and emphasis they place on different parts of the curriculum, for the most part these differences would be negligible.

However, in providing teachers with a syllabus which affords a "reasonable degree of flexibility for teachers and students to make their own choices and pursue their interests" (DES, 2015), we are being encouraged to allow the students to place an emphasis on learning content that they find most interesting, as well as allowing for teacher preferences. This has both its benefits and drawbacks, as will be discovered. It is in this interpretation of the *Specification*, and deciding which topics to place more of an emphasis on, how it is to be taught, and how it is to be assessed in the classroom that a teacher creates a curriculum for their students.

2.3.1.3 Inquiry in the Classroom – The Junior Cycle Science Specification

The new science *Specification* highlights the need for students to engage in inquiry activities. The *Specification* is designed around four content strands: Earth and Space (Strand Two), Chemical World (Strand Three), Physical World (Strand Four) and Biological World (Strand Five). Strand One: Nature of Science comprises of a series of Learning Outcomes (LOs) that are related to the skills, knowledge and attitudes that a scientifically literate citizen would embody. A graphic representing the relationship between the strands of the *Specification* is shown in Figure 2.3.

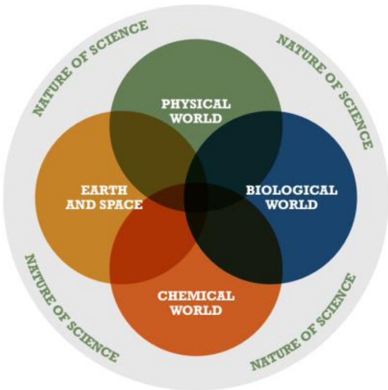

Figure 2.3: The Strands of the Specification for Junior Cycle Science (DES, 2015, p. 10)

The Nature of Science strand is envisioned as an all-encompassing unifying strand, and is designed without specific content to be learned, but rather a series of learning outcomes that influence how the content strands will be taught (DES, 2015, p. 11). The learning outcomes from the Nature of Science strand include an appreciation for how scientists work (LO 1), evaluating media-based arguments concerning science (LO 8) and appreciating how society influences scientific research (LO 9). However, of most interest in this research is how the learning outcomes in the Nature of Science strand of the *Specification* can give the teacher a sense of what it means to incorporate inquiry in their classroom. Figure 2.4 below, from page 16 of the *Specification* outlines the learning outcomes in question.

ELEMENT: Investigating in science

Students should be able to:

2. recognise questions that are appropriate for scientific investigation, pose testable hypotheses, and evaluate and compare strategies for investigating hypotheses
3. design, plan and conduct investigations; explain how reliability, accuracy, precision, fairness, safety, ethics, and the selection of suitable equipment have been considered
4. produce and select data (qualitatively/quantitatively), critically analyse data to identify patterns and relationships, identify anomalous observations, draw and justify conclusions
5. review and reflect on the skills and thinking used in carrying out investigations, and apply their learning and skills to solving problems in unfamiliar contexts.

Figure 2.4: Learning Outcomes 2 – 5 of the Nature of Science Strand (DES, 2015, p. 16)

As can be seen from Figure 2.4, the *Specification* does provide some information on what the students should be learning, in terms of gaining an understanding of what it means to implement inquiry processes in the classroom. However, it is not clear what exactly inquiry should look like in practice or precisely what inquiry learning means. The *Specification* similarly offers no advice on how teachers might incorporate IBL into their lessons. However, the *Specification* does hint that all inquiry might not be the same. It outlines various levels of inquiry on a continuum from those requiring the most teacher intervention, and consequently least amount of student direction to those requiring least teacher guidance, and most student self-direction. This graphic is shown in Figure 2.5 below.

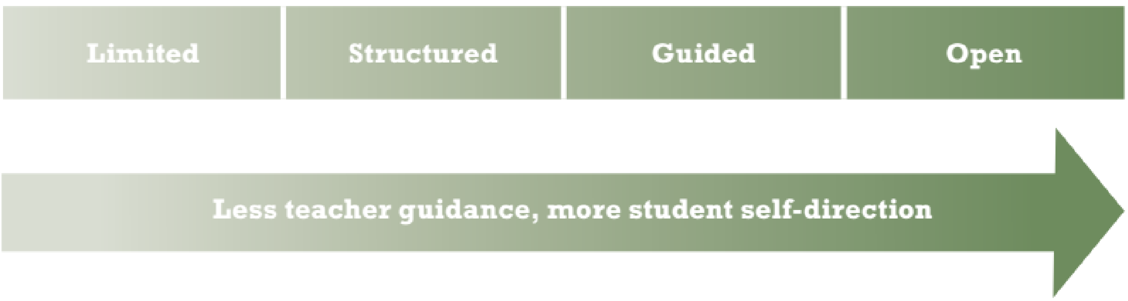

Figure 2.5: Levels of Inquiry (DES, 2015, p. 14)

The *Specification* provides no description of how these levels of inquiry might be identified or when it might be appropriate to use any particular level of inquiry. Rather, the *Specification* describes (DES, 2015, p. 14):

> The first two levels are lower-level inquiries, but they can be used to develop students' inquiry skills so that they can engage in scientific inquiry which has less teacher guidance and more student self-direction. Students often engage with these two levels of inquiry before more open forms of inquiry are used; however, this practice merely reflects a common order of adopting inquiry approaches, and extending the range of approaches available to teaching classes; it does not suggest a progression or improvement along the way. Opportunities to apply inquiry skills in increasingly complex learning situations can be included when students have developed confidence and capacity in inquiry processes.

For a description of what inquiry-based learning is, and what the different levels of inquiry might mean in practice, we must look elsewhere.

2.3.2 Inquiry-Based Learning

There is a wide range of views in the literature in what the term inquiry means (Anderson, 2002; Rutten, van der Veen & van Joolingen, 2015). In addition, the choice of terminology for exactly what to call this methodology will affect the nature of what is being studied, as Cairns and Areepattamannil (2019, p. 2) described when outlining the various terms used: "inquiry-based teaching, inquiry-based instruction, inquiry-based learning, inquiry learning, inquiry-based science instruction, inquiry-oriented learning, inquiry-oriented teaching, inquiry-based science teaching, student inquiry, and inquiry-based teaching." For the purposes of this research, however, I will continue to use the term 'inquiry-based learning', although I recognise that this may reflect my own understanding of IBL, rather than for any precise taxonomic reasons. As can be surmised, the correct term to use in any particular situation would depend on the aims of the implementation of an inquiry approach into a lesson, implying that IBL can have more than one approach, and more than one educational outcome.

2.3.2.1 Inquiry: A Means or an End?

As teachers, and researchers, we are often guilty of conflating and confusing the various aspects of inquiry, and the multiple meanings of the term itself (Furtak, Seidel, Iverson & Briggs, 2012; Gyllenpalm, Wickman & Holmgren, 2010; Kirschner, Sweller & Clark 2006). One aspect, "the teaching of a discipline as inquiry" (Kirschner et al., 2006, p. 78), in which the emphasis is on the processes within science, has a different educational outcome to the other aspect, which is "the teaching of the discipline by inquiry", in which the research process is used as a pedagogical approach to teach content. Heinz, Enghag, Stuchlikova, Cakmakci, Peleg and Baram-Tsabari, (2017) and Gyllenpalm et al., (2010, p. 1153) assert that inquiry can refer to three ideas: "(1) a set of skills to be learned by students; (2) a cognitive understanding of the processes of inquiry, for example the logic of a controlled experiment; and (3) a pedagogical strategy". Ideas (1) and (2) form an integral aspect of the *Specification*, in which it is expected that students understand, and experience, how science works, and can reach the stage in which they can design and carry out their own experiments, and make decisions and judgements throughout the process. The third idea is a pedagogical approach in which the students are expected to "discover" natural and scientific laws and principles through a constructivist approach to learning. This is echoed by Abd-el-Khalick's et al. (2004, p. 398) assertion that there is a distinction between seeing inquiry *in* science and inquiry *about* science:

> An undercurrent theme in these conceptions is advancing and distinguishing between inquiry as means and ends. "Inquiry as means" (or inquiry in science) refers to inquiry as an instructional approach intended to help students develop understandings of science content (i.e., content serves as an end or instructional outcome). "Inquiry as ends" (or inquiry about science) refers to inquiry as an instructional outcome: Students learn to do inquiry in the context of science content and develop epistemological understandings about NOS [Nature of Science] and the development of scientific knowledge, as well as relevant inquiry skills (e.g., identifying problems, generating research questions, designing and conducting investigations, and formulating, communicating, and defending hypotheses, models, and explanations).

Cairns and Areepattamannil (2019), although approaching inquiry from a slightly different point of view, also make the distinction between the educational outcomes of inquiry; they see three distinct outcomes, teaching *of* inquiry, or the science process skills; teaching *about* inquiry, how scientists use inquiry methods; and teaching *through* inquiry, the teaching of scientific content using inquiry.

Capps et al. (2012, p. 294) describe how the National Science Education Standards (NSES) (National Research Council (NRC), 1993) in the USA approach inquiry as an educational outcome in two ways: as one's ability *to do* scientific inquiry (asking questions, planning and designing experiments, analysing data etc.); and inquiry as the study of how scientists do their work. They also outline the NSES third meaning of the term inquiry as a pedagogical approach to teaching science, and although it is "not the only way to effectively teach science". Indeed, the use of inquiry as a means of 'teaching science' has provoked much discussion in recent years, with contradictory results reported in the literature. This will be further discussed in later sections.

What is most interesting is that the Junior Cycle *Specification* does not imply that the students should be learning the science content *by* inquiry. The fact that there is "a body of scientific knowledge" to be acquired as an aim of the *Specification* is a distinctly separate aim to the fact that the students should also be learning science process and scientific literacy skills. However, what is not clear is the interpretation of inquiry in the classroom that science teachers in Ireland will take from the *Specification*. I should note that there is no right or wrong way to view inquiry. Both the educational outcome of learning science through inquiry, or learning about inquiry as a process can be used, bearing in mind the aims of the lesson in question.

This now raises a difficult question. What is inquiry? Although we have seen inquiry described as both a means and an end, we are still no nearer to understanding what inquiry-based learning looks like in practice. Several definitions are available, and it appears that many authors are reluctant to subscribe to any one definition. Unfortunately, a detailed investigation into the various definitions of IBL in all its varieties, with a view to understanding the subtle nuances and shades of meaning within them, is somewhat beyond the scope of this research. Although it might be an interesting exercise to undertake, we shall see in due course that engaging in such a digression will be redundant in terms of this research.

However, in order to gain some understanding of what IBL might be, and how it might be implemented, we might look to the definition proffered by the NSES (NRC, 1993, p. 23), which describes inquiry as:

> a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations, and predictions; and communicating the results.

In this case, it is important that learners should be "answering authentic scientific questions relevant to their own lives" (Capps et al., 2012, p. 295), rather than questions provided by the teacher. Clearly, we can deduce several important points from the definition provided by the NSES (NRC, 1993). The students should be actively participating in the learning process, rather than passive recipients of knowledge, as evinced by the fact that the definition is based on a number of actions that the students are expected to carry out. Inquiry in this definition is an activity that involves actions such as making, posing, examining, planning, and reviewing. Students in an inquiry lesson are acting as scientists. However, what is not clear is how many of these actions are required of the student for them to be considered as participating in inquiry. If the teacher were to provide a question to be asked, for example, rather than the student posing their own, would it still be considered an inquiry lesson? The definition is unclear.

Marshall et al. (2017, p. 789) provide a definition of inquiry-based instruction as "an intentional student-centred pedagogy that challenges the learner to explore concepts, ideas, and/or phenomena before formal explanations are provided by the teacher and/or other students". Students undertake this exploration through engaging with "scientific practices", while studying "science concepts". The key, for Marshall et al. (2017), is that the students explore *before* explanations are given to them, rather than engaging in exercises which confirm information that has already been provided to them. However, what is unclear is the extent to which teacher involvement is permitted. Although the definition describes inquiry as a pedagogy that "challenges" students to explore ideas before they receive an explanation, is it enough that the student are challenged, regardless of what transpires in the rest of the lesson? For example, if the student has been "challenged" to explore an idea but because of a lack of ability or due to behavioural issues can't or won't engage in the lesson, or carry out an investigation of their own, was the original challenge to engage enough to describe the lesson as an inquiry lesson for that student?

I take this slight detour in order to illustrate a point. Academic consensus on the definition of inquiry-based learning remains a challenge. If a definition for IBL is too prescriptive, then specific names and definitions would need to be constructed for every variation of IBL, at which point attempts by the academic community to encourage teachers to adopt inquiry practices, in any form, will be made increasingly difficult. However, if a definition of IBL is constructed that is too vague, then we risk undertaking comparisons of teaching methodologies that are only distantly related to one another. I do not seek to offer a resolution to the problem in this research, but rather to suggest that, from the standpoint of a teacher, perhaps a strict definition is not required. However, notwithstanding the lack of a firm definition of IBL, in any of its forms, most authors agree that there are key features required in order for a lesson to be considered inquiry-based. These features will be described in the following section.

2.3.2.2 Features of Inquiry

The NGSS (NRC, 2013) described some of the essential features of inquiry in the science classroom, as shown in Table 2.1:

Table 2.1: Essential Features of Classroom Inquiry (NRC, 2000, p. 25)

- Learners are engaged by scientifically oriented questions.
- Learners give priority to **evidence**, which allows them to develop and evaluate explanations that address scientifically oriented questions.
- Learners formulate **explanations** from evidence to address scientifically oriented questions.
- Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding
- Learners communicate and justify their proposed explanations.

As can be seen, there are certain features of any lesson that must be fulfilled for the lesson to be considered a full ‘inquiry’ lesson. However, the NRC concedes that not all five features of inquiry will be present in every lesson, and that there are differing levels of inquiry. Lessons which include only some of the features of inquiry are called “partial inquiry” (NRC, 1996, p. 143). The five features can have variations, depending on the amount of teacher direction, or student freedom, in each feature. These are described in Table 2.2:

Table 2.2: Essential Features of Classroom Inquiry and Variations (NRC, 2000, p. 29)

Essential Feature	Variations			
1. Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided by teacher, materials, or other source	Learner engages in question provided by teacher, materials, or other source
2. Learner gives priority to **evidence** in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Learner given data and told how to analyze
3. Learner formulate **explanations** from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence and how to use evidence to formulate explanation
4. Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	
5. Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to use sharpen communication	Learner given steps and procedures for communication

More ——— Amount of Learner Self-Direction ——— Less
Less ——— Amount of Direction from Teacher or Material ——— More

As can be seen, an "inquiry lesson" is not a black-or-white situation; there are many variables which can be changed and the lesson can still be considered to contain inquiry. Most interestingly, upon studying the features listed in Table 2.2, it can be argued that a lesson does not need to include a practical activity for it to be considered to contain inquiry, a claim supported by Turner, Keiffer and Salamo (2018, p. 1458). For instance, if a student were to ask a question, the teacher could offer some information, and then proceed to ask questions of the student, or the whole class. These questions could be recall questions, in order to require students to recall information they had been provided with earlier, or they could be critical thinking questions, which would encourage the students to "analyse, apply and evaluate" (Rutten et al., 2015, p. 1227) the information they already hold in order to formulate their own explanations. Creemers and Kyriakides (2006, p. 357) describe the two kinds of questions: product questions, where one answer is required from students; and process questions, in which students are expected to provide an explanation. Viewed in these terms, the argument could be made that, even without a practical investigation taking place, the integration of some new information, along with the students' prior knowledge and some questioning, could be viewed as an inquiry lesson.

2.3.2.3 Levels of Inquiry

By studying the features of inquiry and their variations, as outlined above, it is evident that not all inquiry lessons are the same. Banchi and Bell (2008), for example, in Table 2.3, described inquiry as a continuum with four levels of inquiry, ranging from confirmation to open, although their model is simplified in that it only addresses three aspects of an inquiry lesson:

Table 2.3: Four Levels of Inquiry (Banchi and Bell, 2008, p. 27)

Inquiry Level	Question	Procedure	Solution
1—Confirmation Inquiry *Students confirm a principle through an activity when the results are known in advance.*	✔	✔	✔
2—Structured Inquiry *Students investigate a teacher-presented question through a prescribed procedure.*	✔	✔	
3—Guided Inquiry *Students investigate a teacher-presented question using student designed/selected procedures.*	✔		
4—Open Inquiry *Students investigate questions that are student formulated through student designed/selected procedures.*			

Smithenry (2010) also describes four main types of inquiry: confirmation, in which teachers give the students the question, the answer, and the method of confirming the answer; structured, where the teacher gives the students the question and the method for finding the answer, but not the answer itself; guided, where the students are given a question, and then expected to find a method of determining the solution; and open inquiry in which students are given the freedom to determine their own question to be investigated. However, Smithenry (2010) describes the first two types as "cook-book" inquiry, due to the recipe-like nature of the information provided to students.

In a similar vein, Jarrett (1997), outlined the four levels of inquiry, as per other models above, but included two more steps that can be included beforehand. These additional steps are activities that focus on textbooks and worksheets, and demonstrations carried out by the teacher. These allow for teachers to scaffold student learning, and model how inquiry activities can be carried out. In turn, this allows the students to learn the necessary information, and to observe the skills in use by a teacher, before progressing to practical activities.

When practical work is involved in the lesson, the task of identifying the level of inquiry in the lesson becomes easier. Table 2.4 shows the work carried out by Blanchard, Southerland, Osborne, Sampson, Annetta and Granger (2010, p. 581) describing the work of Abrams, who in turn draws on the work of Schwab and Colburn, in outlining four levels of inquiry which depend on three factors; who determines the question to be investigated; who determines the method of data collection; and who interprets the results.

Table 2.4: Levels of Inquiry (Blanchard et al., 2010, p. 581)

	Source of the Question	Data Collection Methods	Interpretation of Results
Level 0: Verification	Given by teacher	Given by teacher	Given by teacher
Level 1: Structured	Given by teacher	Given by teacher	**Open to student**
Level 2: Guided	Given by teacher	**Open to student**	**Open to student**
Level 3: Open	**Open to student**	**Open to student**	**Open to student**

The *Specification* states that the first two levels, Level 0: Verification (referred to in the *Specification* as Limited) and Level 1: Structured, can be used to develop students' inquiry skills to allow them to "progress along the continuum of inquiry" (p. 13), which could be interpreted as an indication that the higher levels are somehow preferred. However, the *Specification* specifies that this "does not indicate a progression or improvement" (p. 14), a statement that is echoed by Blanchard et al. (2010) and Smithenry (2010). Rather, the level of inquiry used in any particular situation will depend on several factors, such as the material being covered, the ability and prior knowledge of the students (Blanchard et al., 2010; Smithenry, 2010).

2.3.2.4 The roles of teacher and student in IBL

Teachers inhabit various roles, and how they come to inhabit those roles happens in various ways (Gudmundsdóttir, 2001, p. 227). Rutten et al. (2015, p. 1227) describe one of the main obstacles to teachers implementing inquiry in the classroom as the difficulty the teacher has in adapting "his/her role appropriately" and that the role the teacher must adopt is "less directive and more supportive". This description is echoed by

Crawford (2000), who outlined some of the roles that are adopted by teachers practicing IBL. These include the roles suggested by Osborne and Freyberg (1983, cited in Crawford, 2000), namely those of "motivator, diagnostician, guide, innovator, experimenter, and researcher" (Crawford, 2000, p. 931). In addition, Crawford, in her study of one teacher practicing IBL in his classroom, identified additional roles that are performed by the teacher, namely those of "modeller, mentor, collaborator, and learner" (p. 932). Challenges arise when some of the roles mentioned are in stark contrast to the traditional practices of a teacher, and both teacher and students can have difficulty in adjusting.

Ash and Kluger-Bell (2000) also provide a list of indicators that highlight the actions undertaken by teachers during an inquiry lesson. During such a lesson, teachers:

- Model behaviours and skills by guiding their students and showing them how to use new tools/ materials/ skills, etc;
- Support content learning;
- Use multiple means of assessment;
- Act as facilitators of learning

Interestingly, they also list some of the actions that they view students have should fulfil:

- View themselves as active participants in the process of learning;
- Readily engage in the exploration process;
- Plan and carry out investigations;
- Communicate using a variety of methods;
- Propose explanations and solutions and build a store of concepts;
- Raise questions;
- Use observations;
- Critique their science practices

The traditional roles occupied by both teacher and student also need to be taken into account (Donnelly, McGarr & O'Reilly, 2014). The authors frame their research in terms of the power relationships within the classroom, where frequently the student "frames the activity in terms of what they believe the teacher is looking to hear" in responding to the traditional "question-answer-comment sequences" rather than attempting to make sense of the question. This, they assert, is in stark contrast to an inquiry-based learning approach, which "posits that students need to take ownership of their learning in order to construct their own knowledge" (p. 2031). They further highlighted how the common practice of monitoring students during a lesson can actually inhibit the inquiry process (p. 2045), as it leads to the students inferring that there are specific "expectations of what is to be achieved", and that there is a specific procedure which should be followed, which is contrary to the spirit of an inquiry lesson.

2.3.2.5 Models of IBL

Several models of inquiry exist to facilitate teachers in planning inquiry activities and lessons. One of the most widespread models is the 5E model, developed by Bybee et al. (2006). This model describes an inquiry lesson as taking place over five discrete stages, or phases, which connected together to form an inquiry cycle:

- Engage
- Explore
- Explain
- Elaborate
- Evaluate

Pedaste et al. (2015) similarly outlined a framework for inquiry cycles that need to occur within an inquiry lesson, based on their meta-analysis of 32 journal articles describing phases of inquiry lessons. This framework is shown in Figure 2.6.

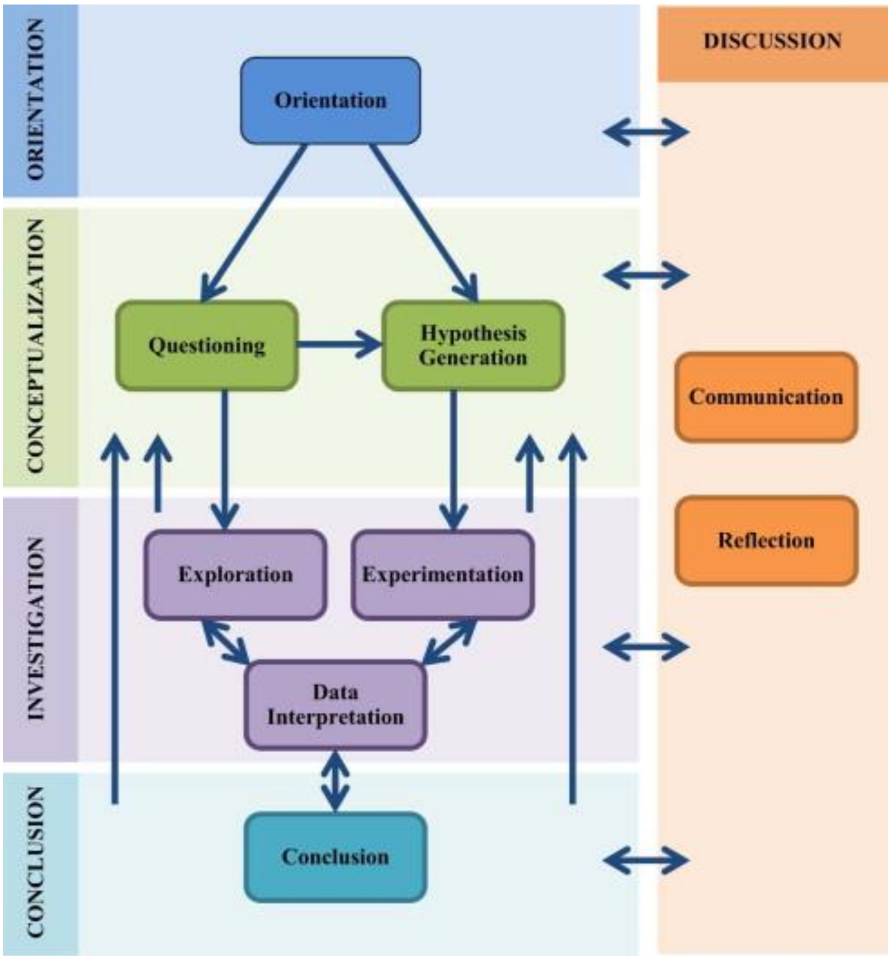

Figure 2.6: Inquiry-based learning framework (Pedaste et al., 2015, p. 56)

The model of IBL proposed by the ISE project, and used in the lessons designed on the Lesson Authoring Tool, consists of five similar stages to the models described by Bybee et al. (2006) and Pedaste et al. (2015):

1. Orienting & Asking Questions, the topic of the lesson is introduced, assumptions the students may have are challenged, and questions they may have are formulated;
2. Hypothesis Generation & Design, during which the students develop one of their questions into a hypothesis;
3. Planning & Investigation, in which the hypothesis previously developed is tested;
4. Analysis & Interpretation, where the students analyse the data collected from their investigation and refute or confirm their hypothesis;
5. Conclusion & Evaluation, when the students communicate their findings.

What can be seen in this case is that there tends to be a common outline to the models of IBL, and that they generally tend to mirror the sequence of the classical scientific method. Using a framework such as these IBL models can often facilitate a teacher's implementation of inquiry in the classroom.

2.3.2.6 Using Technology to Support IBL

Mäeots and Pedaste (2014) claim that inquiry-based learning (IBL) can be an effective method for learning scientific content, as well as improving scientific skills, by allowing the students to act like scientists. Therefore, students learn not only about the results of science, but "the processes and methods used by scientists" (van Joolingen, de Jong & Dimitrakopoulou, 2007). To assist this inquiry process, computer simulations and web-based learning environments have been shown to be effective tools (Mäeots & Pedaste, 2014; van Joolingen et al., 2007). The use of computer simulations in an inquiry-based science lesson can allow students to undertake simulated 'experiments' that they would not normally have the ability to.

Rutten et al. (2015), found several positive correlations in the implementation of computer simulations during an inquiry lesson. For example, the students reported a positive contribution to both their motivation and their understanding. In addition, they note that there is a correlation between the teacher's use of inquiry when integrating computer simulations into a science lesson, and a congruence between the students' and teacher's learning goals for the lesson. Hmelo-Silver, Duncan and Chinn (2007) had predicted such an outcome, when they described how the content of a subject is best learned when the situation in which students learn the content is similar to a context in which the knowledge might be applied. In this case, learning about science, and science content, is best carried out in a practical setting, simulated or otherwise.

2.3.3 Motivations for using IBL: The Why?

If we, as science teachers, are to accept that we *should* implement inquiry methods into our teaching practices, it is also incumbent upon us, at some point, to ask: Why? There are several reasons given in the literature. In aligning my search of the literature with the themes of this research, three aims of science education that can be facilitated by implementing inquiry-based learning in the classroom can be described as: 1) improving the student attitudes to science; 2) developing students life skills, including science literacy; and 3) improving student attainment in science. These three topics will be discussed in subsequent sections.

2.3.3.1 Improving Attitudes to Science

As previously discussed, over the past few decades there has been a declining interest by young people in science, and in pursuing the physical sciences as an upper-secondary school and university subject. Although Matthews (2007, p. 85) cautioned against changing the nature of science education in schools as *the* way to improve students' views on the subjects, arguing that the reasons students have for choosing subjects are complicated, the Rocard report (Rocard et al., 2007, p. 2) contends that implementing inquiry methods "provides the means to increase interest in science". However, Matthews (2007, p. 87) makes the distinction between student *interest* and *motivation*. Interest, he notes, is always roused in students by "the most mundane of practical tasks", an observation that tallies with my own experience, but interest is fleeting, and is often not converted into long-term motivation. I refer throughout this research to student interest, and later chapters often refer to enthusiasm, engagement, enjoyment and like/dislike; additionally, the literature refers to terms such as attitude and motivation. There are competing views in educational psychology as to whether these terms can be used interchangeably, or whether strict definitions should be applied (Krapp & Prenzel, 2011). However, this dissertation uses the terms in their broadest sense. As Potvin and Hasni (2014) noted in their meta-analysis, these concepts are closely related to one another, to the point where the concepts of interest/motivation/attitude (I/M/A) are often studied together. For this dissertation, the focus will be on whether the students enjoy science lessons and display an interest in science in general.

There have been few studies on the impact of inquiry on attitudes (Jiang & McComas, 2015), although there is some evidence that implementing inquiry into science lessons can have a positive impact on student interest. Chen, Wang, Lin, Lawrenz and Hong (2014), for example, found that an inquiry-based after school intervention enhanced student attitudes towards science, and decreased student anxiety about learning science. Capps et al. (2012, p. 294) state that "Classroom inquiry can be modelled after the authentic practice of science to enhance student interest and motivation". Potvin and

Hasni (2014, p. 98) described aspects of science lessons that students enjoyed, and activities which students dislike. For example, inquiry-based and problem-based learning were found to increase I/M/A amongst students, as did students engaging in collaborative work. Bryan, Glynn and Kittleson (2011) also reported that students enjoy 'hands-on' activities, and 'inquiry-based' learning. Clearly, a move to more opportunities for the students to conduct investigations and undertake inquiry activities would lead to an increase in student interest and engagement.

2.3.3.2 Developing Scientific Literacy

The *Specification* (p. 5) similarly incorporates the development of "a sense of enjoyment in the learning of science" into its aims, with the intention of leading to a lifelong interest. It also aims to encourage students to "develop scientific literacy", "develop a scientific habit of mind" through laboratory and problem-solving activities that will "improve their reasoning and decision-making abilities" and aid them in using the key skills of the Junior Cycle to "justify ideas on the basis of evidence". Lederman, in his contribution to Abd-el-Khalick et al. (2004, p. 402) outlines, in my opinion, the key reason for using inquiry in the science classroom:

> To my mind, a stress on understandings about inquiry is clearly more consistent with the goal of scientific literacy than the more perennial stress on doing inquiry. Indeed, do we expect citizens to execute a scientific investigation every time a decision on a science-related personal or social issue is needed: Of course not. Rather, our citizens are expected to know enough about science content, inquiry, and NOS to be able to understand scientific claims and make informed decisions.

We shouldn't be training all of our students to become scientists. As Osborne and Dillon (2008) also argue, we should be aiming towards is to give all of our students an understanding of how science works, so that, in later life, they can make informed decisions about crucial aspects of their lives, and the world around them.

2.3.3.3 Increasing Attainment

IBL leads to improved performance, according to some research (Alfieri, Brooks, Aldrich & Tenenbaum, 2011; Furtak et al., 2012; Jiang & McComas, 2015; Marshall & Alston, 2014; Marshall et al., 2017; Minner, Levy & Century, 2010). For instance, research undertaken by Marshall (Marshall & Alston, 2014; Marshall et al., 2017) reported increased test scores in students when lessons took place using an inquiry-based approach. Von Secker (2002) also reported on the effects of IBL on student achievement, although this study was primarily focussed on equity in education. In the study of over 4,000 students in the US, it was found that using inquiry lead to higher average achievement for all students. However, the study also showed that there was not equal achievement; that the effect is “sensitive to social context differences” (p. 159), there was not an equal increase in achievement amongst advantaged and disadvantaged students, and that using inquiry can lead to a wider achievement gap between students of different socio-economic groups.

However, a number of the meta-analyses undertaken on the effect on student achievement when implementing inquiry point to a common problem. Many of the studies which report increased student achievement use different approaches to inquiry, or conflate the IBL with other discovery learning methods. Some research reports implemented open inquiry, others implemented structured or guided inquiry. However, many of these meta-analyses indicate positive results for the implementation of IBL in science classrooms, although with several caveats.

For example, Alfieri et al. (2011) conducted two meta-analyses on the effects of ‘discovery learning’ on student outcomes. One meta-analysis of 56 papers determined that guided inquiry lessons lead to greater educational outcomes than other teaching methods. The second analysis, of 108 studies, found that direct instruction leads to better outcomes than open inquiry. The authors concluded that enhanced-discovery methods, such as guided inquiry, have better educational outcomes than other teaching methods. In other words, using Smithenry’s (2010) or Blanchard et al.’s (2010) rubrics, Level 1: Structured and Level 2: Guided approaches to inquiry are more effective in terms of student outcomes than Level 3: Open inquiry methods.

Similarly, Furtak et al. (2012) in their meta-analysis found a positive effect on student learning by implementing inquiry-based learning, but that “the evidence from these studies suggests that teacher-led inquiry lessons have a larger effect on student learning than those that are student led” (p. 323). However, they temper the results of their analysis in several terms, not least when indicating that some of the studies included in their research described the teaching taking place as an IBL approach, but did not give detail as to how “inquiry was actually operationalized in the instruction” (p. 324).

In addition, more recent analysis of data from the Trends in International Mathematics and Science Study (TIMSS) by Teig, Scherer and Nilsen (2018) indicate that there is a correlation between increasing use of inquiry in the classroom and higher achievement. However, this relationship is only true until the amount of inquiry reaches a certain optimum value. In reality, the relationship between the amount of inquiry and student achievement is curvilinear, and that excessive use of inquiry teaching can have a negative impact on student attainment. The authors posit that there are several factors which have a negative effect on student achievement. For instance, an over-emphasis on inquiry methods decreases the amount of time spent on direct instruction, which is more appropriate for certain subjects, such as experimental design. In addition, the quality of teacher instruction can be affected when too many inquiry activities are conducted, given the time-consuming nature of the preparation involved, and in carrying out the lesson. However, the authors do not suggest a value for the optimum frequency of inquiry activities, rather that inquiry activities should be complemented with direct instruction.

2.3.4 Critiques of IBL

The learning of scientific knowledge by constructivist inquiry methods has been subject to some criticism. Two seminal meta-analyses (Kirschner et al., 2006; Mayer, 2004) have shown that the quality of student learning is negatively affected by implementing minimal-guidance techniques during instruction. It should be noted that both papers refer to minimal-guidance, i.e. Level 3: Open inquiry (Blanchard et al., 2010; Smithenry, 2010). Although a full discussion of the theories of cognitive psychology underpinning their claims is beyond the scope of this research, a brief synopsis is offered. Mayer (2004) argues that meaningful learning occurs when “the learner strives to make sense of the presented material by selecting relevant incoming information, organizing it into a coherent structure, and integrating it with other organized knowledge” (p. 17), but that pure discovery methods allow the students too much freedom, and therefore they “may fail to come into contact with the to-be-learned material”. Although Mayer admits that "activity may help promote meaningful learning", the kind of activity is critical. Simply offering hands-on and exploratory activities is not enough. "Guidance, structure and focused goals" are required for meaningful learning to occur.

In a similar vein, Kirschner et al. (2006) discuss the question of the efficacy of minimal-guidance constructivist methods from a human cognitive architecture approach. Their argument is that the central structure of human cognition is long-term memory, and that "Everything we see, hear, and think about is critically dependent on and influenced by our long-term memory" (p. 76). The aim of instruction, therefore, is to alter the long-term memory, and if nothing has changed in the long-term memory, "nothing has been learned". Working memory, on the other hand, can only contain a limited number of elements, and that, if newly experienced elements are not rehearsed within approximately 30 seconds, they are lost. Learning, therefore, involves the transfer of information from the working memory to long-term memory. The argument Kirschner et al. make is that during discovery learning, the working memory is searching for solutions to the problem being studied, and therefore "it is not available and cannot be used to learn" (p. 76). In addition, students do not always learn the material that is expected during a pure discovery lesson. Kirschner et al. (p. 79) report on studies that have shown that students become frustrated, confused and lost with minimal-feedback approaches to learning, and their "confusion can lead to misconceptions". The conclusions offered by the authors in this case is that unguided or open instruction techniques are ineffective, and that "Strong instructional guidance" (p. 83) is the most effective instructional method.

2.3.5 Difficulties in Implementing IBL

The organisation of inquiry-based learning is "complex" (Crawford, 2000; Colburn 2000), "challenging" (Smithenry, 2010), and teachers trying to implement IBL in their context are faced with a number of "dilemmas" (Anderson, 2002). Part of the difficulty, according to Furtak et al. (2012, p. 321) is that "reform-oriented science teaching practices are difficult to describe, difficult to enact, and even more difficult to characterize", thereby making effective training for teachers a challenging affair.

The literature documents several challenges which teachers face in implementing IBL in their own situations, including personal beliefs regarding IBL; low teacher self-efficacy; and insufficient Pedagogical Content Knowledge (PCK) (Marshall et al., 2017). Other obstacles encountered by teachers are a lack of understanding of the new roles to be adopted by teacher and student, difficulties of group work (Anderson, 2002), and lack of "access to appropriate inquiry-based curricular material" (Smithenry, 2010). Perceived time constraints similarly impact upon the success of integrating inquiry methods into lessons; inadequate preparation in science; or simply not understanding what inquiry is (Capps et al., 2012).

Effective CPD is critical in enabling teachers to successfully implement inquiry in their classrooms. As previously described, CPD need not refer to the traditional workshop style, but a broader vision is required, in which time for teacher planning and cooperation is viewed as a form of CPD. As Teig et al. (2018, p. 27) describe, "Successful inquiry learning requires considerable time and efforts, both for teachers to plan an elaborate, well-thought lesson and for students to pursue a variety of inquiry activities". This planning activity should be viewed as a form of CPD, and allowances made for such. One of the benefits of engaging with such CPD is that it may lead to a change in teacher beliefs and attitudes, as both Guskey (2002) and Desimone (2009) describe. Colburn (2000) describes a positive attitude towards inquiry as an essential component in successful implementation, and Gess-Newsome, Southerland, Johnston and Woodbury (2003, p. 763) outline similarly highlight the importance of personal beliefs and attitudes in widespread curriculum reform: "The foundation of systematic change is individual change".

Teachers view inquiry-based learning as "an approach that requires more time and materials to develop" (Blanchard et al., 2010), an opinion shared by Nadelson (2009). Part of this difficulty can lead to teachers' over-reliance on textbooks, although I concede other factors can influence this behaviour. The issue, however, is when textbooks are used to undertake practical activities. Capps et al. (2012), for example, argue that many textbooks describe inquiry, incorrectly, as a series of step-by-step instructions, and that teachers who are reliant on textbooks implement an incorrect version of inquiry.

Laboratory investigations which are rigidly prescriptive can resemble "confirmatory exercises, rather than inquiry" (Capps et al., 2012, p. 294).

Finally, the difficulty in making changes to assessment practices can hinder the implementation of inquiry; heretofore the emphasis may have been on lower-order recall of knowledge and application of scientific content, whereas the use of IBL in assessment settings places an emphasis on higher-order thinking skills (Jakobsson, 2015). This may lead to student unhappiness, as some of the literature hints at. Colburn (2000, p. 44) reported that "students initially resist" inquiry, but "grow to like it" eventually. Nadelson (2009, p. 48) similarly highlights how "students consistently responded with numerous questions, confusion, frustration, and/or lack of motivation to learn".

2.3.6 Discussion

The *Specification*, in the footsteps of the Rocard report (2007) and the NGSS (2013), recommend the implementation of inquiry-based learning in science classrooms as a way of increasing student engagement and achievement. However, inquiry-based learning can refer to several things, including inquiry in science, and inquiry on science. Clarity of purpose is required of the teacher in deciding why they are implementing IBL in their specific lessons, a clarity that is not provided by the *Specification*.

Once the purpose of the implementation of inquiry has been decided, the teacher is presented with the problem of how to implement the inquiry. Much of literature on what inquiry looks like in practice, without completing an exhaustive review, generally falls into two categories. The first, and most widespread, is a study with employs one of the structured models of IBL, either the 5E model (Bybee et al., 2006), or some variation as analysed by Pedaste et al. (2015). I would surmise the popularity of using one of the structured models in an academic study is for ease of implementation, comparison, analysis. It has the added benefit of providing a framework around which teachers can plan their own lessons for themselves, using concrete stages with different activities completed by the students in each stage. The second category of inquiry in the literature is a long-term, project-based view of inquiry in which a topic is investigated by the students, either by open discovery, or structured inquiry. This is my own experience of inquiry during my undergraduate education, and would have influenced my understanding of inquiry before undertaking this research. A fuller discussion on my understanding of inquiry will be provided in Chapter Five.

Inquiry, therefore, can be difficult to identify in one's own practice, and difficult to describe succinctly. This has the added drawback of being difficult to encourage people to implement IBL in their classroom. This will be encountered in Chapter Four, in my attempts to provide CPD to science teachers *as Gaeilge*, and in Chapter Seven, where the science teachers in my school were asked to describe how the make use of IBL in their classrooms. If concrete steps and suggestions cannot be offered to teachers who wish to attempt IBL in their lessons, they may be unsure how to proceed, and may be unsure as to whether they are 'doing it correctly'. As this research progressed, this was a common emotion I felt, as will be explored in Chapter Five.

The literature indicates that inquiry is difficult, complex, and requires additional time to prepare for, both in terms of teacher preparation and student scaffolding. Changes in teacher and student attitudes are required, as is a change in how both teachers and students view the traditional roles they fulfilled in the classroom. In return, inquiry-based learning has been shown to result in an increase in student interest and achievement, with the caveat that this may apply only to lower levels of inquiry, and may only apply to certain socio-economic groups. In fact, the opposite is the case for open-discovery inquiry lessons, where students and teachers have reported decreased attitudes and lower levels of achievement. In addition, too much use of inquiry may have negative effects on student achievement.

2.4 Conclusions

Since September 2016, the introduction of the new science *Specification* has placed even more emphasis on the use of inquiry-based learning in science lessons. This follows the international trend in recent decades of moving towards more student-centred teaching methodologies. The general idea of IBL is that students engage in scientific practices to discover science content for themselves. Therefore, in Chapter Seven, I ask the other science teachers in my school whether they have experienced a change in teaching practices since the introduction of the *Specification*, or whether they find the new course has had little impact on how they are teaching science.

Inquiry-based learning is difficult to define precisely, although there is agreement that there are several key features of IBL. However, these features have several variations, depending on the amount of student direction, when compared to teacher direction during the lesson. We can therefore distinguish between four levels of inquiry, from Level 0: Confirmatory inquiry, in which the students merely follow instructions to confirm facts that have already been imparted to them, to Level 3: Open inquiry, in which the students have complete autonomy in undertaking scientific investigations. I ask the question of myself, in Chapter Five, of how I can identify whether inquiry-based learning is taking place in my classroom, and what that looks like. I refer to the literature to aid in identifying aspects of my practice that could be considered inquiry, and the level of inquiry present in my lessons. I similarly ask the other science teachers in my school, in Chapter Seven, whether they think they engage with inquiry methods in their lessons, and ask them to describe what they think inquiry means in their classrooms.

In the literature, the use of IBL is seen to have several benefits. These include an increase in student engagement, increasing scientific literacy, and improved student outcomes. However, some of the research is contradictory on the final point, and several concerns have been raised in terms of the benefits of allowing students to undertake completely open inquiry investigations. In Chapter Seven, I ask the other science teachers in my school whether they see any change in student interest when they engage with inquiry practices, and whether the teachers feel their use of inquiry has an impact on their students' learning.

Given that science teachers are being encouraged to implement more inquiry activities into their classrooms, as part of a wider curriculum change, a certain amount of continuous professional development was, and still is, being implemented in schools around Ireland. Apart from these whole-school CPD days arranged by the JCT, professional development is not mandatory for teachers in Ireland; nor is it available in Irish. In Chapter Four, I will describe how I attempted to improve the provision of CPD for science teachers who teach through the Irish language, by offering CPD on the topic of IBL *as Gaeilge*.

The Inspiring Science Education project, an EU funded project aimed at promoting the implementation of IBL in science classrooms with the integration of eTools and online simulations, was offering CPD to teachers in Ireland at the time, via webinar. To provide CPD to teachers who teach through the Irish language, it was decided to continue with the webinar model of CPD. This was predominantly due to the fact that *Gaelscoileanna* in Ireland are concentrated in *Gaeltacht* areas along the West coast and in the major urban centres, and that it would not have been feasible to organise face-to-face CPD events for such a geographically diverse teacher group. Given the difficulties in organising face-to-face CPD *as Gaeilge*, one of the questions asked of the participating teachers in Chapter Four is whether they attach an importance to the fact that CPD is being offered in Irish, or whether they would have been as likely to attend the same CPD if it was being organised in the English language. Similarly, the teachers are asked for their opinions on attending the CPD via webinar, compared to the likelihood of their attending the CPD in a face-to-face setting.

Effective CPD can be seen as possessing specific features, such as being relevant to the teachers' practice; being of adequate duration; and encouraging active learning among the participants. Engaging in effective CPD can not only increase teacher knowledge and skills but also lead to a change in teacher beliefs, as will be seen in Chapters Five and Seven. Ultimately, these changes may lead to improved student outcomes. However, the narrow focus on the traditional CPD forms such as workshops still predominates. Much research points to a need to expand the concept of CPD to include other modes, such as teachers engaging in action research, curriculum design and school improvement programmes.

Chapter 3: Methodology

3.1 Introduction

In this chapter, I discuss and justify the research methodology used to undertake the research. I begin by describing the ontological and epistemological assumptions underpinning my rationale for choosing a qualitative approach to the research, rather than a quantitative one. In Section 3.2 I discuss Action Research as a methodology, giving an account of the history of action research, as well as a discussion of the different models of action research. The following section describes how I applied action research to the research, justifying the choices I made in the application of this approach. Section 3.5 describes the various sources of data collection that I utilised in the course of the research, and subsequently in Section 3.6 I describe how I attempt to maintain trustworthiness in the process and findings of this research. Section 3.7 describes the ethical aspects of the research which were considered, and the limitations of the research are discussed in Section 3.8. A short summary discussion of the methodological choices is provided in Section 3.9.

3.2 My Ontology & Epistemology: Normative or Interpretive?

No description of methodology used to undertake research in an educational setting can begin without a discussion of the ontological and epistemological viewpoints of the researcher; that is, a review of the researcher's understanding of the nature of reality and the nature of knowledge, what constitutes knowledge, and how it is created. As a graduate of a science programme, and a science teacher, it comes instinctively to me that 'proper' research is conducted in an objective, empirical manner. This means that knowledge is created by controlled experiment, free from any effects that the researchers' own philosophical standpoint may have. Experiments can be replicated in any situation, by any researcher, and by following the methods of the original experimental design, the results obtained will match the results of the original research. This is the positivist or subjectivist view of knowledge, and its creation. This philosophical viewpoint contends that there is one universal truth, and that it can be discovered through empirical observation and experiment (Cohen, Manion & Morrison, 2011). Reason (2006, p. 188) highlights that much of academic research carried out is still carried out in the quantitative tradition: "Quantitative hypothetico-deductive research retains a dominance". Herr and Anderson (2005, p. 18) bemoan the predominance of positivist research in educational settings "that enjoyed greater legitimacy in the natural and social sciences, as well as psychology - education's parent discipline."

However, after years of teaching, and conducting research into my teaching, I have come to realise that whereas knowledge in specific domains may, and indeed should, be created using the empirical, positivist, hypothetico-deductive method, there are far too many variables to take into consideration in educational research to make the positivist paradigm viable for all situations, a viewpoint supported by others (Denzin & Lincoln, 2000; 2005; Kincheloe, McLaren & Steinberg, 2011; Rogers, 2012; Schoenfeld, 2010). If one accepts the premise that positivist research can be used to study and make sense of all educational situations, then it should follow that educational practices become predictable using the laws and theories created by research. To many teachers, I would suspect that this view is questionable.

This view, that social science cannot be investigated using the positivist approaches that are used to investigate the natural world, is variously called the post-positivist, naturalistic, subjective, or interpretive paradigm (Cohen et al., 2011; Hitchcock & Hughes, 1995). Within this interpretive paradigm, there are a number of common beliefs shared by the various approaches, including: events and behaviour are fluid, evolve over time and are affected context; individuals are unique; there are multiple interpretations of events and situations; and a view that the world should be studied without manipulation by the researcher (Cohen et al., 2011).

When studying the educational practices that take place in my classroom, and in the school on a wider basis, I cannot completely separate myself from the actions which are taking place (Denzin & Lincoln, 2005). The sense I make of the world, and the meaning I ascribe to events is shaped by my experience, a notion referred to as reflexivity (Denscombe, 2007). My ontological approach, or "theory of being" (McNiff and Whitehead, 2006, p. 22), leads me to believe that I am part of the research. My own view of the world, and how I see myself in relation to the wider environment, means that I, through my actions, affect the outcome of any research that I am conducting into my own practice, and the practice of those around me. Similarly, my epistemological viewpoint informs my research by making knowledge something that I create, rather than something that is studied by me. McNiff's (1993, p. 5) thoughts on the nature of educational research resonated with me, especially in the statement that "education is not a field of study so much as a field of practice".

When I, as teacher and researcher, realise that my actions influence the outcome of the research, and that different observers can have different interpretations of the outcomes of such research, I site myself firmly in the subjectivist, or interpretivist, paradigm of educational research.

3.3 What is Action Research?

I have chosen to describe the methodology I am using in this research using the term 'action research' as, in the footsteps of Herr and Anderson (2005, p. 3) it is the "most generically used term in all disciplines and fields of study, so it serves as an umbrella term for the others". Action research, as a term, is believed to have been first coined by Kurt Lewin in the 1940's. Put succinctly, action research is a "family of practices of living inquiry that aims… to link practice and ideas in the services of human flourishing" (Reason and Bradbury, 2008, p. 1). Elliot (1991, p. 69) proposes a more grounded definition of action research as "the study of a social situation with a view to improving the quality of action within it".

The research upon which this research is based stems from my understanding that action research is a "form of 'self-reflective enquiry'" (Cohen et al., 2011, p. 345) which I am undertaking to improve my understanding of my practices in context. McNiff (2002) and Carr and Kemmis (1986, p. 162) echo this interpretation of action research. In McNiff's (2002, p. 6) view the "idea of self-reflection is central" in action research, and this is what distinguishes it from other forms of educational research, in which "researchers do research on other people" (McNiff 2002, p. 6). In action research, I as the researcher carry out the research on myself. Elliott (1991), however, voiced a cautionary note. He highlights the discrepancy between research teachers carry out "*on* their practice" in which "teaching and research are posited as separate activities" (p. 14), as opposed to true action research in which action and reflection are merely two aspects of the same process, a viewpoint echoed elsewhere (Cochran-Smith, 2005; Cochran-Smith & Lytle, 1999; Denscombe, 2007; Somekh, 1995; Winter, 1996)

Elliott (1991) also describes some of the reasons that teachers have difficulty in implementing educational theories in their practices – amongst which is the fact that theory is "remote from the practical experience of the way things are" and that "to bow to a 'theory' is to deny the validity of one's own experience-based professional craft knowledge" (p. 46). Reason (2006, p. 188) supports this idea that "there is a division between academic research and the everyday practice that action research seeks to address". Similarly, Cochran-Smith (2005, p. 219) sees action research as a way of blurring the divide between "theorizing and doing". Action research can be seen to overcome the divide between the academic processes in which educational research was traditionally carried out, and the more practice-oriented needs of the classroom teacher (Noffke & Somekh, 2005, p. 89).

Coghlan and Brannick (2014, p. 4) propose a viewpoint on action research as: "inquiry from the inside involves researchers as natives and actors, immersed in local situations" adding that this process generates "contextually embedded knowledge which emerges from experience". In contrast, Elliott (1991, p. 49) states that the "fundamental aim of action research is to improve practice rather than to produce knowledge" and that the production of knowledge is a "subordinate" result. He does, however (Elliott, 1991, p. 53) support the idea that "practical wisdom" is created in action research, and that it is "grounded in reflective experiences of concrete cases". The practitioner's professional knowledge is stored as a series of these cases, and current circumstances are understood by comparison with these past cases. In addition, Elliott (p. 52) acknowledges that action research "informs professional judgement and therefore develop practical wisdom", which Cochran-Smith (2005) refers to as "local knowledge", and acknowledges that this knowledge can be of interest in the public sphere. Elliott (2004) later clarified his position regarding the construction of knowledge in action research. In response to his work being "selectively appropriated" (p. 13) to draw a boundary between action research aimed at the improvement of practice, and research aimed at the construction of knowledge, Elliott (2004) explicitly states that this was not his intention. He argues that "action research need not exclude the development of a theoretical representation" (p. 21), although he acknowledges that this theory will be "highly particularized one".

Reason (2006, p. 188) argues that if "we start from the idea that creating knowledge is a practical affair", we do not begin with questions which we find interesting from a theoretical perspective, but "from what concerns us in practice". Ferrance (2000, p. 1) espouses similar thoughts in describing why action research has become so prevalent within the education sector; with action research, teachers are given the opportunity to work on problems that affect them; the process can help with assessing the needs of the learners and "making informed decisions that can lead to desired outcomes". McNiff

(2002) echoes Ferrance's claims, stating that teachers "work best on problems that they have identified for themselves".

3.3.1 Approaches to Action Research

Models and definitions of action research vary enormously, and there are many different schools of thought on what constitutes action research. Reason and Bradbury (2008, p. 7) describe the range of action research as a "family of approaches" and state that there can "never be one 'right way' of doing action research" (p. 7), an idea supported by McNiff (2002, p. 8).

Lewin's original concept of action research involved a spiral of cycles in which a number of steps were carried out in each cycle. Lewin's steps, as interpreted by Kemmis (1980) are:

- Identifying a general idea
- Reconnaissance
- General planning
- Developing the first action step
- Implementing the first action step
- Evaluation
- Revising the general plan

After completing the first cycle, the researcher would then continue into a second cycle, beginning with developing the second action step, and so on. Elliott (1991) developed this model further, with some modifications, and illustrated the model as shown in Figure 3.1:

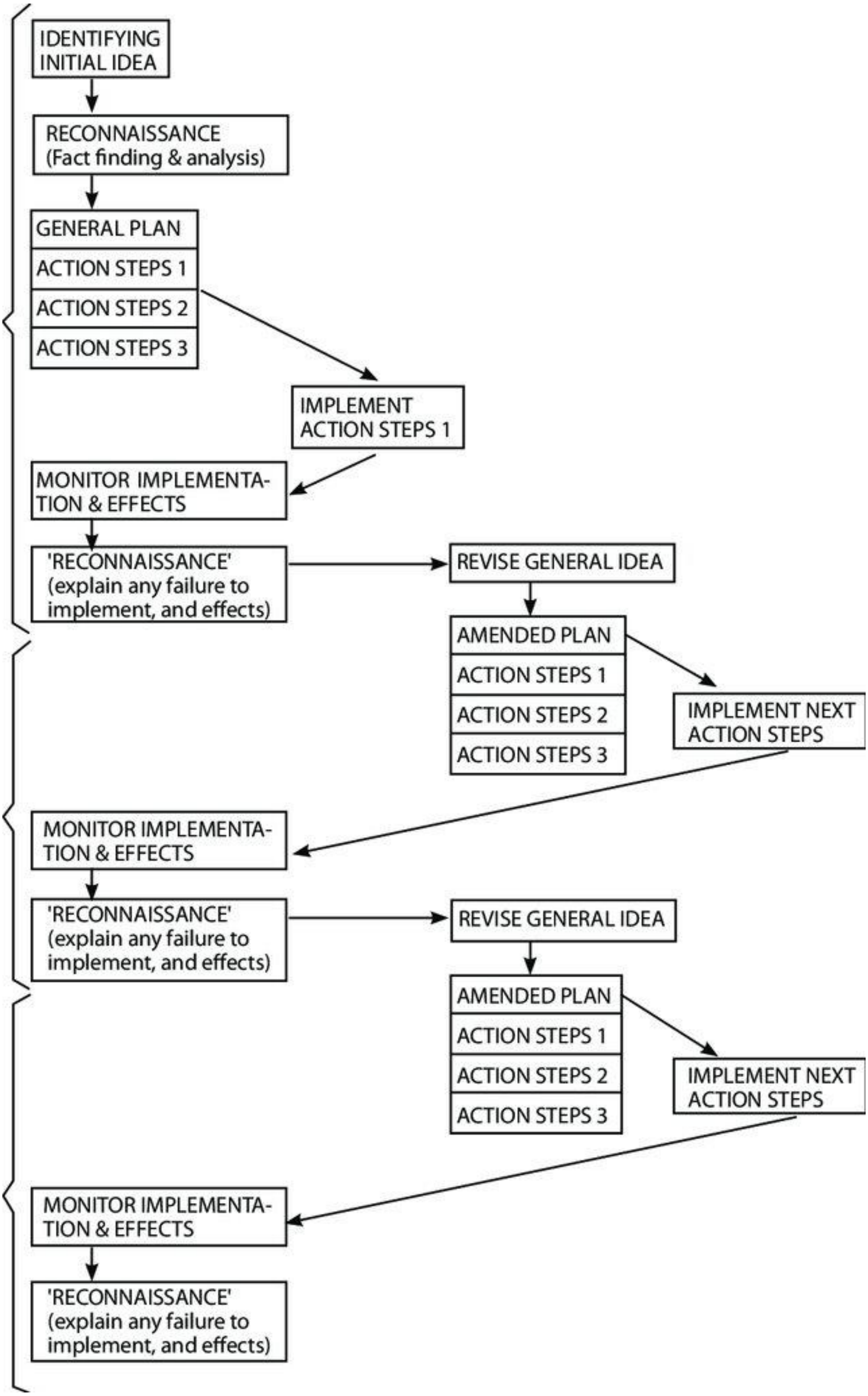

Figure 3.1: Elliott's Action Research Model (Elliott, 1991, p. 71)

Elliott makes the following points, however, which distinguishes it from Lewin's original model; as the research progresses "the general idea should be allowed to shift", reconnaissance should "recur in the spiral of activities" rather than taking place only at the beginning of the research, and that the evaluation of the effects of the action should not begin until the extent to which the implementation has occurred has been evaluated.

McNiff (2002, p. 11; McNiff with Whitehead, 2002, p. 71) describes an eight-step process in which I can carry out action research in my practice; in general, the steps are:

- We review our current practice
- Identify an aspect we want to improve
- Imagine a way forward
- Try it out, and
- Take stock of what happens
- We modify our plan in the light of what we have found, and continue with the 'action'
- Monitor what we do
- Review and evaluate the modified action

This process is then repeated, until "we are satisfied with that aspect of our work" (McNiff with Whitehead 2002, p. 71). This cyclical process is mirrored in other definitions and models of action research, although the number of steps differs. For instance, Carr and Kemmis (1986, p. 162) and Kemmis and McTaggart (2005, p. 564) see action research being undertaken in a four-stage spiral process of: planning, acting, observing and reflecting. Multiple visual representations of this particular model exist; Figure 3.2 illustrates the model as developed by Zuber-Skerritt (2001). Each cycle consist of four stages: planning, acting, observing and reflecting, and the reflections from each cycle lead to changes in the plan for the subsequent cycle.

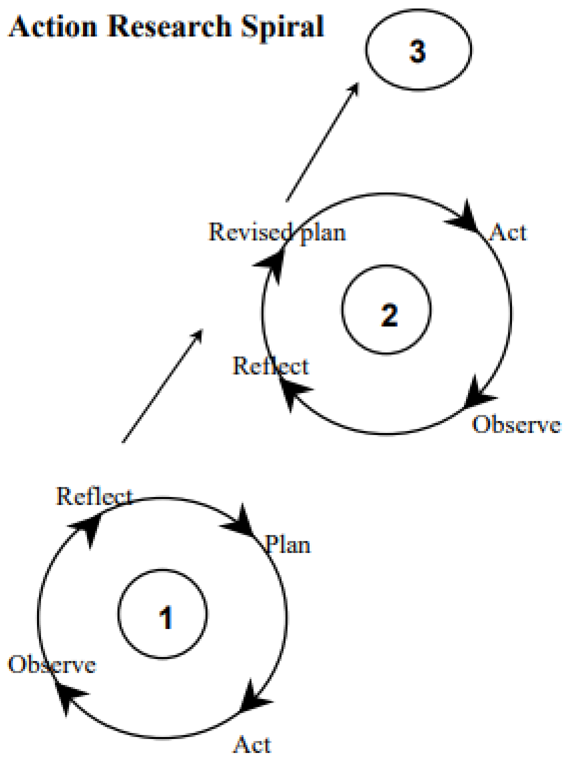

Figure 3.2: The Spiral of Action Research Cycles (Zuber-Skerritt, 2001, p. 20)

However, Somekh (1995, p. 342) contends that these models can be too restrictive, especially for those new to action research, "who tend to interpret them too literally as representing a set of very discrete steps" rather than broad stages. In all models of action research, the progress from one step to the next is not a linear process, but several stages may be overlapping, taking place at the same time. McNiff with Whitehead (2002, p. 51) also agrees that two-dimensional diagrams have little in common with three-dimensional reality, and that they have come to see action research as "a spontaneous, self-recreating system of enquiry", in which the process is not "sequential or necessarily rational" (p. 56). In her attempt to convey the potential messiness of undertaking action research, McNiff proposes an alternative model diagram showing spirals, which consist of action-reflection cycles which "unfold from themselves and fold back again into themselves" (p. 56). This spiral of spirals is shown in Figure 3.3, which aims to portray action research as an image of "non-definitive fluidity" (p. 57).

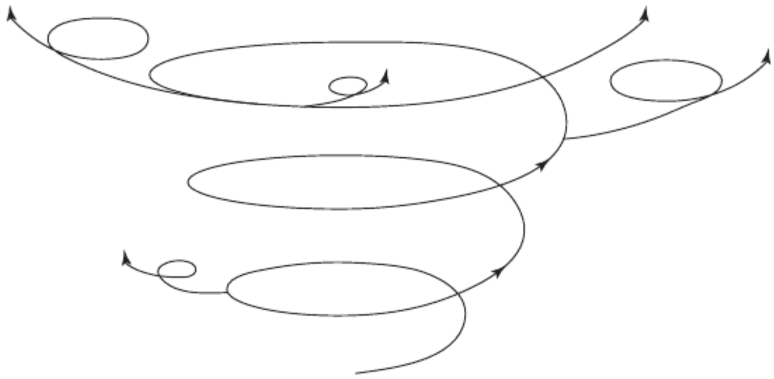

Figure 3.3: McNiff's "Generative Transformational Evolutionary Process" (McNiff with Whitehead, 2002, p. 57)

Although not proposing to use McNiff's spirals within spirals to frame or design the research, the idea that the research process can become muddled is central to my understanding of the action research process, especially in the reporting stage. An effort to avoid this complication is discussed further in the following sections.

3.4 Designing the Research

In partaking in the 'Inspiring Science Education' (ISE) project, and in undertaking this research, I had originally envisaged that the work leading to this research would follow clean, simple cycles of planning, acting, observing and reflecting, as per the models developed by Carr and Kemmis (1982), Kemmis and McTaggart (2005) or Zuber-Skerritt (Altrichter et al., 2002; Zuber-Skerritt, 2001), shown in Figure 3.2 in Section 3.3.1. Each cycle would consist of planning a series of webinars for teachers who teach science in Irish-language schools; delivering those webinars; observations based on my own experiences of delivering the webinars, and teacher feedback; and reflecting upon how to improve upon this training that I was delivering. Subsequent cycles of the webinars would then be organised, each time following the plan-act-observe-reflect steps of the action research cycle.

The first cycle of the ISE webinars did follow this progression, and the planning for the second cycle began in the same way, as will be described in Chapter Four. At this point, more than a year into the research project, and after the first cycle had been completed, I felt that I needed to look at my own practice, as well as the practice of the science department in my school as a whole, but did not know how to fit this within the simple, clean cycles of research that I had envisaged. This raised some concern, as Somekh (1995) had predicted; I was becoming preoccupied with the action research cycles as a series of discrete steps. At this point, the action research cycle concerned with the ISE webinars spawned two spin-off cycles, in much the same way as McNiff's (2002) "spiral of spirals" illustrates in Figure 3.3. However, I was comforted by Elliott's (1991) assertion that the general idea of the research should be allowed to shift as the research progresses, and similarly by Herr and Anderson's (2005, p. 76) thoughts that the methodology may be allowed to evolve as it is implemented.

I was now left with a decision on how best to execute the various aspects of the research I carried out. How would I continue research based on the cycles of the original research, and incorporate the research concerned with investigating my own practice, and that of my colleagues? Clearly, the four-stage model outlined previously would not be the most appropriate way to undertake an investigation of my own practice, nor would it provide an adequate approach to action research in which I and my colleagues develop our understanding of inquiry-based learning, and implementing the new Junior Cycle *Specification* in our context. The research, as a whole, no longer fitted within one approach to action research.

3.4.1 Bricolage

At about this time, somewhat fortuitously, I encountered Denzin and Lincoln's (2000; 2005) idea of *bricolage*.

The original metaphor of the *bricoleur* as a researcher using whatever "strategies, methods and empirical materials are at hand" (Denzin & Lincoln, 2005, p. 4) was coined by Claude Levi-Strauss in his 1966 work 'The Savage Mind' (cited in Campos & Ribeiro, 2016; Denzin & Lincoln, 2000; 2005; Freathy, Doney, Freathy, Walshe & Teece, 2017; Kincheloe, 2001; Kincheloe, McLaren & Steinberg, 2011; Lincoln, 2001; Rogers, 2012). Kincheloe (2005) describes *bricolage* as "multidisciplinary research" (p. 323) in which the *bricoleur* employs methodological strategies from a range of social sciences, resulting in "deep interdisciplinarity" (Kincheloe, 2001, p. 686). These methodological processes are employed "as they are needed in the unfolding context of the research situation" (Kincheloe et al., 2011, p. 168). Rogers (2012, p. 1) provides a succinct summary: "Generally speaking, when the metaphor is used within the domaine of qualitative research it denotes methodological practices explicitly based on notions of eclecticism, emergent design, flexibility and plurality".

Denzin and Lincoln (2000; 2005; see also Freathy et al., 2017; Kincheloe, 2005; Rogers, 2012) refer to five types of *bricoleurs*:

- Interpretive *bricoleur*: uses a range of strategies to "discern their location in the web of reality" (Kincheloe, 2005, p. 335) in order to understand their role in the shaping of the research process. Post-positivist epistemologies are adopted, as "interpretive bricoleurs recognize that knowledge is never free from subjective positioning or political interpretations" (Rogers, 2012, p. 4).
- Theoretical *bricoleur*: utilises varying theoretical frameworks, which may be complementary or conflicting, to "understand the different theoretical contexts in which an object can be interpreted" (Rogers, 2012, p. 6); the *bricoleur* in this

case will study the artefact from various theoretical standpoints, such as feminism, Marxism, critical theory, postmodernism, etc.

- Political *bricoleur*: is conscious that "knowledge and power are related" (Rogers, 2012, p. 6), and that "no mode of knowledge production is free from the inscriptions of power" (Kincheloe, 2005, p. 335). The aim of the political *bricoleur* is to "develop counter-hegemonic forms of inquiry benefiting those who are disenfranchised" (Freathy et al., 2017, p. 429).
- Narrative *bricoleur*: understands that "inquiry is a representation" (Rogers, 2012, p. 6) and that conducting research is "an interpretive process shaped by his or her personal history, biography, gender, social class, race, and ethnicity, and by those of the people in the setting" (Denzin & Lincoln, 2000, p. 6). In this case, the *bricoleur* seeks to "create more complex and sophisticated research by drawing upon multiple perspectives, voices and sources" (Freathy et al., 2017, p. 429).
- Methodological *bricoleur*: derives directly from Levi-Strauss' conception of the term, in which the *bricoleur* "combines multiple research tools to accomplish a meaning-making task" (Rogers, 2012, p. 5). This includes using "numerous data-gathering strategies" (Kincheloe, 2005, p. 335) from a range of disciplines, which results in "methodological eclecticism, permitting the scene and circumstance and presence or absence of coresearchers to dictate method" (Lincoln, 2001, p. 694).

It was primarily this final form of *bricolage*, that of methodological *bricolage*, which appealed to me. Although these types are separate, they are interrelated; the *bricoleur* can move from one mode to another, as the research progresses (Campos & Ribeiro, 2016). Although I am primarily utilising methodological *bricolage*, I am conscious that in conducting this research I am involved in the research, I am providing my interpretation of reality. As will be discussed in subsequent sections, I will attempt to provide alternative representations from other participants in the research; I am also using narrative and interpretive *bricolage*.

Therefore, I, as *bricoleur*, use different methods to investigate the various aspects of the research, as is most appropriate to that aspect. Denzin and Lincoln (2005, p. 4) also refer to the *bricoleur* as quilt-maker, and the product of the "*bricoleur*'s labor is a complex, quiltlike bricolage, a reflexive collage or montage – a set of fluid interconnected images and representations" (Denzin & Lincoln, 2005, p. 6). I have chosen to utilise this metaphor, using the most appropriate methodology and practices available to me for each strand of the research, and subsequently weaving them together into a coherent whole[13]. Wibberley (2012, p. 1) views bricolage in a similar vein, and in his view this is one of the benefits of using bricolage, especially for part-time doctoral students; "bricolage allows for bite-size chunks of research to be carried out that have individual meaning for practice, which can then be pieced together to create a more meaningful whole". In the case of this research, the different strands of the research will be executed using differing approaches, with the aim that they will weave together to form a complete picture.

Having satisfied myself as to firmness of the methodological foundations of the research design, as it evolved and progressed, I was then faced with how best to describe the research in a clear, logical way. A chronological approach, for example, would not provide the clarity required, as too many different aspects of the research were taking place concurrently, and the relationship between them would only become clear towards the end of the research project. For this, I turn to approaches to action research conducted in organisations, as described in the following section.

3.4.2 First-, Second-, and Third-Person Research & Practice

Descriptions of action research carried out in organisations often refer to a framework based on a formulation by Torbert (1998, cited in Coghlan & Brannick, 2014) originally, but more fully described by Reason and Torbert (2001), and subsequently by Coghlan and Brannick (2014), Reason and Bradbury (2008) and Torbert and Taylor (2008). This framework describes "three audiences, voices or practices" (Coghlan & Brannick, 2014) in which action research can be carried out; that of first-, second-, and third-person action research/practice. The three practices are as follows:

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[13] I am aware that weaving and quilt-making are not the same thing, and conscious that I might be accused of mixing my metaphors. However, referring to each part of the research in this dissertation as 'patches' which will be 'sewn together' to make a complete quilt feels irreverent. I feel the metaphor still works when using the concept of 'strands' of research being 'woven together'.

- First-person practice refers to the individual action research, a “form of inquiry” (Coghlan & Brannick, 2014) carried out by a practitioner/researcher on his or her own practice.
- Second-person action research is that which is carried out “with others into issues of mutual concern” (Coghlan & Brannick, 2014, p. 7; Reason & Bradbury, 2008, p. 6).
- Third-person action research involves broadening the impact of the action research inquiry to a wider audience, creating a wider community of inquiry “to engage with whole organisations, communities and countries” (Reason & Torbert, 2001, p. 1).

Coghlan and Brannick (2014) state that research has traditionally focussed on the third person; “researchers doing research on third persons and writing a report for other third persons” (p. 7). Reason and Torbert (2001, p. 1) argue for the integration of all three persons “with action and inquiry” (Coghlan & Brannick, 2014, p. 6), a call echoed by Reason and Bradbury (2008), in which they claim that “the most compelling and enduring kind of action research will engage all three strategies” (Reason & Bradbury, 2008, p. 6).

In making use of the framework described above, I will describe the research using the framework of first-, second- and third-person inquiry. I propose to arrange the three inquiries, and describe them in subsequent chapters, in the following order:

i. the third-person inquiry outlines the work I carried out with teachers from other *Gaelscoileanna*, in order to encourage the adoption of inquiry-based learning in Irish-language classrooms;
ii. the first-person inquiry is clearly an investigation into my own practice, to determine whether I act as I believe, and profess to;
iii. finally, the second-person inquiry details the collaborative effort within my school’s science department, amongst the science teachers with whom I work on a daily basis, to implement a change in our classroom teaching practices.

There follows a more complete outline of each aspect of the research, the research approach used in that strand, and a brief note on data collection, which will be discussed in more detail in Section 3.5.

3.4.3 Working with Outside Teachers – Third-Person Inquiry

Chapter Four will describe the original focus of the research in terms of a four-step action research cycle, as per Carr and Kemmis (1986); involving consecutive steps of planning, acting, observing and reflecting. The action research cycles in this part of the research will similarly follow on consecutively, with the reflection process from each cycle being used to improve subsequent cycles. Data from this inquiry will include my own research journal, as well as feedback from the participants and other observers. A questionnaire eliciting views from the teachers at the end of the series of webinars will also be utilised.

3.4.4 Studying My Own Practice – First-Person Inquiry

As will be described in Chapter Five, the first-person inquiry I am undertaking is to investigate my own practice. This strand of the research runs concurrently with the second of the action research cycles described in Chapter Four. Rather than describing full action research cycles in this strand, I was not yet at the stage of deciding on aspects of my practice I wanted to improve. Instead, having delivered a series of webinars to teachers teaching science through Irish in schools around the country, I found myself wondering whether I actually was using inquiry in my own context, and if so, what does this inquiry look like? The purpose of this chapter is to describe and reflect upon my current practice, and identify whether I am behaving as I believe that I am.

Chapter Five was therefore originally designed to undertake the first of McNiff's (2002) eight steps, that of reviewing my current practice, similar to the Reconnaissance stage of the Elliott (1991) model. However, an alternative viewpoint would be to view this research as a teacher self-study (Loughran, 2004), a methodology initially used by teacher educators.

3.4.4.1 Action Research and Teacher Self-Study

In searching for differences between action research and teacher self-study, we can look to Zeichner and Noffke (2001) who described five traditions of practitioner research: action research, teacher-as-researcher and participatory action research, the North American teacher research movement, self-study research, and participatory research. While all might be viewed as being under the umbrella term of 'action research', there are differences between them, generally in terms of their aims and methods. While an in-depth discussion of all five traditions might be interesting, what is of most interest here is how action research is different to self-study research.

Action research and teacher self-study are extremely closely related (Feldman, Paugh & Mills, 2004). However, one of the primary characteristics in action research is that there is ‘action’, or that action research has “transformative intentions (i.e., to change practice)” (Zeichner & Noffke, 2001, p. 302); in other words that a change has been, or will be, carried out, and that the research is undertaken to determine the effects of that change, with a view to improving practice. In contrast, teacher self-study refers to a study of “teaching and researching practice in order to better understand: oneself; teaching; learning; and, the development of knowledge about these” (Loughran, 2004, p. 9). A change in practice is not necessarily required, but that the research is undertaken in order to improve the understanding of the practice “in context, over time” (Bullough & Pinnegar, 2001, p. 15).

Zeichner and Noffke (2001, p. 305) highlight a second major difference, in that self-study “seldom follows the pattern of action research cycles” found in action research, although they do point to some studies from the UK which connect action research cycles and self-study. Loughran (2004, p. 18) similarly notes that “self-study defines the focus of study, not the way the study is carried out”, implying that methods from any discipline, qualitative or quantitative can be used to enact a self-study. A similar point is made by Feldman et al. (2004); in the three studies used to illustrate the differences between action research and teacher self-study, “there is little that distinguishes them from action research” (p. 970) in terms of methods used.

However, Feldman et al. (2004) use the fact that action research and self-study are so closely related to construct three methodological features that must be present for research to be considered a self-study:

- it must be a form of inquiry that is focused on the self; the self should be made visible in the research process. Feldman et al. (2004, p. 966), however, acknowledge that it is not only the self, but the self engaged “in practice with others” is important.

- this study of the self should be the self in practice, and should make use of practice experiences; that it would make "the experience of teacher educators a resource for research" (Feldman et al., 2004, p. 959). Bullough and Pinnegar (2001, p. 15) provide a slight reframing of this idea when they state "such study does not focus on the self per se but on the space between self and the practice engaged in".
- those who engage in self-study should be "critical of themselves, and their roles as researchers and teacher educators" (Feldman et al., 2004, p. 971). Again, Bullough and Pinnegar (2001, p. 16) provide a note of caution on this point, since "tipping too far toward the self side produces solipsism or a confessional, and tipping too far the other way turns self-study into traditional research".

One additional aspect of importance to self-study is provided by Loughran (2004, pp. 25-26), who provides a distinction between self-study and reflection on practice, as used within action research. Although both focus on a problem, dilemma, tension, or concern within practice, reflection is something that takes place within the researcher. It is a "thoughtful process". In contrast, self-study, although it may "build on the work of reflection", also "demands that the knowledge and understanding derived be communicated". A defining feature of self-study being that it is "available for such public critique and dissemination".

However, as the literature highlights, there is no "one true way" (Loughran, 2004, p. 17) in which to conduct a self-study, or communicate it (p. 25). A multitude of methods are used and a wide variety of reporting styles are utilised. Therefore, in order to report on this phase of my research, and communicate it, I have employed a case study design, as suggested by Cohen et al. (2011, p. 359). As will be described in the following sub-section, case study, action research and self-study share many similarities, not least in that "a case study is both a process of inquiry about the case and the product of that inquiry" (Stake, 2005, p. 444).

3.4.4.2 Case Study and Action Research

As described in the Encyclopaedia of Action Research (Dick, 2014), a case study is an "in-depth examination" of a single unit, "studied within its normal context" (p. 86), and "is in some way bounded or limited". In using such a definition, action research can be understood as a “subset of case study” (p. 87), a definition echoed by Cohen et al. (2011, p. 289). Both methodologies can employ similar data collection methods, and use similar methods in knowledge validation. Chapter Five utilises various methods to investigate aspects of my teaching, and that of my teaching with other teachers in my school. The case study in question examines my own teaching, within normal classes, to investigate whether or not I am implementing inquiry in my practice. To further delimit the scope of the research, I am focussing on teaching practice within the Junior Cycle, that is, my teaching of first-, second- and third-year science classes.

Stake (2005) described a classification system for qualitative case study research in which he described intrinsic and instrumental cases. The study being described in Chapter Five fits within the intrinsic model, wherein the study is being undertaken to gain “better understanding of this particular case” (Stake, 2005, p. 445), in that I am trying to understand what is happening in science classes in my school, and in particular in my own practice. Although generally applied to quantitative studies, using the classification system developed by Yin (2014), this study can be viewed as a single-case study, in which I treat my teaching practice as *the* case under scrutiny.

In order to describe the research, and since school teachers commonly share their experience of practice “through anecdotes, vignettes and stories” (Loughran, 2010, p. 222), I am framing the issues and subsequently describing them as a series of “vignettes” (Stake, 1995, p. 128). Each vignette describes one episode from my teaching, and my teaching with other teachers. These episodes were chosen from my own reflection on my teaching and what I have observed of other teachers’ teaching, as described in my reflective/research journal and supplemented by documentation from the science department. Elliott (1991, p. 87) describes case studies as a way of “publicly reporting action research to date”; ideally a case study report of action research should “adopt a historical format; telling the story as it has unfolded over time”.

Each episode chosen from my reflective journal highlights a particular issue within my teaching context. These vignettes are not chosen to provide a representative description of all of my teaching activities, as “case study is not sampling research” (Stake, 1995, p. 4) but rather the episodes have been chosen as illustrative of aspects my teaching practice, in order to “maximise what we can learn”, and because “balance and variety are important”. From a self-study standpoint, the episodes chosen seek to “make the tacit aspects of [my] practice explicit” (Loughran, 2010, p. 224).

It should be noted that the extracts from my journal, where they refer to students or teachers, have been anonymised.

3.4.5 Working with my Colleagues - Second-Person Inquiry

Chapters Six and Seven will describe the involvement of my colleagues, the other teachers in the science department in my school, in the ISE project, and in implementing the new Junior Cycle in our specific context. Over the course of this research project, from the 2013-2014 school year, in which I first engaged with the ISE project, to the 2017-2018 school year, in which the last of the data gathering for this research took place, the number of teachers in the science department in my school increased from four to seven teachers. A profile of each participant is given in Appendix B, indicating the aspects of the research in which each teacher participated.

The journey, from the beginning of our engagement with the Inspiring Science Education project, including their participation in the Erasmus+ training in Portugal, and using inquiry lessons from the ISE project, through participating in continuous professional development courses, and experiencing the change in our practice as we implement the new *Specification* will be described. The difficulty in applying action research to the messiness of real life raises problems.

A perfectly complete action research cycle would consist of a three-year period, in which one cohort progress through the Junior Cycle, from first to third year. Subsequent cycles would overlap, as each September a new cohort begins in first year. However, such a long-term cycle would not be feasible as part of this research project. On a shorter timescale, academic years provide some clear limits, with the same material being taught year after year to new groups of students, with the feedback from the previous year being used to improve upon our practice.

On the micro-scale, it could be argued that single class periods are the exact representation of an action research cycle. Teachers plan for a class, act and observe during the course of the 40-minute lesson[14], and reflect on the lesson to improve it for the next time it will be taught. The natural actions of teaching fall neatly, in this case, into a four-stage process of plan-act-observe-reflect, as per Carr and Kemmis (1986).

However, notwithstanding the above discussion, teachers engage with planning, acting, observing and reflecting on a number of different timescales simultaneously. As a teacher engaged in my own professional practice, I cannot simultaneously observe other teachers as they undertake their daily practice. Additionally, I cannot in good conscience ask the other teachers in my school to undertake an in-depth interrogation of their practices for the sake of this research. Therefore, I decided that Action Research as a methodology was not the most appropriate for this strand of the research. Given that I was most interested in the end result, the extent to which teachers felt a change in their practice when implementing the new Junior Cycle, rather than the process, a more direct approach was used. For the final strand of the research, therefore, Qualitative Interviews will be utilised to ascertain the teachers' views. Further information on the process of conducting and analysing the information obtained will be provided in Section 3.5.

As this research ended, in order to gain a fuller understanding of what each teacher experienced as we collaboratively planned for and implemented the new *Specification*, I asked each teacher to complete a short online survey, and take part in a semi-structured face-to-face interview, to give the teachers the opportunity to explore their interpretation of inquiry-based learning, and how it fits with the new Junior Cycle *Specification*. The same questions were posed in both the online questionnaire and the interview, where the results from the online questionnaire were used to prompt thoughts and reflections from the teachers during the interviews. The results of these discussions used to provide a comparison between the perceived knowledge and interpretation of inquiry-based learning and the new Junior Cycle curriculum, with how teachers are actually implementing these strategies in their classrooms. This will form the basis of Chapter Seven.

[14] In Ireland, a recent DES circular (DES, 2016b) mandated that all post-primary lessons should last a minimum of 40 minutes. Most schools now have 40-minute lessons (or a multiple thereof), although in recent years some schools have chosen to implement hour-long lessons.

3.5 Data Collection & Analysis

Many of the different qualitative methodologies share a common approach to data collection; in conducting this research, I can draw on those methods of data collection outlined in research approaches such as case study, narrative inquiry, autoethnography and self-study (Pinnegar and Hamilton, 2009, p. 76). For instance, in describing the data collection techniques used in narrative inquiry, Connelly and Clandinin (1990) list such methods as journals, interviews, letters, autobiographical writing, documents such as class plans, and others' observations. Moen (2006) and Winter (1996) add video recordings to this list, as they can be useful in narrative research. These sources of data are all useful in conducting research into my own practice as a teacher, and the collaborative work of the teachers in my subject department in school, although with recent developments in technology, I would replace letters in Connelly and Clandinin's (1990) list with emails. Denscombe (2007) similarly urges the researcher to choose approaches that are "fit for purpose", and that such choices are made explicit as part of the research report.

3.5.1 Journals

As Ortlipp (2008, p. 695) describes, keeping a reflective journal is "a common practice" in qualitative research, in which I use the journal to talk about, and to, myself in order to encourage self-reflection. Encouraged some years ago during the MSc to become a more reflective educator and person, I have since kept a journal of my thoughts and reflections on aspects of my professional practice. As Etherington (2004, p. 28) notes, the writing of notes after each class, or at the end of the day can aid "the internal process of reflection". Pinnegar and Hamilton (2009, p. 123) make the distinction that a journal is more than mere fieldnotes; it is "more free flowing about feelings, interpretations, and judgements" and it offers "a place for writers to expose their personal feelings and perspectives".

Elliott (1991) and Winter (1996) also describe how the keeping of a journal can be a useful tool for gathering evidence. It should contain a personal account of "observations, feelings, reactions, interpretations, reflections, hunches, hypotheses, and explanations" (Elliott, 1991, p. 77); he suggests that the diary not only provide an accounting of the "bald facts" of the situation, but also try to convey a sense of being there, of participating in the situation as it unfolds:

> Anecdotes; near-verbatim accounts of conversations and verbal exchanges; introspective accounts of one's feelings, attitudes, motives, understandings in reacting to things, events, circumstances; these all help one to reconstruct what it was like at the time.

Cochrane-Smith and Lytle (1993, p. 30) similarly endorse teacher journals as a source of data; journals are:

> more than anecdotal records or loose chronological accounts of particular classroom activities. As systematic intentional inquiry, journals provide windows on what goes on in school through teachers' eyes and in teachers' voices and on some of the ways that teachers use writing to shape and inform their work lives.

Ortlipp (2008) further describes how the use of reflective journals in qualitative research can be used to make visible the biases that the researcher may hold, rather than trying to control for them. Similarly, through referring to my thought processes during the data analysis stage, made visible and transparent in my research journal, I can describe and justify the decisions made during the research process, thereby providing justification and validating the conduct of the research.

Within my research journal, I not only keep notes of my own experiences and thoughts, but I also keep notes on observations that I may have undertaken of other teachers work. Coghlan and Brannick (2014, p. 89) describe the possibility of data generation through "participation in and observation of" colleagues at work, and that some of these observations are made in formal settings, such as meetings; while observations can also be carried out in informal settings, "such as over coffee, lunch and other recreational settings". Elliott (1991, p. 63) however, urges caution in using data gathered in informal settings, where the difference between me as 'researcher' and me as 'colleague' are unclear. He states that "the insider researcher feels under an obligation not to record or report information gathered as a participant in the everyday life of the school. Such information carries the status of private knowledge" (p. 63). The balance between the ‘right to privacy’ of the teachers and the ‘right to know’ of the researcher, and subsequent readers of the research report will be addressed in Section 3.7.

3.5.2 Questionnaires

Questionnaires are widely used instruments in both qualitative and quantitative research, and have the benefit, especially in quantitative research, of being relatively easy to analyse (Cohen et al., 2011, p. 377). Where quantitative data is the primary focus, “closed questions are more useful” (ibid., p. 382). This research, however, is more interested in qualitative data, and therefore, the majority of the questions used in the questionnaires created for this research are “word-based and open-ended” questions. This allows for the responses to “reflect the full richness and complexity” (Denscombe, 2007, p. 166) of the opinions of the respondents. One disadvantage Denscombe (2007) highlights in using questionnaires is that the researcher has no way to check the “truthfulness” (p. 171) of the answers, but must accept the validity of the answer given. However, this is balanced by the fact that the use of questionnaires allows for respondents who are geographically remote to provide their opinions, and the fact that they are “at a distance” (p.171) from the researcher means the responses received are free from any effects due to personal interaction with the researcher.

This research made use of three questionnaires to gather data. In Chapter Four, feedback was sought by way of a questionnaire from the teachers who participated in the series of webinars I delivered *as Gaeilge*. The responses to the questionnaire were gathered during March, April and May 2015. This was an online questionnaire, the link for which was sent to the participants by email. The respondents were encouraged to complete the questionnaire, but under no obligation to do so. The respondents also had the option of completing the questionnaire anonymously. Eleven participants were invited to complete the questionnaire, and ten responses were received. However, some respondents provided their names on the questionnaire, and it was observed that some participants answered the questionnaire more than once. Had the questions been of quantitative significance, this would have created an issue. However, the qualitative data was of more importance in this research, and the view was taken that multiple responses by the same participant would not affect the results. The questions and responses are recorded in Appendix C.

Chapter Six used data gathered in the second questionnaire in this research. This questionnaire gathered feedback on the training course in Portugal in February 2015 which was attended by some of the teachers in my school. The questions also sought teachers' views on the ISE project, and the resources it provided. This questionnaire was created by the ISE project, and was completed by respondents in May 2016. It was an online questionnaire, which gave the respondents the opportunity to respond anonymously. The data gathered was also used to compile a short report for the ISE, which is included in Appendix D.

The final questionnaire in this research was used to obtain teachers' impressions of the new Junior Cycle course, views on their teaching practices, and thoughts on inquiry-based learning in science. The questionnaire was completed by respondents over the course of the 2017-2018 academic year. The data from this questionnaire was used in this research, as described in Chapter Seven. It was an online questionnaire, and the respondents were given the opportunity for anonymity. However, respondents were informed that if they provided their name, their responses to the questionnaire could be used as prompts during the subsequent interviews. Of the six people invited by email to complete the survey, five did so. All provided their name. The respondents to the questionnaire are shown in Appendix B. The questions and responses from this questionnaire are included in Appendix E.

3.5.3 Interviews

Interviews, or as Pinnegar and Hamilton (2009) refers to them "purposeful conversations", are widely used in qualitative research. Elliott (1991, p. 80) describes interviewing as a good way to find out "what the situation looks like from other points of view". In conducting this research, the other science teachers in my school were asked to take part in semi-structured interviews, where specific pre-set questions were asked, but the participants were given the "freedom to digress and raise their own topics" (Elliott, 1991, p. 81) during the course of the interview. This also allows the interviewee to "develop ideas and speak more widely" (Denscombe, 2007, p. 176) on issues that they find interesting. McNiff (McNiff with Whitehead, 2002, p. 96) describes interviews as a "valuable" source of data, it allows me as the researcher to capture the lived experience of the interviewee. Similarly, Coghlan and Brannick (2014, p. 90) see interviews as open-ended and unstructured, where the focus is on what the interviewee has to say. The interviews were intended as a follow-on to the questionnaires the teachers had already completed, so that the teachers could expand on their opinions expressed in the questionnaire responses.

There are, however, some drawbacks to the interview method in data generation. Denscombe (2007), for example highlights how the data gathered by interview are affected by the "personal identity of the researcher" (p. 184). In addition, Hitchcock and Hughes (1995) identify the "interviewer-interviewee relationship" (p. 158) as having an impact on the data gathered during an interview. Cicourel (1964 cited in Hitchcock & Hughes, 1995, p. 158) similarly describes how the researcher influences the outcome of an interview process, in that the researcher is "forced to make snap judgements, extended inferences, reveal his views, overlook material…". Cohen et al. (2011) also acknowledge that the researcher affects the outcome of the interview, although they recognise that the role of the interviewer is to "keep the conversation going" (p. 422) by providing verbal and non-verbal feedback to the respondent. A final disadvantage in the use of interviews in data gathering is the "potential for massive data loss, distortion and the reduction in complexity" (Cohen et al., 2011, p.426) during the transcription of the interview. Interviews are an example of a "social encounter" (Cohen et al., 2011, p. 426) which produce "situated accounts" (Hitchcock & Hughes, 1995, p. 160). Reducing the data from the richness of the complete oral, interpersonal and visual experience of the interview to the written language will inevitably result in loss of context of what is said by the respondents, such as tone of voice, body language, emphases placed by the speaker and pauses in speech.

The interviews in this research took place during the 2017-2018 academic year, on a one-to-one basis. All science teachers in my school were invited to take part in the questionnaire and interview process. Participants were recruited by verbally asking them if they would be interested in taking part. It was envisaged that teacher responses to the questionnaire could be used as prompts for the teachers during their interviews, hence the lack of the option of anonymity in the questionnaire. Of the six teachers invited to take part, five completed the questionnaire, and five took part in an interview. One teacher completed the questionnaire but declined to undertake an interview. One teacher did not complete the questionnaire but was willing to be interviewed. Four of the interviews lasted 25 minutes. The interview of Teacher E, who did not complete a questionnaire, took 13 minutes. The interviews took place in the school. The teachers, and whether they took part in the questionnaire and interview, are described in Appendix B. The interviews were transcribed to include all spoken words and sounds including hesitations, cutoffs, and laughter; pauses are indicated by an ellipsis (…); edits, including English translations of any Irish words used during the interview are included in square brackets []; reported speech is included in inverted commas; and commas are used as per a grammatical comma in written language (Braun and Clarke, 2012, p. 60). Since the participants would be readily identifiable from the full transcripts of the interviews, they are not included as an appendix, to preserve the anonymity of the participants.

3.5.4 Written documentation

Elliott (1991, p. 78) and Winter (1996, p. 11) describe several sources of documentary evidence that can be used during action research. I have found that the sources of evidence described therein have been useful in the aspects of this research, including:

- Syllabi
- Schemes of work
- Examination papers and school tests
- Minutes of staff meetings
- Sections of textbooks

These written documents have allowed me to chart any changes in the collaborative planning and reflecting in the science department in my school, as well as a useful data source to triangulate the claims made by myself and other teachers.

3.5.5 Data Analysis

In the case of the questionnaires and interviews underpinning the research in Chapter Seven, the data was analysed using Thematic Analysis (Braun & Clarke, 2006; Braun &

Clarke, 2012). Thematic analysis was chosen because it allows me, as researcher, to identify patterns of meaning, while acknowledging that I have a role in the research, and in the generation of meaning from the data. In analysing the data, both deductive and inductive approaches were used. In the case of the questionnaires, a deductive approach was used in analysing the data, as the responses provided in the case of all questionnaires were brief, and to the point. In analysing the interview data, an initial deductive approach was used in order to answer the research questions as posed.

However, the data sources were analysed only at a "semantic", rather than a "latent level" (Braun & Clarke, 2012, p. 61). Although the "latent themes" (Braun & Clarke, 2006, p. 84) might prove a fruitful source of insight into teacher attitudes and beliefs, a deeper interrogation and interpretation of the responses to the questionnaires and interview transcripts are beyond the scope of this research (Yates, 2014).

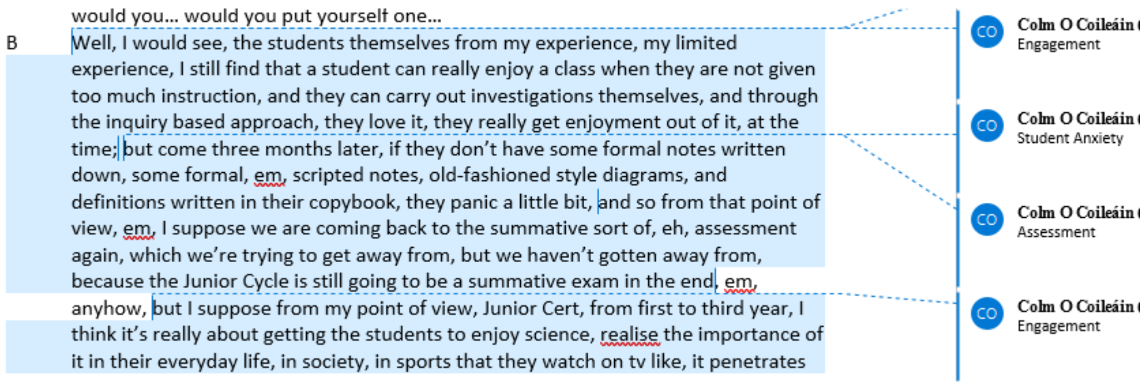
Thematic analysis consists of six phases (Braun & Clarke, 2012), which will be described in turn in the following sub-sections. It should be noted at this point that thematic analysis is not a linear process, where each phase leads directly to the subsequent phase. It is a recursive process, where I go back and forth through the phases as needed. Braun and Clarke (2006, p. 15) also note that "writing is an integral part of analysis", not something that is carried out at the end of the research. The process of writing this dissertation has caused me to reflect on the outcomes of the thematic analysis, revisit and refine the decisions made, the themes and sub-themes created, and my understanding of the data set.

3.5.5.1 Phase 1

I begin familiarising myself with the data by reading and re-reading the data; listening to the recordings of the interviews; and making notes in a casual way. The aim is to think about what the data means, and to look for "meanings and patterns and so on" (Braun & Clarke, 2006, p. 16). Some initial codes may be developed during this phase, although it should be noted that coding will continue to be developed and defined as the analysis progresses.

3.5.5.2 Phase 2

I use the initial codes to "identify and provide a label" (Braun & Clarke, 2012, p. 61) for a feature of the data. Codes should be a succinct, shorthand indicator for something that is potentially relevant to the research question. Figure 3.4 below shows the first attempt at coding the transcript of Teacher B, using comments on a word document.



would you… would you put yourself one…

B Well, I would see, the students themselves from my experience, my limited experience, I still find that a student can really enjoy a class when they are not given too much instruction, and they can carry out investigations themselves, and through the inquiry based approach, they love it, they really get enjoyment out of it, at the time; but come three months later, if they don't have some formal notes written down, some formal, em, scripted notes, old-fashioned style diagrams, and definitions written in their copybook, they panic a little bit, and so from that point of view, em, I suppose we are coming back to the summative sort of, eh, assessment again, which we're trying to get away from, but we haven't gotten away from, because the Junior Cycle is still going to be a summative exam in the end, em, anyhow, but I suppose from my point of view, Junior Cert, from first to third year, I think it's really about getting the students to enjoy science, realise the importance of it in their everyday life, in society, in sports that they watch on tv like, it penetrates

CO Colm O Coileáin
Engagement

CO Colm O Coileáin
Student Anxiety

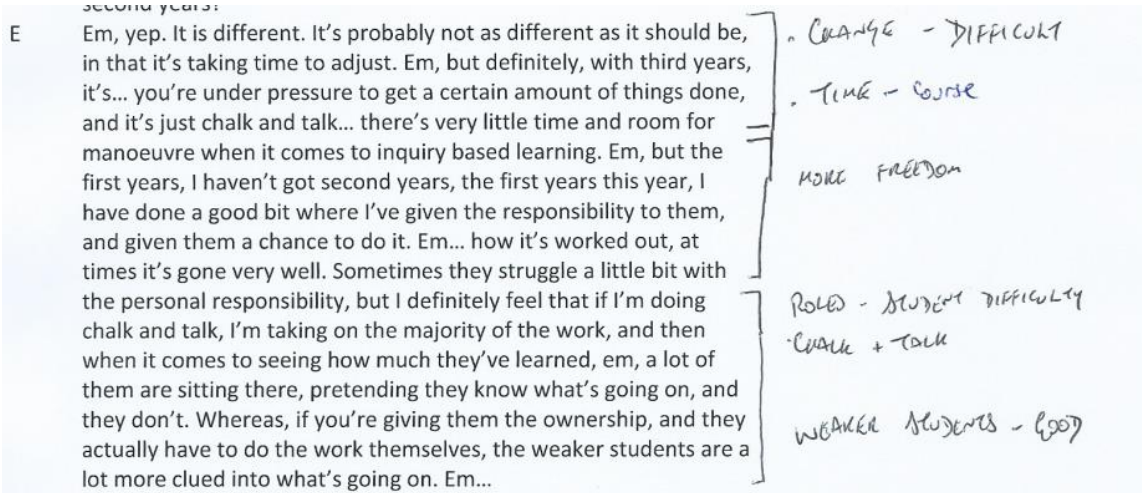
CO Colm O Coileáin
Assessment

CO Colm O Coileáin
Engagement

Figure 3.4: Interview transcript showing initial coding

Braun and Clarke (2006; 2012) recommend coding for as many potential patterns as possible, and note that each extract of data "may be uncoded, coded once, or coded many times" (2006, p. 19). They also recommend that some of the surrounding data be kept, if relevant, in order to keep some of the context. As can be seen in the above figure, using the comments feature in Microsoft Word was not ideal, as it was not immediately obvious which extract of data corresponded with which code, as many of the extracts overlapped with one another.

Not completely satisfied with the coding undertaken as shown in Figure 3.4 above, the coding process was conducted again, using pen and paper. An extract of this process is shown in Figure 3.5.


second years?

E Em, yep. It is different. It's probably not as different as it should be, in that it's taking time to adjust. Em, but definitely, with third years, it's… you're under pressure to get a certain amount of things done, and it's just chalk and talk… there's very little time and room for manoeuvre when it comes to inquiry based learning. Em, but the first years, I haven't got second years, the first years this year, I have done a good bit where I've given the responsibility to them, and given them a chance to do it. Em… how it's worked out, at times it's gone very well. Sometimes they struggle a little bit with the personal responsibility, but I definitely feel that if I'm doing chalk and talk, I'm taking on the majority of the work, and then when it comes to seeing how much they've learned, em, a lot of them are sitting there, pretending they know what's going on, and they don't. Whereas, if you're giving them the ownership, and they actually have to do the work themselves, the weaker students are a lot more clued into what's going on. Em…

Figure 3.5: Coding of interview transcript

Braun and Clarke (2006, p.19) suggest at this point that all the data extracts relating to a code are collated together within each code. This ensures that each data extract coded with a particular code forms a coherent pattern. Table 3.1 below shows some of the extracts from the interview transcripts which were coded with the word 'time'.

Table 3.1: Extract of some data coded 'time'

A	I	Yeah, well, cos I know a lot of the videos we watched are about, like, weeks-long inquiry-based projects, and I haven't, I certainly haven't gotten to that… I pose a question, and they've answered it by the end of class, cos the idea of giving them that much freedom… again, your weaker students would be god-knows where by the end of two or three weeks
C	I	you mightn't always get the chance to focus on, or notice when they're just doing a class for 40 minutes, or 1 hour 20, and you want to get a topic covered and move on, whereas I think it's different…
D	I	and there's a lot of time wasted, and we only have a certain amount of time, and… at the end of the day, we do have to cover a certain amount of material.
D	I	You know, there's more than one way to skin a cat, you just need to make sure it's within a certain parameter, so they're not wasting their time, or your time

3.5.5.3 Phase 3

At this stage, all the data has been coded, and I begin searching for themes, by reviewing the coded data to identify topics or issues that together construct a theme, or sub-theme. The codes, and the collated data extracts, are sorted into potential themes, and I considered how the different codes combined to form an overarching theme. Table 3.2 shows an early attempt at collating some of the codes used into coherent themes.

Table 3.2: Collating codes into possible themes

2	More student decision Student decision Discover for themselves Investigations IBL Less Instructions	Deeper understanding Teacher training Features of IBL Student questions Student investigations Student research Communication Critical thinking	Student decision making Problem solving Teacher instructions Student freedom Student decisions Scaffolding Learning from failure Being 'right'	Student decisions Discovering Scaffolding Teacher instruction Rote learning
3	Teacher questioning Critical thinking Group work Student research Student activity Whole class activity Practical activity IBL Student skills Communication Teacher-led (discussion)	Aspects of IBL Not exclusively IBL Communication - student Student investigation Student activity Critical thinking Student freedom Student decision Not following teacher instructions Not so much teacher-led Student research	Teacher input – give equipment Student activity, experimentation Open-ended question or investigation Communication Discussion	Student research Scientific method Student skills Student decisions Designing experiment

As can be seen from Table 3.2 above, at this stage I was keeping the codes from different teachers in separate columns. Eventually, I realised this initial analysis was not satisfactory, which lead to several additional attempts at creating themes from the codes. This phase should also include an exploration of how the themes are related to one another, and how they fit together to give an overall picture, so that by the end of this phase, I have a "collection of candidate themes, and sub-themes" (Braun & Clarke, 2006, p.20).

3.5.5.4 Phase 4

The themes constructed in phase 3 are reviewed in a "recursive process" in relation to the coded data, and the entire data set, in order to see whether the theme works, or should be amended. At this stage, potential themes can be collapsed together, or bigger themes can be split into more coherent ones. This phase of Thematic Analysis involves two levels (Braun & Clarke, 2006, p. 20).

In level one, I review all of the coded data extracts, to see whether they form a coherent pattern. As an example, re-using the data provided in Table 3.1, coded for 'time', we can see that all the data extracts do not fit within one theme. In this case, the teachers had two different reasons for discussion time, and time pressure; in one case they referred to the amount of time it takes to conduct an inquiry lessons; in the other case they were referring to the uncertainty arising from teaching a new course, and whether they were allowing enough time for the different topics, so that the course would be completed within the three years. Therefore, the initial candidate theme of 'Time' was no longer a viable theme. Coded data extracts for 'time' were then divided between the two new codes of 'time – course' and 'time – IBL', and the data was re-coded accordingly. The data coding shown in Figure 3.5 shows the addition of the new code. Each of these collections of newly recoded data extract were not large enough to be considered themes by themselves, but now were used as supporting codes within other themes.

The second level involves considering whether my themes reflect the meanings in the data set as a whole. The data is therefore re-read to determine "whether the themes 'work' in relation to the data set" (Braun & Clarke, 2006, p. 21). In doing so, I also add codes to any data that I may have missed in the initial stages, or re-code data as my understanding of the data set, and 'thematic map' of the data evolves. Figure 3.6 below shows an early attempt at using a mind map to sort codes from the data into the theme of teacher understanding of IBL.

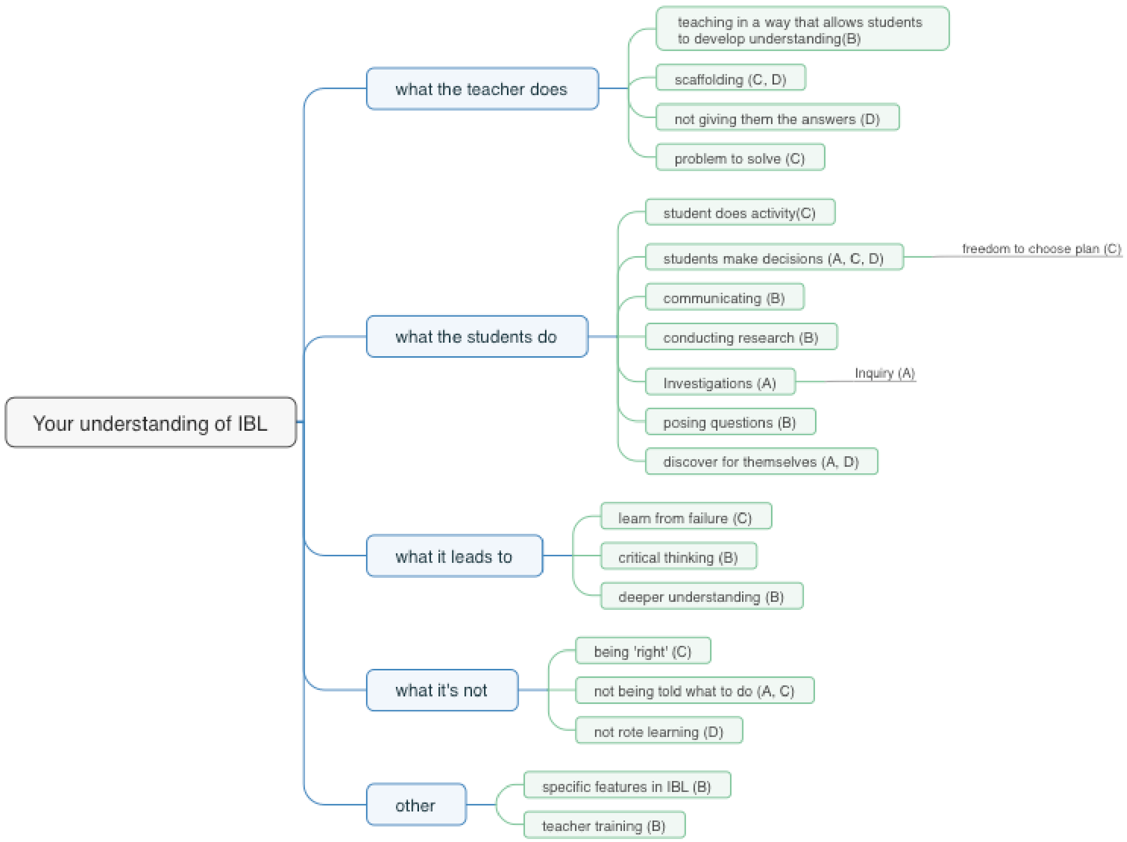


Figure 3.6: Codes sorted into theme and sub-themes

Initially one large, unwieldy, theme, the codes regarding teacher understanding of IBL were divided into sub-themes including teacher views of IBL including some idea of the teacher doing something, the student doing something, and so on.

3.5.5.5 Phase 5

At this stage, the themes are defined and named. The 'essence' (Braun & Clarke, 2006, p. 22) of each theme should be identified, and the themes should have a singular focus, be related to each other, and directly contribute to answering the research question. Sub-themes may be identified, as shown in Figure 3.6, when the main theme becomes too diverse and complex. Table 3.3 shows the thematic map for this dissertation towards the end of this phase.

Table 3.3: Late-stage 'Thematic Map'

Change in Practice	Teacher Understanding of IBL	Student Enjoyment	Student Learning	Aim of JC Science	Challenges Encountered

Comparison with old JC
• Old course specific
• Old course more structured
• More practical work in new course
• More activities
• Less distinction between sciences in new course
Freedom
• More freedom for teacher
• Teacher Judgement
• Freedom for student in investigations
• But still specific learning intentions
Uncertainty
• Uncertainty around syllabus
• Uncertainty about assessment
• Uncertainty around teaching methods
• Roles of teacher and student
	Discovery
	• Process of inquiry
	• Emphasis on scientific method
	• Way of thinking
	• Open vs guided
	Scaffolding
	• Features of IBL
	• Levels of IBL
	Freedom
	• Choice for students
	• Student independence
	• Can lead to misconceptions
	Actions/Roles of Teacher
	• Pose Question before giving info
	• Promote discussion
	• Support
	• Scaffolding
	• Student opinion
	Actions/Roles of Student
	• Students compose own questions
	• Students engage in discussion
	• Control
		• More interest in new course
		• Weaker more interested
		• Not every student likes science
		Depends on activity
		• More interest with IBL
		• More interest with practical work
		Depends on ability
		• Weaker more engaged
		• Failure leads to disengagement
		• Stronger students less happy
		• Stronger students uncertain
		• Will middling students suffer?
			• Learning intentions
			• Learning focus
			• Less spoon-feeding
			• Misconceptions
			Sub: Student learning and ability
			• Weaker not as focused
			• Stronger students work ahead
			• Weaker don't learn as well from rote learning – don't understand
			Sub: skills vs content
			• Change in focus
			• Students have better investigative skills
				Broad understanding
				• Better understanding
				• Less rote learning
				Appreciation of science
				• Enjoyment of science
				• Role of science in life
				• Science skills
				• Other skills – graphs
				• Social skills
				• Progression to LC
				• Rote learning in LC
					• Time – course
					  • Time – IBL
					Exam Focus
					• Uncertainty
					• Students focus on exams
					• Different teachers, different approaches
					• Assessing understanding difficult
					Balance – skills vs content
					  • Facts are important
					  • Balance of IBL & didactic

It should be noted that this draft of the Thematic Map has been influenced by the final phase, where the need to tell a coherent story about the research has required a re-shaping of some of the themes, and where additional sub-themes were merged or discarded.

3.5.5.6 Phase 6

The report is produced, which in itself is a part of the analysis in qualitative research. Braun and Clarke (2012) encourage the telling of a story in the report, where the themes are laid out in an order which is logical and that they should build on previous themes “to tell a coherent story about the data” (ibid., p. 69).

3.6 Quality & Validity

Although much research in teacher education is being undertaken by teacher educators, Cochran-Smith (2005) details some of the objections that scholars have raised in opposition to this kind of 'practitioner research'; that these studies might not count as rigorous or useful, and do not make easily generalizable findings (p. 222). Indeed, Stake (1995, p. 6) argues that "case study seems a poor basis for generalization", and Denscombe (2007, p. 130) agrees. Yet, these types of inquiries do have a place in the spectrum of research into teaching, in that they can provide rich case studies into "what teacher candidates learn, how they learn it, under what conditions, and how this learning is translated into professional practice" (Cochran-Smith, 2005, p. 223).

Moen (2006) argues that the terms used to determine standards of quality adopted by quantitative methods of inquiry should not be used, yet given the lack of alternatives in qualitative research, leaves it up to the researcher to "seek and defend the criteria that best apply" (p. 64). In that vein, and again drawing on the notion of *bricolage*, I look to a range of qualitative methodologies to determine which methods of determining the quality of the research can be applied. The validity and rigour of the research undertaken can be maintained through several means; various authors describe methods of ensuring the validity of qualitative research (Bullough & Pinnegar, 2001; Feldman, 2003; Feldman et al., 2004; Loughran, 2004; McNiff with Whitehead, 2002; Moen, 2006; Ortlipp, 2008; Stake, 1995; Yin, 2014). Winter (1996) describes six principles by which action research can be considered rigorous. Additionally, McNiff (McNiff with Whitehead, 2002, p. 104) builds on the work of Habermas by outlining how an action research project can be validated.

Reason and Bradbury (2008, p. 7) argue that to judge the quality of action research, the choices made should be "clear, transparent, articulate" both to the researcher, and others, which moves away from "validity as policing toward 'incitement to dialogue'". Similarly, a good narrative should be seen as "an invitation to participate", and that a case study may be "read, and lived vicariously, by others" (Connelly & Clandinin, 1990, p. 8). Several steps can be carried out to avoid bias in qualitative research, such as listening to feedback from participants; undertaking preliminary evaluations of data gathered, taking account of the interpretation of others; and ensuring triangulation during the data gathering phase. This is facilitated by being "open, authentic, honest, deeply interested in the experience of one's research participants, and committed to accurately and adequately representing their experience" (DCU, 2017, p. 3).

3.6.1 Generalisability

To establish validity in case studies, Yin (2014, p. 45) describes two tests which could be undertaken; external validity and reliability. External validity refers to "knowing whether a study's findings are generalizable beyond the immediate study". However, this conflicts directly with Stake's (1995, p. 3) view of the intrinsic case study where "we are interested in it, not because by studying it we learn about other cases or about some general problem, but because we need to learn about that particular case". Upon reflection, I would tend towards Stake's definition here.

Similarly, Yin's test of "reliability" (2014, p. 45) states that the case study could be carried out again, and that the same results would be obtained. Yin notes that this does not mean that the results of this case study could be replicated by carrying out another case study; rather that the *same* case could be carried out again. I would argue here that, especially in terms of educational research, that carrying out the exact case study again is not feasible. Although the teacher may be the same, the material being taught may be the same, and the students may be similar to other groups, there are multiple factors that can influence how a lesson may be carried out. For instance, the emotional state of the teacher or students, or in extreme cases even one student; indeed "all sorts of other factors" (Carr & Kemmis, 1986, p. 37) can affect the overall mood of the classroom, thereby altering how the participants in the lesson act and react. This 'difficulty' with action research is acknowledged by Gustavsen, Hansson and Qvale (2008) when they state that "the problem is that action research is dependent upon working with specific people in specific contexts".

An alternative viewpoint is offered by Elliott (1991, p. 65), who argues that teacher case studies are, in fact, generalizable. He argues that teacher knowledge and understanding of specific situations is based on comparing the situation with previous cases and "discovering the ways in which it is similar to and different from" those previous cases.

By that basis, Elliott argues that a similar process could be used in which teacher case studies could be generalised to other professionals' own situations. A similar argument is made by Bassey (1995, p. 6) who argues that "clearly the study of a singularity cannot be used to predict probabilities but, if it can be related to other situations, it may be valuable in suggesting possibilities for future action".

3.6.2 Triangulation

Triangulation (Elliott, 1991, p. 82) "is not so much a technique for monitoring as a more general method for bringing different kinds of evidence into some relationship with each other so that they can be compared and contrasted". In this research, this includes using the observations that I have conducted of my own, and other teachers, teaching being compared with the answers teachers gave during the interviews they conducted.

Stake (1995) describes some methods of triangulation that can be used by researchers in order to increase the validity of the claims made in case study research. One suggestion Stake (1995, p. 113) and Elliott (1991, p. 79) proposed is that I could have other researchers, or an 'outside observer' observe the same phenomena as I do. However, I would disagree, feeling that this would not be feasible as the presence of 'strangers' in the classroom has a profound effect on the behaviour of the students, and indeed on the teacher, a view with which Carr and Kemmis (1986, p. 27) and Cohen et al. (2011, p. 473) agree. Denscombe (2007, p. 46 and p. 53) refers to this effect as "the observer effect", where those under observation behave differently to normal, knowing that they are being observed.

Stake (1995, p. 12) describes case study as "noninterventive", extolling the researcher to "try not to disturb the ordinary activity of the case", "if we can get the information we want by discrete observation or examination of records". For this reason, the presence of outsiders in my own classroom was not used as part of the research process. However, the written reports were shared with others, both within and without my own practice, and their thoughts on my actions, reflections and conclusions were discussed with them; in a process of triangulation described in the following section.

3.6.3 Critical Friends

In this research, "investigator triangulation" (Stake, 1995, p. 113) seems most appropriate, in which the observation data be presented to another researcher to discuss alternative interpretations. Yin (2014, p. 45) regards this as one method of "construct validity", in which I would have the "draft case study report reviewed by key informants". In action research, and to a certain extent in self-study, this method of ensuring validity is known as making use of a 'Critical Friend' (McNiff, 2002; McNiff with Whitehead, 2002) or 'critical others' (Pinnegar & Hamilton, 2009, p. 113); one who can "ask difficult questions" and who "listens, questions, feeds back, reflects" on the research (O'Brien, McNamara & O'Hara, 2015, p. 390). Pinnegar and Hamilton (2009, p. 113) continue, stating that "interactions with critical others can cause the sharpening, reshaping, and refocusing of questions in unpredictable ways"; although warning that the questions of these critical others may "obfuscate issues", they do admit that engaging "with them and their ideas forces the researcher to think more deeply". Denscombe (2007, p. 129) similarly encourages this method of validation, in which an outsider may have alternative insights.

In the case of this research, three critical friends were used. One is a science teacher with whom I co-teach and who was present in the lesson described in Section 5.3.2, and involved in the research undertaken for Chapters Six and Seven. Since this teacher is also one of the 'actors' in the research, "member checking" (Stake, 1995, p. 115) took place, in that the teacher was shown rough drafts of the writing, and asked to "review the material for accuracy and palatability". The second teacher is from outside the science department, who comes to the research with little to no knowledge of science education but with an understanding of qualitative research design and methods. The third critical friend was recruited towards the end of the research, who undertook to review the dissertation as a whole, and offer clarity and criticism on different aspects of the research. These critical friends thereby became "familiar with the research" and offered "advice and criticism" (McNiff with Whitehead, 2002, p. 105). As Zuber-Skerritt (2012, p. 9) argues, action research is interpretive, that is, the solutions outlined in this dissertation are "considered 'authentic' when the results are recognized and validated by the participants". My critical friends' questions, suggestions of alternative interpretations, identification of contradictions, and ultimately their agreement with my conclusions have allowed my observations and the construction of my interpretations to be validated.

3.6.4 Winter's Six Criteria

As previously mentioned, Winter (1996) described six criteria to determine the validity of qualitative research. The presence of each in the research, as it progresses, should be made explicit in order to consider the research valid. Each, in turn, will be addressed here.

3.6.4.1 Reflexive Critique

Reflexivity refers to the idea that all judgements are made based on previous experience, and that those previous experiences influence how we interpret new experiences, knowledge and the world around us. In order to provide a dimension of validity to claims, those claims must be modest, and not statements of absolute truth, but rather questioning claims, inviting the reader to engage in a dialogue regarding possible interpretations.

3.6.4.2 Dialectic Critique

The dialectic refers to the notion of a contradiction; that as individuals, we are a product of a social world composed of contradictions, and that therefore we possess within us contradictions. These contradictions can give rise to a tendency to change, as we seek to confront these internal contradictions. As I progress through the research, will I uncover contradictions that cause me to behave differently to my beliefs?

3.6.4.3 Collaborative Resource

Collaboration in this case is seen as all participants in the research will have their voices taken as a contribution to the research, and that no one voice will dominate as the final viewpoint of the collective. It should not be mistaken with the reaching of a consensus, but that disagreements should be viewed as a richness in the data of the research.

3.6.4.4 Risk

By initiating this research, I am placing myself at risk, by having my own, and my colleagues, work practices critiqued. In undergoing this process of critique, I am opening myself to change, and by changing to improve my practice.

3.6.4.5 Plural Structure

Most research reports "summarise and unify" (Winter, p. 18), presenting the final product in one voice. However, by encouraging colleagues and critical friends to engage in a dialogue and offer alternative interpretations, I intend to offer the voices of all who contribute. By allowing a full plurality of opinions, the structure of the situation might be revealed, and similarities to other situations may be observed, which may lead to the report being of value to a wider audience.

3.6.4.6 Theory, Practice, Transformation

This principle concerns the relationship between theory and practice; between action and research. They are "two different and yet interdependent and complementary phases of the change process" (Winter, p. 19). By undertaking this action research process, I am carrying out research my practice with a view to improving it, and my understanding of it; through this process I am generating teacher knowledge to expand the knowledge base on this topic; this, in turn, can inform theory; and the cyclical nature of the theory/practice relationship continues.

3.6.5 Quality and Validity in Self-Study

Bullough and Pinnegar (2001) describe a series of guidelines that may be employed, to enable those who engage in self-study establish the quality of their contributions. They draw on the study of literature, and narratives in particular, to determine how a story might be worth studying, or "What makes a self-study worth reading?" (p. 16). Whilst Bullough and Pinnegar (2001) are careful to point out that these guidelines are closely interrelated, I also note that there is a significant overlap between these guidelines and the other approaches to quality, validity and trustworthiness addressed in this section. Bullough and Pinnegar's (2001, p. 19) guidelines may be summarized, by the authors themselves, as:

> A self-study is a good read, attends to the "nodal moments" of teaching and being a teacher educator and thereby enables reader insight or understanding into self, reveals a lively conscience and balanced sense of self-importance, tells a recognizable teacher or teacher educator story, portrays character development

> in the face of serious issues within a complex setting, gives place to the dynamic struggle of living life whole, and offers new perspective.

However, Feldman (2003) argues that quality is not enough to ensure good self-study, and that validity must also be viewed as important in making self-studies more trustworthy. He argues that when we engage in reflective practices that focus on the self, we cannot always be aware of the accuracy of the reflection; that when we reflect, "we do not know if what we see in the mirror is accurate, or the distorted view provided by the funhouse mirror". Feldman (2003, pp. 27-28) outlines four ways of increasing the validity of self-study:

- Provide clear, detailed description of how I collected the data, and make explicit what counts as data in this self-study.
- Provide clear, detailed description of how I constructed the representation from the data
- Include explorations of multiple ways to represent the same self-study
- Provide evidence of the value of the changes in my way of being a teacher

Many of these ways of increasing validity and quality, provided by Bullough and Pinnegar (2001) and Feldman (2003) have been addressed throughout this chapter. However, as the dissertation continues, and the research unfolds, these guidelines and suggestions will be revisited.

3.6.6 Habermas' Social Validation

In addition to the above methods of ensuring quality research, I look to Habermas' four criteria of social validation, as outlined by McNiff (McNiff with Whitehead, 2002, p. 104). Based on this work, there are four questions which need to be answered in the affirmative when I invite people to judge the validity of the research:

- Is what I say about my practice true?
- Do I use words, expressions and language that is understood by all?
- Am I being sincere, and avoiding deception?
- Is the situation right for us to be discussing this issue?

Social validation depends on the questions above being borne in mind when the research is being validated; McNiff suggests four critics that might be invited to assess the rigour of the work:

- Self-validation, in which I "interrogate" my assumptions, and test my opinions and interpretations; to check against "self-delusion and factual error or misinterpretation" the following critics may be employed (McNiff with Whitehead, 2002, p. 104);
- Critical friends, as discussed above in Section 3.6.3, will be involved throughout, offering alternative interpretations and criticism;
- Validation groups, which would consist of a small group of several interested parties, can be convened on a regular basis to review the research as it progresses, offer support and guidance, and consider whether the claims being made in the research are true, according to the four questions above;
- Academic validation, in which the final report is judged by the Academy.

By submitting myself to three of the four critics above: namely myself, my critical friends and validation groups, as well as ensuring that the research that I am conducting reflects the truth of the situation, and by employing Winter's criteria of rigour, I can confirm that the research is valid.

3.7 Ethics

DCU's Research Ethics Committee 'guidelines on insider research' (DCU, 2017) outlines some of the responsibilities of those undertaking insider or teacher research in their own organisation. Many of these responsibilities are echoed across the literature on ethics in educational research. Elliott (1991, p. 64), for example lists four strategies for protecting individuals, many of which are described in Section 3.6 above, such as:

- Cross-checking eyewitness accounts of events and observations
- Giving individuals the opportunity to reply, and have these incorporated into documents and reports
- Presenting alternative descriptions, interpretations and explanations
- Consulting individuals about the contexts in which their actions and views are represented.

These procedures are similar to those offered by Winter (1996, p. 12), who also describes some of the ethical considerations that must be taken into account:

- Ensuring all participants and authorities are notified in advance
- All participants must be allowed to influence the work
- The development of the research must remain visible and open to suggestion from others
- Permission should be obtained before conducting observations or examining documents
- Descriptions of others' points of view and work must be negotiated with those concerned
- I, as researcher, must accept responsibility for maintaining confidentiality

In response to the above considerations, permission was obtained from school management and my colleagues to undertake this research in the school. Through the participative nature of the research, giving the teachers the opportunity to view, comment upon and influence the research as it unfolded, I believe I have fulfilled the second, third and fifth of Winter's considerations above. As previously mentioned, although the online questionnaire for teachers was not anonymous, the resulting answers and the transcripts of the corresponding interviews were anonymised, as were any references to teachers or students in extracts of my reflective journal, when referenced.

Denscombe (2007, p. 128) and Brooks, te Riele and Maguire (2014, p. 115) warn of one of the ethical quandaries of action research, that although the research centres on the actions of the practitioner/researcher, very often the activity of colleagues comes under the microscope at some stage. In addition, it can be difficult to guarantee complete anonymity, especially in the case of the data analysis stage, where the participants in the study may be able to identify each other when asked to undertake participatory member checking. In the case of the research underpinning this dissertation, this includes the other teachers in the science department in my school. Ethical consideration was given to the extent to which the day-to-day activities of my colleagues would be scrutinised, and realising the impact that this scrutiny could have, the research being conducted was explained to them, including the possibility that complete anonymity could not be guaranteed, especially with a "local audience" (Reiss, 2005, p. 133), and their express consent was sought, as per DCU's ethical guidelines (DCU, 2018).

3.8 Limitations

In much of the literature, teacher beliefs are described as having an impact on their classroom practices. Indeed, some would go so far as to claim that teacher beliefs "directly influence their practice" (Hutner & Markman, 2016, p. 676). These beliefs include those relating to educational processes, such as "beliefs about teaching, beliefs about students, beliefs about confidence to achieve a task (self-efficacy), and beliefs about subject matter." (Roehrig & Luft, 2004, p. 4). My espoused, conscious and unconscious, values and beliefs have an impact on how I act within my practice, and I will, during the process of the dissertation outline and develop my understanding of these beliefs. However, an in-depth investigation of the values and beliefs of my, and the other teachers in my school, is beyond the scope of this dissertation.

As Roth et al. (1999) noted in their description of a teacher's classroom, I do not seek to create an account which can be read as a criticism, either of my own practices, or those of other teachers. This dissertation is intended as an account, and is written without judgement. Reiss (2005) encountered a similar problem, and advocates an "overarching adherence to 'respect for persons'" in order to avoid any perceived breach of trust, and possible hurt amongst my colleagues.

It should be noted that the data collected is based on teachers' perceptions of their own teaching practices, their personal understanding of inquiry and its implementation, and their perception of students' interest in the subject, and learning in science lessons. It may be expected that as a teacher gains experience, they may more accurately judge the needs and attitudes of their students, but such a depth of treatment is beyond the scope of this research. Additionally, student interest and learning may be affected by any number of factors (Osborne et al., 2003, p. 1054), however it would not be prudent to infer their effects on student interest based on the data available.

The study is not designed to be replicable, and generalisability across the teaching profession, although possible, is not to be inferred from any conclusions drawn.

3.9 Conclusion

This chapter has provided an overview of the methodology utilised during this research project. I began by outlining my philosophical stance, and reasons for choosing an interpretivist approach. I then provided some of the history of the action research methodology, including some of the models of action research. The following section described my use of the action research approach in the first art of the research project. My dilemma regarding the application of action research to the different sections of the research was described, and my reasons for choosing *bricolage* as an overarching methodology for the entire dissertation, incorporating action research, self-study, elements of case study, and qualitative interviews, was explicated. Subsequent sections outlined how I collected and analysed the data during the research process, and how I attempted to ensure truthfulness. The final sections outlined how I tried to act ethically, and the limitations of this research, as well as a comment on my positioning within the research.

Chapter 4: The Inspiring Science Education Project

4.1 Introduction

This chapter describes the work carried out as part of this research as I design and deliver a series of webinars to teachers who teach science through Irish. I begin by describing the context and rationale for the research. I provide background information relating to the Inspiring Science Education (ISE) project, and how the project delivered upon its aims in Ireland. I continue by describing the webinar platform used during the webinar series delivered in English by the ISE team, and then subsequently used by me in delivering the Irish language version of the webinars. Subsequent sections of the chapter then follow my personal progression as I seek to recruit teachers to take part in the series of webinars in Irish, how the delivery of the webinar series progressed, my observations and changes for the future cycles of webinars and the continuation of the research project.

4.2 Context

As explained in Chapter Two, teacher CPD in Ireland is primarily provided by way of short courses and workshops through English, even for teachers who teach in Irish-medium education. Until the 2015-2016 academic year, no provision had been made for CPD in Irish for teachers who teach in *Gaelscoileanna* or in *Gaeltacht* areas. The impetus for the research, therefore, came from a desire to provide CPD workshops to science teachers who teach through the Irish language. Given that these teachers are geographically dispersed, and building on the work that had already been carried out by the ISE project, I decided to make use of webinars to facilitate the provision of the CPD workshops. I planned to organise and present a series of webinars *as Gaeilge*, under the aegis of the ISE project, to promote inquiry-based learning as a methodology to teachers who taught through the Irish language.

4.2.1 Research Questions

The research, as it began, therefore focussed on investigating the following question, within an action research framework of improving my practice:

I. How can I improve the provision of CPD for science teachers who teach *as Gaeilge*?

However, as described in Section 1.5, echoing McNiff's (McNiff with Whitehead, 2002, p. 57) "spiral of spirals", this initial question underpinning the research spun off several sub-questions that arose as the research progressed.

i. How can technology be used to support the introduction of inquiry-based learning in Irish-language science classrooms?
ii. Do teachers who teach through the medium of Irish attach importance to undertaking their CPD *as Gaeilge*?
iii. What are the benefits and drawbacks to providing CPD opportunities via webinar, rather than face-to-face?

The first research question relates to the emphasis the ISE project placed on the use of technologies such as virtual laboratories, simulations, data logging and other eTools, and how they can be used in a classroom setting to foster student interest and engagement with science. The question, therefore, relates not only to the extent to which the participants in the research engaged with eTools, but the extent to which they implemented inquiry-based learning methods and strategies in their lessons. This question also arises in Chapter Six, where I focus on the implementation of inquiry-based learning amongst the teachers in my school setting.

In asking the second research question, I wanted to find out whether science teachers who teach in *Gaelscoileanna* had a preference for the language in which their CPD was being conducted. Personally, I found it an affront that no CPD was offered to teachers who taught *as Gaeilge*, however, it is possible that others may have no such attitudes. Would the teachers who participated in this research have undertaken the same CPD if it had been offered through English? How important was it for the teachers who participated that the webinar series was being offered through Irish? Perhaps teachers would actually prefer to attend CPD in English.

Finally, the decision to make use of webinars to provide the CPD made sense on two fronts; it was the medium through which the ISE provided their CPD in Ireland, and working with the support of the ISE project, it seemed logical to continue in that vein; in addition, if I was to present that face-to-face CPD in person, I would have to limit my research to schools in the Dublin area, neglecting the CPD needs of *Gaelscoileanna* around the country. However, having made the decision to present the CPD online, I was interested in determining to what extent participants would see this mode of presentation as successful. There could be reasons that teachers might prefer to undertake CPD in a face-to-face setting. Given that most teachers are within a reasonable distance of an Education Centre, it would not be unreasonable to find that some of them would prefer to travel in order to participate in a face-to-face workshop for the opportunity to engage with other teachers on a personal level.

I begin, however, with some background information on the ISE project, and how the English version of the webinars was conducted.

4.3 The ISE Project

The Inspiring Science Education (ISE) project was developed with the intention that IBL could be combined with the wide range of online resources that are available to educators to facilitate their adoption of the methodology, and make their teaching, and therefore science education, more interesting and relevant to the students' lives. These electronic resources included simulations, virtual laboratories, remote experiments, online meetings and conversations with scientists and virtual tours of scientific facilities. The project was composed of a number of partners from industry and education across 15 countries and aimed to recruit students in over 5,000 schools across the continent.

While the design of the project aims and resources was agreed by the project partners, the actual methods of delivery in each country was left to the national partners. In Ireland, the chosen method of information dissemination was by webinar, where each of the recruited teachers would meet online at a specific time each week. Each webinar was based around a different theme, such as what IBL is; ways of implementing IBL in the classroom; the online resources available to teachers; and how to go about obtaining EU funding for training courses under the Erasmus+ programme (Crotty, Lowry, Farren & English, 2014). Each webinar was recorded for online access so that participants could access the webinar if they could not attend at the time, or if they wished to return to a specific piece of information. The first series of webinars took place in Spring of 2014, with 21 schools taking part, and would be repeated annually with previous generations of participants sharing their experiences and expertise with each new group. An approximate timeline is provided in Appendix A. A brief description of each of the webinars is provided in the following section.

4.3.1 Outline of the ISE webinars

In this section, I will describe each of the webinars delivered by the ISE project team in Ireland led by Dr. Yvonne Crotty, as they took place during the first cycle of webinars. I do not intend to provide a detailed account of the webinars, but rather a general overview describing the principal points that I might include in my own delivery of webinars, as well as my thoughts on aspects of the webinars that went well, and that I might want to emulate, as well as aspects of the webinars that I might avoid. The platform used throughout was the Adobe Connect webinar platform.

4.3.1.1 Webinar One – General Introduction

This preliminary webinar welcomed all the participants to the ISE project, and introduced the organisers and presenters. The webinar platform was explained, and the 'house rules' regarding how to mute the microphone, how to attract the speakers' attention and how to ask questions by typing in the text box were explained. A general outline of the purpose of the ISE project was given, as well as how to access further information on the project. A timetable of the planned webinars was also provided.

4.3.1.2 Webinar Two – Funding Opportunities through Erasmus+

In order to apply for Erasmus+ funding to attend courses overseas, a school is required to complete an application form, outlining the organisation's need for staff development, as part of a wider school improvement plan. The purpose of this second webinar was to share with participants how to complete a school improvement plan, how best to describe the needs of the participating teachers in terms of their development, and how to find applicable courses which would fulfil their training needs. The information was presented by a representative of Léargas, the national agency charged with assessing the applications for Erasmus+ funding from Irish organisations. As part of our participation in the ISE project, each school was encouraged to apply to Léargas for Erasmus+ funding, to take part in courses which would make us more informed about, and comfortable with, the IBL methodology. Further information on my school's Erasmus+ training will be described in Chapter Six.

4.3.1.3 Webinar Three – Datalogging Tools

One of the ISE project partners from industry was Vernier International, a company which produces data logging software and sensors. For the third in this series of webinars, the CEO of Vernier Europe, which is based in Ireland, explained the various ways in which datalogging technology can be used in the science classroom in promoting scientific thinking and facilitate the carrying out of scientific investigations. The datalogging software Logger Pro, which was created by Vernier Software & Technology, would be provided to all participating schools free of charge, and should ISE schools request additional support, a representative would call out to the school, and provide a loan of various sensors to the school as part of the project.

This particular webinar highlighted one of the strengths of this method of synchronous online meetings, one which is designed as a lecture, with minimal audience participation. For a one-way content delivery system, lecturing via webinar is almost perfect. Audience microphones can be turned off by default, and the presenter is free to deliver the information with the aid of a PowerPoint presentation. Questions can be sought from the audience via the text box, which is a more dependable method of communication than restoring audience microphone rights.

4.3.1.4 Webinar Four – Why use IBL? And How?

The fourth webinar in the series began to focus on why teachers might feel they should implement IBL in their classrooms. The webinar was delivered by a teacher who attempts to incorporate IBL into his mathematics teaching. The webinar began with the usual reminders to mute microphones, check speaker levels, and set up appropriate microphone levels for the presenter.

The presenter began by asked the teachers for their thoughts on why they wanted to implement IBL in their lessons. Initially, it seemed as if teachers were taken by surprise by the question. Several seconds of silence ensued. Although in a face-to-face setting, it would be obvious that people are taking the time to think of their responses, and perhaps viewing the other participants to see if someone was prepared to provide a response, no such visual cues were available to the presenter or participants in a webinar setting. For me, at least, this silence became uncomfortable, and although it lasted perhaps ten or fifteen seconds, without the visual feedback it felt much longer.

When the presenter asked for opinions from the participants, their microphones were 'turned on' to allow participation in the discussion. However, those teachers who did not use headphones created feedback through the webinar platform as their microphones picked up the audio from their speakers. This lead to several minutes in which the participants were asked to mute their microphones if they were not actively being used. However, in the case of some teachers who were perhaps not paying full attention to the webinar, they did not realise that their microphone was causing a problem, and it took an additional several minutes before all participants were ready.

As in the case of any group discussion, several participants would attempt to speak at once. Unlike a face-to-face discussion, however, there were no visual cues available that made it possible to discern who was about to speak, or indeed who was speaking. Several times more than one person would begin speaking at once, and it was not always possible to deduce who was speaking. Once a person had begun speaking, it was not always immediately obvious to them that someone else was also speaking at the same time, and it took several minutes before the discussion could be reined in.

Some participating teachers were, perhaps, viewing the webinar in a situation which allowed them to passively view the proceedings, but not actively engage using the microphone; in addition, some participants reported that their microphones were not operational. These teachers made use of the chat box instead, typing in their input and questions. This created the complex scenario in which one conversation was taking place audibly, with additional sub-conversations and responses to the audible conversation taking place via text. It soon became unclear whether comments were being posted in relation to other typed comments, towards the speakers, or indeed as stand-alone comments or questions.

4.3.1.5 Webinar Five – Ideas on Implementing IBL

This webinar was presented by a teacher who makes use of IBL in her science classes. She spoke about how teachers can go about making small changes to their practice in order to make the lesson more inquiry-oriented. Again, the first few minutes were occupied with housekeeping duties, as the presenter set up the microphone and camera. The presenter gave an overview of small, incremental changes that any teacher can implement in their classroom to make the lesson more inquiry based, and then outlined the homework that participants would be expected to complete for participating in the ISE project.

Having participated in several webinars on inquiry-based learning, each participating teacher was asked to outline a lesson they could now envisage teaching to one of their classes. The teachers were to pick a topic, and using a template provided by the ISE, design a lesson plan that would teach that topic in an inquiry manner, utilising some of the eTools that had been referenced throughout the webinar series. As the webinar progressed, a discussion emerged. However, this time, rather than the microphones being used, most participants seemed content to use the text box to type comments and questions, with the presenter steering the conversation and answering questions as they arose. The presenter also asked questions of the participants, and for yes/no answers, many participants were now comfortable enough using the 'hands-up', 'thumbs-up' or 'thumbs-down' features to answer the questions simply.

One drawback of relying on typed responses for more complex ideas, is that while the respondents are typing, it can be tempting for the presenter to fill in the quiet time by asking additional questions, which leads to comments being posted after the conversation has moved on to new topics of discussion. The time delay introduced by typing, rather than inputting vocally, means that the presenter must allow more time for people to contribute.

4.3.1.6 Webinar Six – eTools and the ISE Portal

In the intervening weeks, while the webinars were taking place, the ISE project had been developing their 'Community Portal', a digital space developed in conjunction with the Open Discovery Space project (http://portal.opendiscoveryspace.eu/en/ise). This website would serve as a place for ISE project groups to come together online, to share resources and ideas, and as a repository for links and digital resources. The final webinar in the series focused on using the ISE Portal, creating an account, finding relevant communities and searching the database for eTools that could be used to supplement inquiry lesson plans. In addition, the ISE five-step model of inquiry, previously described in Section 2.3.2.5 was also outlined to participants.

As happened in webinar five (see Section 4.3.1.5), the decision not to allow participant discussion vocally, but rather to engage by chat box, meant that the difficulty of people talking over each other was avoided, but there was, again, the same delay between the presenter asking questions, and the responses being typed by the participants.

4.3.2 Discussion and Points to Note in My Planning

Having been a participant for the series of webinars organised by the ISE, I had observed some aspects of delivering workshops via this online synchronous medium which struck me as an important factor to consider during the planning phase. Carrying out a review of the literature surrounding the use of webinars *after* I had completed the first cycle of webinar delivery confirmed much of my original thoughts. Hence, the literature referred to in the following sections was found after completing the first cycle of webinars.

First was the question of participation by the teachers in group discussion. I had resolved not to deliver the webinars as lectures, but rather wanted to have the teachers engage in discussion, and exchange ideas amongst themselves, in order to improve engagement with the material (Zoumenou et al., 2015). However, the difficulties presented in the ISE webinars, as described, made me wary of providing microphone permissions to all the teachers, all of the time. I was reluctant to spend the first five minutes of every webinar asking the participants to ensure that their microphones were muted, but at the same time making sure they all understood how to un-mute them if required. I was similarly conscious of the difficulties encountered by the presenters in the ISE webinars of having several people speak at once, only for them all to stop when they realised others were speaking, and the ensuing halting conversations that took place. Although I wanted the participants to participate, and conscious of the lack of interactivity participants feel when microphone rights are removed (Olson & McCracken, 2015; Vaccani et al., 2016) I had decided that I would not place a great emphasis on group discussion during the webinars.

Similarly, I realised that care should be taken to keep track of comments and questions appearing in the text chat box, and respond appropriately; to note that when participants are typing that a message appears to notify everyone that they are doing so, and to wait until they have finished typing before speaking again. This would, at least, allow for coherent conversation to take place in the text box. However, as Yates (2014) notes, this would depend on the typing speed of the participants, and I was conscious that I would have to allow for plenty of silence during the webinars if I wanted each participant's opinions to be ‘heard’, and to resist the temptation to fill that silence with more comments and questions.

Although the ISE portal had been developed in the weeks leading up to the end of the ISE webinars, it was cumbersome and slow, even by the time I was preparing to present my own series of webinars *as Gaeilge*. It was meant to serve as a repository of digital resources and links, and to offer the different ISE groups somewhere to communicate with each other outside of the webinars. However, the difficulties encountered trying to navigate the portal meant that I was not happy using it, and it seemed other teachers had similar views of the portal. Although it seemed like an important aspect of the ISE project, I did not want the teachers participating in my webinars to feel that it was expected of them to make use of the portal as a *quid pro quo* for participating in the project. If the nature of the portal changed in the intervening weeks, and became more usable and useful, I would recommend its use by the *Gaelscoil* teachers.

4.4 Delivering the webinars *As Gaeilge*

The research was designed to follow a cyclical action research approach. I would repeat the cycle, making improvements each time based on my experiences of, and learning from, the previous cycles. Although each cycle consists of the steps Plan, Act, Observe and Reflect, as Somekh (1995) noted these are not discrete steps that take place sequentially, but rather the steps can overlap, and previous steps can be revisited as the cycle progresses. It would not make sense, therefore, to describe the action research cycles as discrete steps, but rather in the more fluid format as now detailed.

4.4.1 Cycle One Planning

Preparation for the cycle of webinars *as Gaeilge* began in the Summer of 2014, when I translated the publicity materials for the ISE project to the Irish language. This consisted of a leaflet explaining the aims of the project, and how teachers and schools could get involved. Further materials were translated as the project progressed. I also began planning the recruitment of teachers from *Gaelscoileanna* around the country. The Department of Education and Skills provides a list of all the secondary schools in the country, with various pieces of information, such as contact information, enrolment and whether the school teaches subjects through the Irish language. At the time, the most recent list of schools available was for the 2012 – 2013 school year[15]. A breakdown of the post-primary schools in Ireland is given in Table 4.1 below.

Table 4.1: Breakdown of Post-Primary Schools in Ireland by Language of Instruction

Type of School	No. of Schools (Total 721)
No subjects taught through Irish	656
Some pupils taught all subjects through Irish	11
Some pupils taught some subjects through Irish	9
All pupils taught all subjects through Irish	45

[15] This data is available on the Department of Education website: www.education.ie/en/Publications/Statistics/Data-on-Individual-Schools

For the purposes of this research, I elected to focus only on those schools that taught all pupils all of their subjects through Irish. Of those 45 schools, I chose an initial 16 with which to make contact, which gave a geographical spread across the country. Six schools returned a positive response over the course of the following few weeks.

As the recruitment phase was ongoing, I was also engaged in planning how many webinars would be needed, and what topics to cover in each of the webinars. At the time, I thought three one-hour webinars would be a reasonable number, and this retrospectively tallied with the suggestion by Zoumenou et al. (2015) that a one-hour webinar is a good length. These three hours, I felt, reflected the amount of material that I would be comfortable covering, given my own lack of conscious engagement with inquiry-based learning, which will be discussed in further detail in Chapter Five. In addition, unlike the ISE webinars, I had not planned on inviting additional speakers on different topics, and felt that three hours of listening to the same speaker would be adequate.

The outline plan that I had decided on was as follows:

- Webinar 1 would begin with an explanation of the webinar platform and the housekeeping rules that relate to participating in a webinar; followed then by an introduction to the ISE project; a brief overview of how to apply for Erasmus+ funding; and an introduction to IBL.
- Webinar 2 would focus more in depth on IBL, how teachers can make small changes to introduce IBL in their lessons; I would introduce the ISE portal and how to access online resources; and I would discuss the ISE five-stage model of IBL, and how to use the model to construct an inquiry lesson. Homework would be assigned at this point, and I would ask teachers to design a lesson incorporating IBL and making use of an eTool.
- Webinar 3 would then allow the teachers to present their lesson plan and discuss their experience of implementing IBL over the previous few weeks. I would, by that point, be more comfortable myself in discussing IBL, as I will have spent the previous week attending an Erasmus+ funded course on IBL and online resources.

4.4.2 Webinar One – Acting, Observing & Reflecting

I sent a final reminder email to the participants, as recommended (Zoumenou et al., 2015) outlining the topics that would be covered in the webinar, and a reminder that the webinar would be recorded for later access if a teacher was not available to log into the webinar at the time of broadcast. My recollection of the webinar is recorded in my journal from the time.

> And, after that, most of it is a blur. Deep breaths; talk slowly; vary the tone of your voice; make sure to stop for comments or questions every once in a while; keep an eye on the chat box in case there were problems. Keeping all that going, as well as trying to get the information across, is enough of a job, and leaves little in terms of cognitive capacity to mentally keep a record of how things are progressing. (Journal Entry, February 5th, 2015)

I covered all the information I had planned to, including an introduction to the ISE project; an overview of how to complete an Erasmus+ application; I shared the access to the Vernier software and tools available; and gave a general introduction to inquiry-based learning, which would be further developed during the second webinar. I asked the participants to have access to a microphone for the following week's webinar, at which point I would ask them to introduce themselves to the group.

On reflection, and indeed at the time, I was happy with the webinar, with my own performance and glad that the participants seemed engaged, to the extent I could determine their engagement. One of the final points in my journal from the time highlighted what, for me, would be one of the primary drawbacks of the webinar platform, versus face-to-face interaction:

> My main feeling, at the end of the webinar, and at a few points throughout, was that it was quite disconcerting speaking to my screen for an hour, with little to no feedback, watching only the video from my webcam. Normally with a group of people in a room, you can easily gauge how engaged people are with the content; whether what you are saying makes sense (some nodding); whether they find it interesting (yawns or fidgeting if not); whether some people do not follow what

> you're saying (frowns); etc. But, with the webinar system, there is none of that immediate feedback. (Journal Entry, February 5th, 2015).

4.4.3 Webinar Two – Acting, Observing & Reflecting

The second webinar described inquiry-based learning in greater detail, outlining the model of inquiry-based learning that the Inspiring Science Education project follows. This webinar also provided the participants with some examples of the eTools that I use in my own practice, describing how they can easily be incorporated into a lesson. Participants were asked at the end of this webinar to pick a topic in the Junior Cycle science course, to think about how they could design an inquiry-based lesson on that topic and prepare a short talk on how they would deliver that lesson. I asked them all to be prepared to do so during the final webinar, and reminded them to have appropriate equipment ready to do so, such as a microphone at the least, and a webcam if they were willing to present using video.

Given that the first webinar had gone so smoothly, I was much more relaxed before this webinar began. Again, I was struck by the same feeling of uncertainty, again highlighting the difference between presenting live in front of a group of people, as I do as a teacher every day, and presenting via webcam. Unless a participant is willing to interrupt the presentation by interjecting verbally or communicating their confusion by some other means, there is no way to know whether you are communicating your message effectively. Indeed, there is no real way of knowing whether the audience is actually still listening, or whether they have logged in and then left the computer to focus on other things.

4.4.4 Webinar Three – Acting, Observing & Reflecting

As previously mentioned, the participants had been asked to prepare a short explanation of how they would implement an inquiry-based lesson in their own context. Unfortunately, only three participants attended this final webinar, one of whom did not have a working microphone. The second teacher was happy to speak for a few minutes, but unfortunately the quality of the audio deteriorated as they spoke; therefore, I had to ask her to stop after a minute or two. It again emphasises the point that in order for the webinars to become fully interactive, as some of the feedback from the participant questionnaire highlighted, all participants must have a minimum amount of computer equipment; namely a working microphone and headphones. The addition of a webcam so that all participants can see each other, and each other's facial expressions, would be advantageous but not completely necessary.

The gradual fall-off in teacher participation was disappointing, but not completely unexpected. I had been contacted that morning by one teacher who could not attend, at short notice. Other teachers had possibly lost interest, or were happy to skip the live webinar, knowing that a recording would be made available to them. The results of the questionnaire completed by them showed that most of the teachers had watched most of the webinars, so they must have watched them through the recordings sent to them.

4.4.5 Cycle One Feedback & Reflection

Upon completion of the cycle of webinars, and following a period of two months, which would give the participating teachers time to process the information and perhaps implement some of the learning from the webinars in their own practice, I sent an anonymous online survey to the teachers requesting feedback on the series of webinars. This survey consisted of some general housekeeping questions, followed by some questions that related specifically to the research that forms the basis of this dissertation. Appendix E shows the questions posed, as well as the responses. The option was given to the participants to enter their name on the questionnaire, and most did so, however I have anonymised the responses for the purposes of this research.

Based on the responses, the participating teachers were happy with the quality of the presentations, the standard of my Irish, the clarity and quality of the emails and follow-up information, and with the information shared on most of the topics during the webinars.

The responses from the teachers to the question "What were you expecting to gain by attending this webinar series?" can be grouped into several primary themes. In participating in this course, teachers wanted to make connections with other teachers; they wanted to improve their understanding of IBL; and they were looking for teaching resources they could use in their lessons. These topics, and other feedback provided on the questionnaire will be discussed in subsequent sections.

4.4.5.1 Making Connections

Most of the teachers expressed that they had hoped to make connections with other science teachers teaching in the Irish language, to share resources, and to generally have the opportunity to talk with each other. The free-form responses on this theme included "*bhí mé ag súil le buaileadh le múinteoirí eile leis na suimeanna múinteoireachta céanna*" [I was looking forward to meeting other teachers with the same interests]; "*bhí mé ag súil le dul i dteagmháil le múinteoirí meánscoile eile agus a bheidh a phlé leo*…" [I was looking forward to making contact with other second-level teachers, and have discussions with them…]; "*bhí mé ag iarraidh aithne a chur ar mhúinteoirí eile*…" [I wanted to get to know other teachers…]; and "*nasc a dhéanamh le múinteoirí eolaíochta eile timpeall na tíre*" [make connections with other science teachers around the country]. I hadn't expected this facet of CPD events to be such an important one for teachers, although that may have more to do with my own personality. It is, however, something that is pointed to in the literature (Yates, 2014).

In fact, with the benefit of hindsight, one of my biggest disappointments in having carried out this research is the lack of regular ongoing contact between the participating teachers. Delivering the webinars to groups of science teachers who teach in the Irish language would have been the perfect opportunity to create a community of practice; bringing together a group of science teachers from across the country that would regularly keep in contact with one another, share ideas and resources, and provide each other with support would have had a long-lasting effect on their, and my, practice. To a certain extent, however, this group would have been redundant, as the email-based group sharingscience[16] was, and indeed still is, a popular email list, and many of the teachers who took part in the webinar series are active participants on the sharingscience group. Although this group has over one thousand subscribers, and is quite active, it is predominated by teachers teaching through the English language. There are occasional requests and questions by teachers teaching through Irish, as well as some who willingly

[16] The sharingscience email group is an email-based google group, created and maintained by Noel Cunningham, a science teacher in King's Hospital School in Dublin. Teachers, or indeed anybody with an interest, can add their email address to the group and they will receive all emails sent within the group. As of January 2019, there were 1,164 members of the group.

share Irish-language resources they have created, but the majority of the conversation is carried out in English, as are most of the resources being shared.

4.4.5.2 Length of Webinar Series

Interestingly, the participants were almost evenly divided on how suitable the length of the cycle of webinars was. There is an almost even split between those participants who thought that the cycle of webinars was too short and those who thought it was just the right length. One participant felt the series of webinars was too long. If I am to improve the webinars for future cycles, I'm left confused at the feedback. Should I continue as I had originally planned, or should I add to the length? I had originally felt that three hours was long enough, as scheduling more webinars might initially dissuade teachers from signing up in the first place. However, I did feel that some of the webinars were slightly rushed. A longer series of webinars would be of benefit, giving the participants more opportunity to compare notes, discuss the challenges that are unique to *Gaeltacht* and *Gaelscoil* teaching, as well as discuss topics that are more generally relevant to science teachers.

4.4.5.3 Teaching Resources

Some of the other responses to the question of teachers' expectations of what they would gain by attending the webinars included "*áiseanna teagaisc a bhailiú*", or to receive teaching resources. One of the reasons that teachers attend CPD events it the opportunity to leave with something tangible; perhaps a ready-made PowerPoint presentation, or worksheets; leaflets and books that could be used in class; or in extremely rare cases some computer software or a piece of equipment. It is not uncommon to overhear teachers discussing the usefulness of a CPD event in terms of the quality of the resources they were provided with. However, the resources teachers expect from CPD events are not limited to physical artefacts. Links to useful websites and ideas can be just as important. As the series of webinars progressed, and we discussed in more detail the different eTools that could be used in the science classroom, teachers were able to collect ideas and techniques that they could implement in their own lessons.

4.4.5.4 Provision of CPD in English vs Irish

The central aim of this series of webinars was to provide CPD on the integration of technology into science teaching to facilitate teachers *who teach through the Irish language* in making use of IBL in their lessons. In such a situation, it was only logical that the webinars be provided through the Irish language, since all other provision of CPD at the time was in English only. Therefore, the teachers were questioned whether (i) they would have chosen to attend these webinars if they were provided in the English language only, and (ii) how important they felt that the webinars be delivered through Irish only. Of the responses, again there was an almost even split between those who would have chosen to attend the CPD, and those who would not have attended had the CPD been delivered through English. I believe this mentality is best summed up by the response of one participant who stated "*b'fhearr liom gan freastail ar i mBéarla, ach muna raibh rogha agam – déanfainn i mBéarla é*"; which means they would have preferred not to attend the CPD if it was in English, but if there was no choice available to them, they would have done so. All teachers, except one, said that the fact the CPD was being offered in the Irish language was "*An-Tábhachtach*", or very important, to their choosing to undertake this CPD.

These responses may be interpreted in several ways. Perhaps they feel that CPD in the Irish language, and tailored to those who teach in *Gaelscoileanna*, would be the most beneficial to them as teachers as any discussions that take place, and any resources shared during the CPD, would be more appropriate for their own situation. This would give the teachers the opportunity to speak Irish, and use the terminology they are learning in a situation that is similar to their classrooms. Another explanation for their motivations may be linked to the expectations the teachers had for signing up for the CPD in the first place, as discussed in Section 4.4.5.1 above. Many of these teachers were looking forward to the possibility of meeting other science teachers who teach through Irish, discussing and sharing ideas with them, and generally getting to know other teachers.

There are, I believe, two ways in assigning a motivation to this. Had the CPD taken place through English, and any practicing science teacher in the country given the opportunity to take part, the number of *Gaeilgeoirí*[17] would have been heavily outweighed by the number of English-speakers. In this case, the sense of providing tailored CPD for those who teach in a minority language would have been negated. The teachers who teach through the Irish language would have found themselves in the same situation as any other CPD event, where they do not have the opportunity to discuss the issues and difficulties faced by teachers who work in similar contexts.

Secondly, had this CPD taken place through the English language but limited the participants only to those who taught through the Irish language, the webinars would have lost one of the primary motivations. If CPD is being provided to those who speak the national language, to enable them to improve their teaching, which takes place *as Gaeilge*, the opportunity for us to use our language, and express our identity, should be taken advantage of. Granted, the same information could have been shared, but there would have been a missed opportunity for us as Irish speakers to speak our language. At that point, the question would have to be asked: what is the point in having a national language that we *can* speak, if we *don't* speak it when we are given the opportunity? As Darmody and Daly (2015, p. 1) state, "the language we speak is part of our identity as individuals", and similar thoughts are expressed by Ó Ceallaigh and Ní Dhonnabháin (2015). To organise CPD in English, but limit it to people who speak Irish would not only be redundant, but denying part of our identity.

4.4.5.5 Provision of CPD Face-to-Face vs Online

The second major element of this research was whether the provision of CPD in an online environment would facilitate teachers to attend the CPD, rather than having to travel to their nearest education centre. The teachers were again asked two linked questions, (i) whether they would have chosen to undertake this CPD if it was only being offered in a face-to-face capacity, say in their local education centre, and (ii) how important was it to them, when deciding to take part in the CPD, that it was being offered online.

The responses to the first question surprised me, although it mirrors results described in the literature (Allred & Smallidge, 2010; Olson & McCracken, 2015; Vaccani et al., 2016;

[17] Irish-Speaker

Yates, 2014). The majority of teachers responded that they would have been happy to travel to attend this course in a face-to-face setting, if that option had been available to them, with only two teachers saying that they wouldn't have taken part.

As previously described, Education Centres are geographically dispersed across the country, with most teachers being within an hour's drive of their nearest centre. In fact, the participants in this research were all based in schools in large urban centres, and the nearest education centre would have been a much shorter journey for them. This would have enabled the participants to interact with each other in a much easier way than participating in a webinar. In the case of the webinar, the majority of the interaction that takes place is between the presenter and the participants, in a back-and-forth interaction (Yates, 2014). As described previously, interpersonal communication is quite limited, and difficult, in the webinar setting. In a face-to-face setting, participants can see each other, talk to each other, pass written notes, partake in group activities, and get to know each other during the coffee break during the workshop. Given that so many teachers expressed a wish to network with other teachers in Section 4.4.5.1, it may have been that a face-to-face series of workshops would have been more beneficial to them. In fact, this is one of the drawbacks of webinar-based CPD (Olson & McCracken, 2015; Vaccani et al., 2016; Yates, 2014).

However, in what may seem as a contradiction, the majority of the teachers said that they viewed the fact that this course was being offered in an online capacity as "*An-Tábhachtach*" or very important when deciding to participate. Again, given the questions posed, and the lack of follow-up questions as to motivation, any discussion on the reasons would amount to mere speculation.

4.4.5.6 Did teachers implement their learning?

The teachers were also asked if they would implement what they had learned in their own lessons. This took the form of two questions, the likelihood of their implementing IBL in their lessons, and the likelihood of using eTools. Teachers were given the option of choosing from a list of answers or giving their own freeform answer. Most of the teachers indicated that they had already implemented some IBL strategies in their classrooms, with the others indicating that they were "*Cinnte*" [certain] that they would be doing so in the future. It was encouraging to see that teachers had already begun implementing some of the ideas that they had learned from the course in their own context. On reflection, the questionnaire did not ask how much experience they had with IBL before undertaking the course. It could be that many of the teachers already implemented IBL in their lessons, or that the course merely allowed them to identify the classroom practices they engaged in on a regular basis as IBL.

The responses to the question of whether the participating teachers would utilise eTools in their lessons was more mixed. Only one teacher had already used some of the eTools in their lessons by the time the questionnaire had been completed. Most of the remainder were, again, "*Cinnte*" [certain] that they would make use of eTools in their lessons, with two indicating there was a good chance, and one indicating that there was a low probability that they would make use of such tools. The fact that most teachers felt they would in future make use of the eTools was validation enough for the first cycle of this research.

4.4.5.7 Suggestions for future iterations of the webinars

Finally, teachers were asked for any recommendations or suggestions they might have to improve the series of webinars for future cycles. Two teachers suggested having more contact time. One wanted "*níos mó ceardlann* […] *go mbeadh níos mó teagmháil ann idir na rannpháirtíochta*", essentially that there be more workshops, with more interaction between the participants. A second was that there would be "*am gach mí, no mar sin, chun deis plé na abhar* [sic]*"*, that there would be a time once a month where the participants would have the opportunity to discuss the material. This is an interesting proposition, and directly relates to the idea that CPD should have an ongoing component, to support the participants in implementing what they have learned (Cordingley, 2015). It also relates to the idea in Section 4.4.5.2 of creating a community of practice, where the teachers could remain in contact with one another, sharing ideas and resources, and generally having the opportunity to discuss and reflect on their experiences, a finding supported by the literature (Gaines et al., 2019). This would be a central component of any future webinar cycles.

Two teachers suggested providing more examples of IBL in practice, and how it can be implemented in different lessons. From personal experience, this is a common suggestion at the end of workshops on IBL, as well as CPD in general (Gaines et al., 2019). As engaging and stimulating as a workshop on implementing inquiry in your practice can be, very often it feels a daunting prospect to move from knowing the theory of IBL and applying it to actually teaching in a classroom. It can be difficult to look at one's own teaching, and the topics that are to be taught, and visualise how you can teach them in an inquiry manner after only a few hours of learning about IBL. This is again linked to the discussion above on the length of the series of webinars. A longer series would, of course, have had more time to enable the participants to discuss specific topics on the curriculum, and how IBL could be implemented in teaching those specific topics. Or I could have taken more of the easier topics that I teach by inquiry and shown how I teach by them inquiry. However, this raised an issue for me, which will be discussed in Section 4.5.

4.4.6 Cycle Two Planning

Some of the suggestions made by the teachers after completing their cycle of webinars would be taken on board in implementing future cycles of webinars. I had planned again on running the webinar series in the Spring, sometime around January or February 2016. Based on a suggestion from my supervisor, I planned on advertising and organising one stand-alone webinar on how a school could apply for Erasmus+ funding, which would be primarily aimed at science teachers, but open to teachers of any subject, and offered through the Irish language. The aim then would be to suggest to the science teachers that took part in the webinar that they might be interested in attending the cycle of webinars discussing the implementation of IBL in their lessons, incorporating eTools and other online resources.

In early January 2016, I made initial contact with the schools. For this cycle, rather than selecting a number of schools from the list, I chose to send an email to every *Gaelscoil* in the country, publicising the webinar, with a link to an online form they could fill in to express an interest in attending. In all, five teachers filled out the form.

4.4.7 Cycle Two Acting, Observing & Reflecting

The webinar took place in mid-January, 2016. I had sent out an email to the five teachers that morning reminding them of the webinar and providing them with the link so that they could log into the webinar platform. However, there was one major issue that arose as I clicked the record button to begin the webinar. There were no participants.

I persevered in any case, and went through the material, as if there were participants listening to me, because I felt that the least I could do was record the webinar and send it to those teachers who had taken the time to express an interest. In the end, I finished the recording, wrote a short email to those teachers who had expressed an interest in the material, adding the link to the recording to the email so that they could watch it at their leisure, as well as links to the other materials and forms that would be required of them to complete the Erasmus+ application.

4.4.8 Cycle Two Ends

After the Erasmus+ webinar, and the lack of participants, I decided against persevering with the series of ISE webinars in Irish. The difficulties trying to recruit teachers had become apparent. In addition, in carrying out the first cycle of webinars, I had begun to have doubts in relation to my own teaching. Was I really that proficient in implementing IBL in my own classroom? Did I really behave as I professed to?

I was giving a series of webinars to teachers on how to incorporate IBL and technology into teaching, and somehow that made me feel as if I was expected to be some kind of expert in these things, as Dadds (1997) had highlighted. However, I had deep reservations about whether I actually behaved this way with my own students. The first cycle of webinars had been a re-working of material from the ISE webinars, but I felt that for the second series of webinars I would have to provide more specific examples of how I was using IBL in my lessons, how I was using the eTools, and specific examples of lessons that I had created for my own students. And I was beginning to doubt whether I actually understood IBL, and whether I implemented it in my classes.

4.5 Discussion

My thoughts at the time were that surely PhD research is meant to go smoothly and be seen through to completion. Surely, I should be able to state at the end of this chapter that I had managed to reach every science teacher that teaches through the Irish language, and that we are all united in the common goal of improving our students learning by incorporating inquiry-based learning and online tools into our lessons. And, beginning this process of research, that was exactly the vision that I had.

In retrospect, the 2015-2016 academic year was possibly one of the worst years to be trying to recruit science teachers to take part in an unknown venture. The new Junior Cycle *Specification* was in its first year of implementation. As teachers, we were all trying to make sense of a curriculum that had changed from a very specific list of objectives to one which had not only broadened in terms of material, but also become a list of 'Learning Outcomes'. This meant that teachers were under an inordinate amount of pressure trying to determine exactly what we were meant to be teaching, and what the students were meant to be doing and learning, in order to cover each topic. This will be further discussed in Chapter Seven.

However, the experience was not without its learning. The feedback from the first cycle of webinars was especially enlightening. Signing up for the course, teachers expressed an interest in learning new teaching methodologies, and accessing resources to improve their practice. However, one of the key messages that I had not anticipated from teachers' expectations in registering for the webinars, and highlighted in their feedback after the webinars, was that teachers also wanted an opportunity to interact with other teachers. In registering for a CPD workshop, most teachers expect to talk to other teachers, discuss ideas and share experiences (Glogowska et al., 2011; Ng, 2007; Yates, 2014). Although the formal learning that takes place in a CPD programme is useful, especially in times of curriculum reform, it is the informal sharing of knowledge that takes place in the margins of such events that teachers treasure. Indeed, the literature (Boud & Hager, 2012; Gaines et al., 2019) points towards the increasing importance of recognising informal CPD opportunities, while acknowledging the need for formal courses and training activities.

In reference to the research sub-questions, however, the outcomes of the research are mixed. I cannot provide a definitive answer to the first research question, whether technology can be used to support the implementation of inquiry-based learning in *Gaelscoil* science classrooms. As had originally been planned, the series of webinars would be repeated over the course of three years. The ISE portal was available, but so cumbersome to use during the first cycle of webinars, that I only mentioned it in passing during the last webinar. The Lesson Authoring Tool, of which more will be discussed in Chapter Six, was only coming online at the time. However, the further iterations of the webinar cycles would have given the ISE project more time to develop these technologies, which would have greatly facilitated my recommending them to the teachers participating in the webinars. Had the research cycles continued through a second, third and perhaps fourth iteration, more data would have been available to answer that question. As it happens, it cannot be answered at this point.

In terms of the second and third research questions, however, there is data to begin to at least suggest answers to the questions. In terms of whether teachers attach an importance to the language in which the CPD is being offered, I would have to answer in the affirmative. Although the teachers indicated that they would have attended this CPD if it had been offered only in English, most teachers said that the fact that the CPD was being offered in Irish was very important to them. I believe that this shows there is a demand for teacher CPD to take place in the language of instruction. It is not just teachers of Irish as a language that want CPD in Irish, but teachers who teach *through* the Irish language, regardless of their subject. I recognise that this poses difficulties for groups such as the PDST, JCT and the DES itself. Nonetheless, it is vital that if we teach through the national language, it should be incumbent upon organisations with responsibility for teacher CPD to provide training and resources in that language.

The answer to the third research question is more interesting. When asked if the teachers would have attended this training if it had been offered face-to-face the majority said they would. As discussed previously in Section 4.4.5.5, since the webinar platform allowed for participants in geographically dispersed areas to undertake the CPD from the comfort of their own homes, I was surprised that so many of the participants would have travelled to their local education centre to attend the course in a face-to-face setting. I believe that this is related to the teachers' wish for informal discussion amongst the participants, and making connections with other science teachers, especially if those teachers taught in a similar context as themselves, i.e. in a *Gaelscoil*. Much of these points are highlighted in the emerging discourse on using technology to facilitate online learning (Glogowska et al., 2011; Ng, 2007; McBrien, Jones & Cheng, 2009; Yates, 2014).

Finally, and more importantly perhaps, in terms of the evolving nature of the research, was the change in my own understanding of my practice. In preparing for the series of webinars, and in reflecting upon them afterwards, I was undergoing a process that allowed me to focus on my practice, both as a deliverer of CPD, and as a teacher. If I was delivering a CPD programme on inquiry-based learning, I was in effect presenting myself as an 'expert' on IBL, as Dadds (1997) highlights. The process of presenting the series of webinars raised doubts about whether I was actually behaving as I believed.

Although I had undertaken an undergraduate science teaching degree in which an emphasis was placed on teaching by inquiry, the intervening years had shown little evidence of me teaching in this manner, as I understood inquiry. Even having participated in the initial series of webinars by the ISE project, I hadn't fully engaged with IBL, and made an effort to understand what it meant in my practice. In addition, as alluded to in Section 4.4.5.7, the feedback from the teachers participating in the webinar series requested some additional examples of IBL in practice, a request I would have struggled with at the time.

I did not have a firm understanding of IBL. I therefore became curious as to the extent to which inquiry features could be identified in my lessons. I had to clarify for myself my own thoughts on IBL, and determine whether I actually behaved this way. This would require additional reflection on my practice.

Chapter 5: Investigating My Own Practice

5.1 Introduction

In an effort to better understand inquiry-based learning, and the extent to which I can claim I use inquiry methods in my lessons, I reflected on my own practice. There were a number of questions that I had regarding my teaching including: when I planned an inquiry activity, or lesson, did the lesson progress as I had planned?; similarly, if I planned a lesson that did not explicitly contain an inquiry element, were there still some features of inquiry present?; to what extent would a stranger observing my lessons agree that there was inquiry present in my lessons?; and do my teaching practices inform what I think inquiry-based learning is, or is the converse true?

The majority of teachers in Ireland, after they had completed their initial teacher training, will experience few observations of their lessons by third parties. I am inclined therefore, for the purposes of this chapter, to imagine a Department of Education inspector undertaking an observation of my lessons, and whether they would agree with my own opinions on my teaching practice. The chapter begins with a brief explanation of DES inspections, and outlines the research questions this chapter seeks to address. I then offer a brief description of my understanding of IBL before I undertook this research, and go on to outline a number of episodes from my teaching practice. Each episode describes one of my lessons, or lessons with a team-teaching partner, or other aspects of science teaching in my school, and attempts to investigate whether inquiry is present and the extent to which inquiry is present. I conclude the chapter with a discussion of how the episodes have contributed to my understanding of inquiry-based learning.

5.2 Context - Department of Education Inspections

The Department of Education and Science Inspectorate was instituted by the Education Act 1998 (DES, 1998). The functions of the Inspectorate, as described in the Act, include visiting schools to evaluate the "quality and effectiveness of the education provided… including the quality of teaching and effectiveness of individual teachers"; evaluating "the education standards" in schools; and advising "teachers and boards [of management] in respect of the performance of their duties, and, in particular, assist teachers in employing improved methods of teaching and conducting classes" (p. 16). These school visits can take one of several forms. Whole-school evaluation (WSE) inspections generally take place over the course of five days and look at all aspects of the school including management, planning, school self-evaluation, and teaching and learning. Shorter inspections include Management, Leadership and Learning (MLL) inspections, which tends to focus on school administration, and Subject Inspections, which focus on the teaching and learning in one subject area. In all inspections, observations of teachers in a classroom setting take place.

As a result of such school inspections, the Inspectorate issues a report, which highlights areas which are satisfactory, and recommendations for improvement. All Inspectorate reports are published on the DES website[18]. An examination of Department of Education inspection reports into science teaching shows that greater emphasis on IBL is being expected of science teachers in recent years. A majority of reports include either a satisfactory level of inquiry methods being used in classes, or have as one of the recommendations for improvement an increase in the use of inquiry. However, it is unclear how familiar the inspectors are with IBL and its variations, which were described in Section 2.3. In addition, unfortunately, the inspection reports do not state the material being covered in the observed lessons, the age groups involved, the learning objectives planned for the lessons or any other factors. These factors can impact on the use of inquiry in the lesson, as described in Section 5.3.6.4.

[18] www.education.ie/en/Publications/Inspection-Reports-Publications

5.2.1 Research Questions

With regard to both the new Junior Cycle Science *Specification*, and the increased requirement to demonstrate the use of inquiry methods by the DES Inspectorate, as well as my experiences of delivering the CPD described in Chapter Four, I have found myself questioning whether I am actually using IBL in my lessons. Thus, the research in this self-study can be framed in terms of searching for answers to the following question:

II. Can I claim to be using inquiry in my practice?

Again, McNiff's (2002) concept of the research resembling a "spiral of spirals", with additional questions for investigation spinning out from the original inquiry, emerges during the research, resulting in two related sub-questions:

iv. What does inquiry in the classroom look like in my practice?
v. Do our assessment approaches support the introduction of inquiry?

5.3 Research Narrative – Am I teaching by Inquiry?

In order to determine whether I can claim that I am implementing inquiry in my teaching, I will undertake a self-study of my practice in this chapter. Several episodes, as described in my reflective journal, will be outlined in turn in the following subsections. Bearing in mind the discussions that have taken place in Chapter Three, these episodes have been chosen as vignettes of my practice, illustrating "nodal moments" (Bullough and Pinnegar, 2001, p. 19). These moments, or episodes, are being presented as separate cases in my study of my practice, although a common tread runs through them. In each case my approach, or our collaborative approach, to aspects of the lesson will be retrospectively viewed and analysed using an appropriate rubric, be it Blanchard et al. (2010), Smithenry (2010), or the features and variations of inquiry described by the NSES (NRC, 2002). Inquiry characteristics as described in Chapter Two will be highlighted, if present. To further aid in reflection on my practice, several approaches will be used as appropriate to the situation: both Brookfield's (2017) lenses and assumptions will be used, as alternative viewpoints through which the episode can be viewed, and as a means of interrogating my underlying assumptions about my practice, respectively; Ghaye's (2011) strengths-based reflection will add a positive perspective to the reflection; and Gibbs' (1998) reflection cycle will be employed to study my emotions as the episode progressed.

The episodes under study in this chapter primarily took place in October, November and December 2016. However, in Episode 5 (Section 5.3.6) I have included reflections on two additional lessons, which took place in October 2017 and November 2018 to illustrate a progression from year to year. As explained in Chapter Three, the major source of data in this chapter is my own journal from the period in question, although this is supplemented in Section 5.3.3 by additional materials such as excerpts from examinations, and references to a subject department meeting, the minutes of which are included in Appendix F.

I am conscious, in using this data from my journal, of both Feldman's (2003) and Wibberley's (2012) exhortation to provide a description of how the data is used to construct the representation of my practice. Each episode described in this chapter is derived from one journal entry, which provides a narrative of one lesson. Although other journal entries also discussed many of the same issues, such as the second-year class group discussed in Episode 1, or other experiences of co-teaching with Teacher D, discussed in Episode 5, I decided to limit each episode to one journal entry, to try to provide a boundary to each case being studied.

Furthermore, I decided not to provide a transcript of each journal entry in its entirety for two reasons: first, that the entries tended to veer into related, but irrelevant, topics as the narrative progressed; and second, that some of these segues tended to discuss students, other teachers or my own personal life in detail. For these reasons, the journal entries would have required substantive editing before being presented, thereby negating the purpose of their inclusion. For the same reason, I decided that it would not be realistic to include their contents as an appendix. In order to construct the episodes below, the general narrative presented in each journal entry is preserved, describing the structure of the lesson, my observations and emotions. As many quotations from the journal entries as possible are included to add richness to the episode, where their inclusion did not overly affect the flow of the description.

5.3.1 Prologue – My Understanding of IBL

In order to chart the development of my understanding of IBL, I begin by looking back to my understanding of IBL before undertaking this research. I described myself in Chapter One (p. 2) as entering the teaching profession with 'an understanding of IBL'. This understanding was primarily shaped by two experiences as an undergraduate. The first was a semester-long electronics laboratory conducted through inquiry, based on the "Physics by Inquiry" textbooks (McDermott, 1996). Based on that understanding of inquiry, as part of my undergraduate final-year project, I designed and delivered a series of inquiry lessons on the topic of chemical bonding to a group of students who were considering choosing chemistry as a subject for the Leaving Certificate.

In retrospect, both of these cases were examples of structured inquiry (Blanchard et al., 2010). In each case, the student was guided through the concepts by a series of worksheets, answering each problem in turn as the instructor circled from group to group to check progress and understanding. The worksheets were designed to keep the students on-task, and allowed the lessons to be structured so that the material would be covered within the desired timeframe.

My impression of IBL before undertaking the ISE webinars was therefore somewhat incomplete. Although I had knowledge of the existence of different models of inquiry, I had no experience of using any of them in class, or of being in a situation in which I was the student in a lesson designed in that manner. I was also aware of the fact that there were levels of inquiry, although if I were to be honest with myself, that awareness was limited to a difference between 'open' and 'not open' inquiry. For me, designing an inquiry lesson meant creating worksheets of questions and problems to guide students through material, thereby allowing me to circulate through the class and check student understanding. Needless to say, given the work involved in creating the worksheets, lessons of this type did not happen very often. Similarly, planning one lesson within the framework provided by one of the models of IBL, just so that I could say 'this was an inquiry lesson', was something that I rarely attempted within my teaching practice.

To a degree, participating in the ISE webinars did not strengthen my understanding. As previously described, the ISE project had developed their own 5-stage model of IBL, and this did not seem radically different to the other models of IBL available. In addition, the development of the ISE Lesson Authoring Tool, which will be discussed in further detail in Chapter Six, further reinforced the concept that inquiry means using an IBL model to plan a lesson in a particular sequence of activities and/or using structured worksheets to guide students through an activity.

Upon embarking on delivering the series of webinars described in Chapter Four, I was not convinced that I made use of inquiry on a regular basis in my teaching. I found it difficult to identify small changes that could be made to a 'regular' lesson to begin incorporating elements of inquiry. This was the predominant reason for the first cycle of webinars being little more than a regurgitation of the ISE webinars, but *as Gaeilge*. I had heard the original webinars being delivered, and I had subsequently re-delivered the same content, but, in retrospect, I don't think I had digested that information to form my own understanding of inquiry. I was merely mirroring other people's understanding.

The subsequent episodes in this chapter, therefore, show some of the stages in my developing understanding of IBL in my teaching practice.

5.3.2 Episode 1: When a non-inquiry lesson does contain inquiry

This episode relates to a double class period, 80 minutes in duration, on a Monday morning, with the second-year group that I teach. This group is noisy, easily distracted and can be difficult to keep motivated and on-track. On this day, I had returned from a foreign trip late the night before, and my cooperating teacher[19] (Teacher B) had just moved house that weekend, and was coping with living on a building site with a young child. Neither of us were feeling particularly energetic, and we discussed how we were going to approach the material for the class.

> Which is why I was *really* not looking forward to the double second years first thing.… I decided we were going to do the experiment on measuring heart rate before and after exercise. We discussed whether to attempt doing it in an inquiry method, but given the class group, and my emotional and physical state, we decided we wouldn't. And, that's the thing about inquiry, isn't it? (Journal Entry, 5 December 2016)

Upon later reflection, the idea of attempting to undertake this particular experiment as 'an investigation' or making use of one particular IBL model doesn't make a lot of sense. To break the students into small groups so that they can individually discuss the 'best' method of measuring heartrate before and after exercise seems excessive. There aren't many different ways of conducting such an experiment. At the time, however, it was not this rational objection to the inquiry method that was behind the decision not to attempt

[19] Our school, due to increasing enrolment in Gaelscoileanna, had seen a large increase in student numbers in the previous 6 or 7 years, with the number of students doubling in this time. In order to cope with the number of students, class sizes have increased, with 30 students per class being common. This is above the maximum number of students permitted in the science laboratory, which should be no more than 24. To circumvent this restriction, two teachers are timetabled together when practical double lessons are scheduled, and they may decide to each take half of the students to separate laboratories. However, there are rarely two laboratories free at the same time, and teachers in this case tend to engage in what we call "team teaching". This is not actually team teaching, as generally one teacher does the teaching, and the other teacher tends to help with crowd control and assisting the primary teacher during practical activities.

an inquiry method, but more personal reasons relating to the humour of the teachers, and the general behaviour of the class. So, instead, we conducted the class as a plenary group, and posed questions relating to the experiment that lead to the students providing their opinions on how the class could conduct the experiment.

> That much said, we did discuss with the students various aspects of how to carry out the experiment, and sought their opinions. (Journal Entry, 5 December 2016)

Together, as one large group, we carried out the experiment, based in part on the suggestions from the class, and in part from the teacher's suggestions. The group chose the length of time for which to count the pulse, the length of time to exercise, and for how many minutes afterwards to measure the pulse rate. Donnelly et al.'s (2014) question-answer-comment sequences would have been much in evidence to any observer in this particular lesson, but the students did not have any difficulty in providing their own interpretations and thoughts on how the experiment should be performed, in contrast to the expected "what the teachers wants to hear" responses (p. 2031).

And for this particular experiment, it is more fun conducting the experiment as a group. There is concentrated silence for several seconds, as they all measure their pulse. Then two minutes of complete mayhem as the entire class exercises together – jumping jacks, running on the spot, or just plain dancing to the music we had playing at high volume. Followed again by cycles of chat while they calculate their pulse rate, punctuated by that intense silence as they all measure their pulse at one-minute intervals. After several cycles of measuring pulse rate, the students had already begun to notice a trend in their results, with no input required from the teachers. Given the age group of this particular class, it had to be suggested to them that a graph might be an appropriate visual way of presenting the data obtained from the experiment, and it was explained to them how to draw a scatter graph in this case.

Upon reflection, using Ghaye's (2011) strengths-based reflective practice, I argue that deciding to conduct the planned lesson, but in a slightly different way, is a sign of the flexibility of the teachers. Rather than engaging in a chalk-and-talk lesson, which would have suited the needs of the teachers that morning, we instead altered the existing plan slightly. Looking at the lesson through Brookfield's (2017) student lens, the students were given the opportunity to take part in an engaging lesson, and enjoyed themselves while still meeting the objectives the teachers had set for the lesson. Similarly, employing Brookfield's (ibid.) lens of colleagues' perceptions, both of us teaching the class that day were agreed that the amended lesson had gone better than the original plan would have. The collegial atmosphere observed between the students, and between the students and teachers, which created a constructive learning environment was a positive experience for all of us. Conducting the class even altered my own mood, as my journal from that evening showed: "But it was fine - good, even. I was a little bit giddy, a bit hyper. [Teacher B] helped, a lot, so I should really say thanks properly" (Journal Extract, 5 December 2016).

It is only now (2019), at a remove from the process of constructing the bricolage from these vignettes and the rest of the research underpinning the dissertation, that upon re-reading my journal entries for the umpteenth time, I realise that this lesson also marked my own initial engagement with the concept of different levels of inquiry:

> In any case, we didn't do "an inquiry" class. Sorry. I just googled "continuum of inquiry" - the phrase had been used in the new science specification, but hadn't really been explained very well. There are a couple of pretty good tables comparing the different levels of inquiry. Why hadn't I done that before? (Journal Extract, 5 December 2016)

Using a table found on the internet from a non-refereed source (plcmets.pbworks.com/w/page/17241037/Bonnstetter%20Levels%20of%20Inquiry), I compared the features of inquiry to my thinking back over the lesson from that morning, and concluded "What does this mini-analysis lead us to conclude about the class I carried out this morning with [Teacher B]? I think it was somewhere between Structured and Guided - which actually isn't too bad for a class that I had initially thought wasn't inquiry at all." (Journal Extract, 5 December 2016). Although, as I stated in Section 5.3.1, I was aware of the existence of levels of inquiry, and had both participated in, and delivered, a webinar on inquiry that specifically addressed the concept, it was not until this point that I fully understood what the differences between the levels of inquiry meant. The process of reflection undertaken in mapping the extent of inquiry in my own lesson against a table found on a random website did more for my understanding of levels of inquiry than any lecture or workshop had done before.

A similar conclusion regarding the level of inquiry present in the lesson is reached when comparing the lesson with Blanchard et al.'s (2010) characteristics of an inquiry lesson presented in Table 2.4. Although it was the teachers who had suggested the question to be investigated, the students determined how best to collect the data, tabulated the results as best they saw fit, and most students were then able to provide their own interpretation of what was taking place. In this case, the lesson sits somewhere between Level 1: Structured, and Level 2: Guided. As can be seen, although it may be planned that a didactic, chalk-and-talk approach may take place, with some simple questioning, and encouraging the students to become involved in the process, the lesson would not be completely without inquiry characteristics.

5.3.3 Episode 2: When assessment contains inquiry characteristics

One of the ongoing discussions in the literature surrounding IBL pertains to assessment. For my practice, and as will be further discussed in Chapter Seven, the introduction of the Junior Cycle Science *Specification* has highlighted one crucial issue as teachers: what are we supposed to teach if we don't know how the terminal exam will be designed; to what extent will content knowledge be assessed, versus skills and scientific reasoning? As discussed previously, the *Specification* was published in its final form in the Spring of 2016, some six or seven months before its implementation in the new academic year beginning September 2016. At that stage, and indeed until November 2016, final decisions had yet to be made by the State Examinations Commission (SEC), the National Council for Curriculum and Assessment (NCCA) and the Department of Education and Skills (DES) regarding what form the continuous assessment portion of the award would take. Until that late stage, all that was certain was that 90% of the final grade would be awarded on the basis of a terminal, written, common-level, two-hour exam. The remaining 10% would be awarded for some form of work that would be carried out by the students over the course of the three years. Although, to some, it may appear that a full 10% of the grade being awarded for continuous assessment is generous, this is actually a retrograde step. Under the previous system, 35% of the marks for the terminal grade are awarded for continuous assessment components.

However, the main issue in my context at the time[20], as the first academic year of the new course continued, was interpreting the new *Specification* with a view to determining what material may be assessed on the terminal written examination, and thereby planning the material that will be taught in class and assessed on the school house examinations at Winter and Summer. The *Specification* is deliberately open enough that teachers have sufficient leeway to teach the course as they feel most comfortable, either organising the material topically, thematically or in whatever manner they see fit. On the one hand, this flexibility allows for greater freedom in allowing teachers and students to study the topics that most interest them in greater depth, allowing for a richer learning experience. On the other hand, it is highly unlikely that any two teachers will teach the same material to the same depth and breadth.

This situation was highlighted in my own practice as the science department discussed the layout of the Winter examinations at a subject department meeting, in November 2016. It quickly became clear that different teachers had placed greater emphasis on different aspects of the material. This is highlighted by one extract from the very beginning of the meeting minutes (the full minutes of the meeting can be found in Appendix F), which states:

> Easaontas/difríochtaí idir ábhar múinte ag múinteoirí difriúla – eg tréithe nithe beo: 7 sean-tréithe vs 5 tréithe i leabhair eile *[Disagreement/differences between material taught by different teachers – eg characteristics of living things: 7 old characteristics vs 5 characteristics in other books]* (Meeting Minutes Extract, 8 November 2016).

We can see that, at the very beginning of the first year of the new course, in the first topic that was taught to students, different teachers had approached the same material differently. This difficulty was especially evident on a section of the course that we had not taught before; the section on 'Earth and Space'. As a physics and chemistry specialist,

[20] 2016/2017 academic year

I have had a long-standing interest in astronomy and space exploration and a love of science fiction books and films. However, upon discussion with the biology specialists in school, when planning for the new science course, it quickly became evident that some lacked the ability to name the planets of the solar system, not to mention describing phenomena further afield. This discrepancy in scientific knowledge inevitably lead to differences in teaching the 'Earth and Space' component of the new *Specification*.

At the beginning of the year, as the science department was planning the material to be covered, it was decided that we would focus on Learning Outcomes (LO) 1 and 3 from the Earth and Space strand. The wording for these Learning Outcomes from the *Specification* are:

> LO1: Students should be able to describe the relationships between various celestial objects including moons, asteroids, comets, planets, stars, solar systems, galaxies and space
>
> LO3: Students should be able to interpret data to compare the Earth with other planets and moons in the solar system, with respect to properties including mass, gravity, size, and composition.

As can be seen, LO1 covers a wide range of celestial bodies, and students should be able to describe "the relationships between" each of them. However, what is not clear is what relationships the *Specification* refers to. Nor is it clear to what depth these relationships should be studied. Clearly a mathematical treatment of the gravitational relationship between the celestial bodies is beyond the ability of most Junior Cycle students. However, it is not expressly excluded by the *Specification* as it stands. In addition, the inclusion of the word "including" implies that teachers are free to include other celestial bodies as their own preference and knowledge allows. Similarly, LO3 allows for the flexibility to study the planets in more depth than the *Specification* describes. However, we are faced again with the lack of detail regarding depth of treatment. When describing the composition of the planets, is it merely enough to say that they are solid, or gaseous? Or should the composition include such details as the percentage, say, of iron in Earth be compared to that of Mars?

Some teachers had spent time discussing the planets in the solar system in great detail, but placed less emphasis on other features of the solar system such as comets and asteroids, only mentioning that they exist. Other teachers spent less time on the minutiae of the planets and their composition, but included in their lessons details about the asteroid belt, including some of the principal asteroids and some of the main comets. Clearly, to incorporate the disparate learning encountered by the students into one common written examination, some innovative questions were needed.

At a subject department meeting, we decided that, although some of the questions on the Winter examination would be 'standard' recall questions, assessing the students' understanding and retention of basic scientific facts and knowledge, several questions would be more open ended, allowing the students who had more of an interest, and who had undertaken more in-depth independent study, the ability to 'show off' their knowledge. Rather than being asked to merely name the planets in the solar system, and describe their features, which would have disadvantaged those students who had placed less emphasis on the planets, more open questions were used to allow the students to displaying their knowledge. The question, as asked on the paper, and is shown below in Figure 5.1 asks the students to "*draw a diagram of the solar system in which you live. These details should be visible and labelled. (a) The star; (b) The planets and any dwarf planet in the correct order; (c) The location of the Oort cloud; (d) The location of the Kuiper belt; (e) The location of the Asteroid belt.*"

Ceist 7

Tarraing léaráid den ghrianchóras ina bhfuil tusa i do chonaí. Bíodh na sonraí seo le feiceáil agus **lipéadaithe** ann.

a) An Réalt

b) Na plainéid agus aon abhacphlainéad san ord ceart

c) Suíomh an Scamall Oort

d) Suíomh an Chrios Kiuper

e) Suíomh an Chrios Astaróideach

Figure 5.1: A Question on the First-Year Winter Science Examination

However, what we did not include in the question, but which was discussed as part of the marking of the examination, was that students would be given extra marks for making an effort to draw the diagram to scale; this scale could be either drawing the planets to scale or drawing the distance between the objects and the sun to scale. These points from the minutes of the meeting indicate that the concept of 'bonus points' was discussed, and between the time of the meeting and the examination the teachers agreed with this course of action: "Bonus points más féidir fithis coiméad éigin a tharraingt? [*Bonus points if the orbit of a comet is drawn?*]" (Meeting Minutes Extract, 8 November 2016).

This was done to give recognition to those students who had taken an extra interest in the model of the solar system, and obtained a greater understanding of the need for the use of scales in describing the heavens. Similarly, although the question did not explicitly look for it, we would award additional marks to those students who, in studying the planets, had paid attention to any moons that planets may have orbiting them, and marked them on their diagram. It should be noted that these extra marks did not in any way punish those students who had only answered the question as asked; these marks were awarded *in addition* to what was asked. In theory, a student who otherwise would have achieved 100% on the test, could have scored higher that 100% if they had provided additional information in answering this question; in reality this didn't happen.

Another question on the Winter examination provided to the first-year students was a question relating to investigations, and how to best construct a scientific experiment. Although Blanchard et al.'s (2010) rubric cannot be used to ascertain the level of inquiry in this question, or indeed in the examination as a whole, it may be possible to use the variations of inquiry as described in Table 2.2 (discussed in Section 2.3.2.2, and replicated below for convenience) to examine the question.

Table 2.2: Essential Features of Classroom Inquiry and Variations (NRC, 2000, p. 29)

Essential Feature	Variations			
1. Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided by teacher, materials, or other source	Learner engages in question provided by teacher, materials, or other source
2. Learner gives priority to **evidence** in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Learner given data and told how to analyze
3. Learner formulate **explanations** from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence and how to use evidence to formulate explanation
4. Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	
5. Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to use sharpen communication	Learner given steps and procedures for communication

More ——————————Amount of Learner Self-Direction —————————— Less
Less —————————— Amount of Direction from Teacher or Material —————————— More

The question began with a situation and asked the student to construct a testable hypothesis, as shown in Figure 5.2. The question asks "*Aoife wants to come in first place in the race next weekend. She has two pairs of running shoes and wants to determine which pair of shoes would be best to use to win. She decides to design an experiment. (a) Write a suitable hypothesis that Aoife could use for this experiment*".

Teastaíonn ó Aoife a theacht sa chéad áit i rás reatha an tseachtain seo chugainn. Tá dhá phéire bróga reatha aici agus teastaíonn uaithi a fháil amach cé acu péire bróg is fearr le n-úsáid chun an bua a fháil. Beartaíonn sí turgnamh a dhearadh.

a) Scríobh síos hipitéis oiriúnach a d'fheadfadh Aoife a úsáid don turgnamh seo

Figure 5.2: The students are asked to compose a "suitable hypothesis"

In this case, the students had to compose a hypothesis in which 'Aoife' could test her two pairs of running shoes to see which would be best to wear to win a race. This correlates, in essential feature 1 (Table 2.2), with the student sharpening or clarifying the question provided by the material. Figure 5.3 then shows the question continuing "*In the experiment, Aoife decides to run two 100m races with the different shoes and measure* *the time taken. She runs the first race with one pair of shoes on a Monday after school. The day is windy and wet. She records a time of 12.2 seconds. She runs the second race on Tuesday morning after breakfast when the weather is nice. The takes 12.0 seconds. The conclusion Aoife reaches is that the second pair of shoes is the best to use".* In this case, in essential feature 2 (Table 2.2), the student is being given data, and asked to analyse it, rather being told how to analyse it.

Don turgnamh, socraíonn Aoife ar dhá rás 100m a rith leis na bróga difriúla agus an t-am a thógann sé a thomhas. Déanann sí an chéad rás le péire bróga amháin Dé Luain tar éis na scoile. Tá an lá gaofar agus fliuch. Éiríonn léi é a dhéanamh i 12.2 soicind.

Déanann sí an dara rás maidin Dé Máirt tar éis an bhricfeasta nuair atá an aimsir go deas. Tógann sé 12.0 soicind.

Is é an conclúid a dhéanann Aoife ná gurbh iad an dara péire bróga is fearr le n-úsáid.

b) An turgnamh maith é seo an gceapann tú? Cén fáth?

____

____

____

c) Ainmnigh dhá athróg gur chomhair do Aoife a choiméad mar an gcéanna

1. ______________________________

2. ______________________________

d) Cén athróg gur chóir a bheith difriúl sa turgnamh?

____

e) Scríobh síos dhá moladh a bheadh agat chun an turgnamh seo a fheabhsú

1. ______________________________

____

2. ______________________________

____

Figure 5.3: Continuation of question on experiment design

The students are then asked for their opinions; "*(b) Is this a good experiment, do you think? Why?; (c) Name two variables that Aoife should keep the same; (d) Which variable should be different in the experiment?; (e) Write two recommendations you would have to improve the experiment".* Part (b) could be interpreted as essential feature 3 (Table 2.2) in which the students are asked to formulate an explanation from the evidence with which they have been provided. The final part of the question, part (e) asks the students to give two suggestions to improve the experiment, which could correlate with essential feature 5 (Table 2.2) in which the student communicates reasonable and logical arguments. In fact, the only essential feature missing is feature 4, in which the student connects their explanations to scientific knowledge. In this case, this feature may be present in the answers the students provide, but the question does not explicitly look for it.

This episode describes an examination, rather than a lesson or an investigation. As such, it could be claimed that it cannot contain inquiry elements, and to ask the question whether inquiry is present may not make sense. However, I make the argument that, as part of a wider implementation of an inquiry approach in my school's science department, the incorporation of more open questions, and the acceptance of a wider range of answers, on the science Winter examination indicates an increased openness to inquiry amongst the science teachers in my school. For me, and the other science teachers in my school, it signals a shift away from science being seen as merely the rote learning of facts, and assessment being a method of determining the recall abilities of students, towards one in which science skills and understanding are important. This will be further addressed in Chapter Seven. Similarly, the inclusion of questions asking the students to give their opinions on the design of investigations indicates that inquiry is taking place in the classroom, and that the teachers, myself included, are willing that our students' experiences of inquiry be reflected in examinations.

5.3.4 Episode 3: When questions are answered with questions

As so much of teaching takes place in a whole-class situation, it is important from an inquiry perspective that the teacher uses different types of questioning to promote higher-level thinking amongst the students. Donnelly et al. (2014) discuss question-answer-comment sequences, so widespread within classrooms. As described in Section 2.3.2.4, students often respond with what they think the teacher wants to hear, which is the 'correct answer'. Upon receipt of the answer, the students is rewarded with a positive comment, and subsequent high marks. Given that, when a teacher poses higher-order questions in the science classroom, there may not be one correct answer, or the teacher is eliciting the students' honest opinion, in my experience the answer has often been an embarrassed silence, or a careless shrug. However, in one to one, or small group interactions with the teacher, students seem less inhibited, and are more willing to take a chance on being wrong. This is highlighted in an episode which relates to the third-year class I co-teach. On this particular day, the main teacher was absent, and I had taken the entire class group by myself to the computer laboratory, to carry out some virtual experiments.

As part of the science department's experimentation with interactive simulations and online resources, we carry out some experiments virtually, making use of the simulations provided by the University of Colorado on the Phet website (phet.coloradu.edu). In this lesson, we were conducting two experiments: determining whether a material is a conductor or insulator, and verifying Ohm's law. In each case, the simulation allows the student to construct a simple electronic circuit, and realistically simulates the results that would be obtained in the real world. As a teacher, it allows me to walk around the room interacting with the students on a one-to-one basis, or in small groups, safe in the knowledge that I can turn my back on the others without the fear that they would damage equipment or injure themselves.

Each year, when we conduct the classes in the computer laboratory to complete these experiments, I provide as little information to the students to carry out the first experiment beyond simple instructions such as "use this Phet simulation to construct a simple circuit from a battery, a bulb and the assorted materials in the 'grab bag', and note which of them are insulators and which are conductors". The Ohm's law experiment generally needed a little more guidance, and was usually accompanied with a worksheet to guide the students. Although this was never a conscious decision at the time, I now realise that I was allowing for the more able students to complete the experiment at Level 2: Guided (Blanchard et al., 2010), and that the support and directions I provided to students who needed it would lower the level to Level 1: Structured, or Level 0: Verification, as the needs of the student dictated.

Most students, of any ability, are able to construct a circuit with a battery, some wires and a bulb. However, occasionally, a student has difficulty with this seemingly simple task, as occurred on this particular day.

> In any case, some of them were working away independently. And got both experiments done properly within the double class. But then there was A, over on his own by B and he did not have a breeze what was going on. It took him a good forty minutes to figure out how to use the simulation, despite B on one side trying to help, and C on the other. And once he got up and running, of course the first thing he did was connect up a battery in a circuit, without a bulb… and lo and behold - fire! (Journal Entry, 9 January 2017)

It happens to everyone when using this simulation. Rather than an error message being displayed notifying the user that there is a short circuit, the simulation simulated the battery catching fire, a scenario the students find highly amusing. However, given that the students had a limited amount of time in the computer laboratory, *"I finally got annoyed with him a bit, so he asked for help. Being the annoying teacher that I am, I didn't just answer questions! I had to respond to all of his questions with another question…"* (Journal Entry, 9 January 2017). The following extract from my reflective journal is representative of the conversation that took place between us, with students B and C listening occasionally; representative only, in that the original conversation took place in the Irish language, and was occasionally interrupted. This, however, should not be viewed as a fault in the research, as Stake (1995, p. 66) stated that "getting the exact words of the respondent is usually not very important, it is what they mean that is important", and I believe that the meaning of the student's questions and answers are clear from the interaction below.

> A: "Why is my battery on fire?"
>
> Me: "I don't know… why is your battery on fire?"
>
> A: "… I don't know"
>
> Me: "Well… look at these things moving around the circuit through the wires really quickly… what are they?"
>
> A: "Eh… electrons"

Me: “Okay… and what does a battery do to electrons?”

A: “It pushes them…”

Me: “Try saying that in more scientific language”

A: “It gives them energy?”

Me: “Better. So, all these electrons are coming out of the battery with energy, they are going around the circuit, and back to the battery. Do they have more, less or the same amount of energy when they get back to the battery, do you think?”

A: “Less?”

Me: “Why?”

A: “Uh… no. The same”

Me: “Why?”

A: “Cos there is nothing there to use the energy the electrons have”

Me: “Exact…”

A: “Oooh… so I need to put a something… like a bulb or something in there? To use the energy?… And then my battery won’t be on fire!”

At this point, the student inserted a bulb into the circuit they had constructed, and the circuit behaved as expected, i.e. without the battery catching fire. The student, with that problem solved, was then free to continue with the experiment, inserting various materials into the circuit, thereby classifying them as conductors or insulators. Given that the interaction between me and the student took place in a one-on-one setting, with only two possible eavesdroppers, the student was more than willing to attempt to answer the questions. This is in contrast with how this student behaves in class, where this student is more likely to offer a “don’t know” as a response to a question in a plenary class setting.

As viewed through Brookfield’s (2017) student lens, this encounter was frustrating for the student, as was evident from their facial expression. And, trying to understand their emotion from their perspective, the frustration is understandable; they had asked for help, but rather than giving the answer directly, I persisted with asking questions. Brookfield’s (2017) theory lens provides some explanation. As described by Rutten et al. (2015), Crawford (2006) and Donnelly et al. (2014), during an inquiry lessons, the traditional roles of the teacher and student are no longer occupied, and this can be difficult, not only for the teacher, but also for the student. Traditionally, the student would ask a question, and receive an answer. In this episode, the student did not receive an answer, but was asked a question in return, creating the evidenced frustration. It is a situation in which neither the teacher nor student inhabiting their traditional roles would be comfortable.

A key component of IBL is the students' construction of new knowledge, based on their previous knowledge. The teacher can support this process through the use of judicious questioning, rather than the provision of outright knowledge, as evidenced above, in order to weave together the various pieces of knowledge that the student already has, along with the observations they are making during an investigation or other research, in order to 'discover' new phenomena or explanations for themselves. As discussed in Section 2.3, this episode tallies with the description by Creemers and Kyriakides (2006) of this type of questioning. I made use not only of product questions, eliciting the student's prior knowledge, but asked process questions, encouraging the student to make the connections between what he was seeing on the screen, and the information he already held, in order to construct new knowledge.

I don't know at what point I became a teacher that answered questions with more questions. I suspect it is something I have been doing since I began teaching, although I can't be sure. If I feel that the answer to the question the student is asking is something they should know, or that the student is merely being lazy in asking for help rather than thinking for themselves, I will generally ask a question in return. Similarly, if I feel that the students should have enough information to be able to 'put two and two together' to make a reasoned guess, I will ask for their opinion on the matter. Any attempt at logical thought to provide a response, even if the answer they give is completely incorrect, is satisfactory, in my opinion. Obviously, the student is encouraged for providing an opinion, and the misconception is corrected. The idea of asking questions of students, and correcting their misconceptions is also a point raised in Chapter Seven.

However, there are times when a simple answer is provided directly. There is no amount of support that could allow students to answer their own questions, sometimes.

5.3.5 Episode 4: When a lesson should be 'Inquiry'

This episode relates again to the misconception that there is one way of conducting a lesson for it to be considered an inquiry lesson. Given a black-or-white construct of inquiry versus traditional teaching methods, it can be easy to identify a lesson as inquiry if that was the original motivation, or if the lesson was planned a specific way. However, there is often a difference between how a lesson is planned, and how the lesson is actually carried out. The former Junior Certificate science syllabus awarded 25% of the final marks for a two investigations carried out by the students in the third year of the course. In late Autumn, the State Examinations Commission (SEC) issues three investigation titles, one each from biology, chemistry and physics, which the students would not necessarily have seen in the course of their studies, but which would bear some relation to some of the topics they had been studying. The investigation titles for the cohort completing the Junior Certificate examinations in 2017 were as follows (SEC, 2016a):

> Biology: Investigate quantitatively, to determine the impact of each additive, the effects on samples of a garden soil of adding 20% by mass of (a) sand, (b) potting compost, and (c) clay* on (i) the soil's ability to retain water, (ii) the rate of drainage of water through the soil. *Some readily available cat litter is composed of dry clay.
>
> Chemistry: Investigate quantitatively, at room temperature, the effect of dilution on the pH of (i) vinegar, (ii) a solution containing 5 g washing soda per litre of water, (iii) a solution containing 5 g sucrose per litre of water.
>
> Physics: Using conductors made of children's play (modelling) dough, investigate quantitatively the effect on resistance, calculated from measurements of voltage across and current through the conductors, of changing the conductor length and obtain data to establish whether dough colour has an effect on its resistance

The students are required to choose two of these titles. The students are then required, based on their previous knowledge, and independent research, to design an investigation that would answer the title they have chosen, carry out the investigation in class, and write a scientific report on their work. Using Blanchard et al's (2010) rubric, this can be viewed as a Level 2: guided investigation. Although it is the teacher, or rather the SEC, who chooses the question, it is the responsibility of the student to choose the data collection methods, and the method of analysing any data they collect. In theory, at least, all third-year students across the country are conducting these investigations in an inquiry manner.

The guidelines issued each year by the SEC with the investigation titles state that “The investigation(s) and report(s) presented in Reporting Booklet must be the candidate’s own individual work” and “Any incidence of suspected copying, improper assistance from another party, plagiarism or procurement of pieces prepared by another party will be thoroughly investigated” (SEC, 2016b). From time to time, accusations of plagiarism are highlighted in the press (Donnelly, 2011), although the fate of those accused is not made public. My personal interpretation of the guidelines is that there should be little to no teacher direction in the course of the investigation. However, as with any state examination component, teachers are focussed on their students achieving as high a mark as possible, and generally will give as much assistance to the students as they feel comfortable with. This amount varies from teacher to teacher.

Inevitably, even I end up providing assistance to the students, yet, as described in Episode 3 (Section 5.3.4) it is usually in the form of questions rather than directions. The students are always free to follow the questioning through to its conclusion, or to continue as they were. For the majority of students, some general direction is adequate. This year, the physics investigation raised some issues, as I described in my journal:

> Some of them really hadn’t understood the concept of resistance when they were learning about it in class, back in December. Not grasping the difference between current and voltage is understandable, to a point. But I would have thought that resistance was a fairly straightforward concept - a measure of how difficult it is for electricity to flow through a material. I had to a have a whole 5 minute conversation with the girls at the back of the room […] about what resistance was, and how the experiment they carried out showed the relationship between the length of the piece of play-doh they used and the resistance of the play-doh. And

> then, when they changed the colour of the play-doh, the resistance of the play-doh changed. (Journal Extract, 31 March 2017)

Unfortunately, this was not an isolated incident. Many of the groups of students undertaking the physics investigation required assistance, not least with groups needing reminding of the difference between how ammeters and voltmeters are connected in a circuit. Once this hurdle was overcome, most groups needed little further assistance;

> X and the person he was working with, as well as Y and Z, once they had the circuit constructed correctly, seemed to be able to carry out the experiment in much the same way as I would have done, although I probably would have changed the variables more than just three times. (Journal Extract, 31 March 2017)

However, occasionally, students lack the ability to realise that they are conducting an investigation that it no way answers the title as provided to them. Or they lack the prior knowledge to design an experiment that would satisfactorily answer the title.

> Plus, he seemed to have this notion that the same mass of play-doh had to be used for each measurement - which is fine in theory, but that means that when you change the length of the length of the conductor, you would have to change the diameter of the conductor to keep the mass the same - which I think negates the experiment completely. (Journal Extract, 31 March 2017)

Unfortunately, once one group seizes on a misconception, it can percolate through the entire class, as other students mimic what they see.

> P and Q really needed a lot more help. Again, I'm not sure they completely understood what they were measuring… and then they had the misconception that they needed to keep the mass of the play-doh constant throughout the experiment, thereby changing two of the variables at the same time… unlike the first years, who have a firm grasp on experiment design because of how we are teaching the new course, the second and third years are completely at sea when they are first provided with this level of freedom. (Journal Extract, 31 March 2017)

Therefore, these students require additional direction, to the point where, using Blanchard et al.'s (2010) rubric the students are no longer conducting a "Level 2: Guided" investigation. Depending on the students, the level can fall to a "Level 1: Structured" investigation when the students need help in deciding what data to collect, and how to collect it. This can be further decreased to a "Level 0: Verification" investigation when students have collected the data, but need the teachers' help in interpreting it. For instance, these weaker students will often need to be guided towards presenting their data in graphical form, and once this course has been decided on, the different types of graph need to be explained to them, and which one would be most appropriate for the data collected. In the case of students "P" and "Q" above, further questioning was required to lead them to a conclusion that the longer the piece of play-doh, the higher the resistance, as their data suggested.

As can be seen, although these lessons were initially intended to be carried out in an inquiry manner, as Blanchard et al. (2010) describes as a "Level 2: Guided" lesson, the difficulties students have with the material, their lack of understanding regarding previous knowledge they did not fully comprehend, and the lack of research carried out before undertaking the investigation means that increased teacher assistance is required. Similarly, the students' lack of experience in carrying out investigations independently over the preceding two years would also explain the lack of investigative skills by the students. The amount of direction provided by the teacher varies from student to student, therefore the level of inquiry experienced is different for each student, and can, for the weakest students, mean that what they are experiencing is not inquiry at all, but rather carrying out a sequence of instructions from the teacher.

5.3.6 Episode 5: A Series of Lessons

This particular episode is composed of three lessons, all with the aim of teaching the same material, but separated in time by a year between lessons. The topic in each case is 'measuring volume' and is taught to first-year students at about the same time each year. In the case of some of these lessons, it was not my own class that was being studied, but rather a lesson in which team teaching was taking place (see footnote 19 on page 144). I was acting as the second teacher, and the main teacher (Teacher D) was conducting the lessons. At this point, I wish to sound a note of caution. The extracts from my journals illustrating the progress of the lessons, and my thoughts on my actions and those of

Teacher D, read as somewhat arrogant, condescending and judgemental. At the time, they perhaps were written with those emotions. In retrospect, I think I have come to understand the motivations of Teacher D somewhat better. I will begin, however, with a description of how I imagine the lesson might be taught, and how used to teach it myself[21].

5.3.6.1 Me – How I remember teaching the topic

As described, the topic of measuring volume is generally taught to first-year students in Autumn each year. The students learn how to measure length, then area, and we move on then to the volume of a regular shape such as a cube or cuboid, the volume of a liquid, and finally the volume of an irregular shape, such as a stone.

Measuring the volume of a regular shape consists of using a ruler to measure the height, width and length, and multiplying the three values obtained. When moving on to liquids, during the discussion at the beginning of class, either as a plenary or in small groups, many students would automatically think of trying to measure the height, width and length of the volume of water given to them in a beaker but struggle to do so accurately. Some students would have had the experience of measuring the volume of a liquid at some stage, either in school in Home Economics or at home, when measuring the volume of an ingredient. Students would, however, quickly grasp the idea behind using a beaker to measure the volume of a liquid, or by using a graduated cylinder for a more accurate measurement.

Once students had understood how to measure the volume of a regularly shaped solid, and the volume of a liquid, the next step was to give each group of students a small stone, or other similar solid, and ask them to measure the volume of that stone. At this point, it would not be unusual for some of the students to automatically refer back to length, width and height, but more of the students would make the leap from their experience

[21] Until the 2108-2019 academic year, I had not had 'my own' first year class since my first year of teaching, in 2010-2011. Being a teacher with two Leaving Certificate subjects in which teachers are in short supply, Physics and Chemistry, my timetable has tended to be dominated by those classes, as for many years I was the only teacher in the school qualified to teach them. I have, however, tended to 'pick up' classes in second- or third-year as a result of teachers leaving, going on maternity leave, etc.

of measuring the volume of a liquid and realise that they couldn't simply measure the three dimensions and multiply them by each other to determine the volume.

Some of the stronger students, or simply those who were more imaginative, would at this point make the connection between measuring the volume of a liquid and this new task, and would place the stone in the graduated cylinder of water. Noting the fact that the level of water in the cylinder rose when they did so, they were able to determine that the volume of the stone was the amount by which the level of the water in the graduated cylinder rose.

Finally, the students were given another stone, this time one that was too large to fit into their graduated cylinder. After several minutes of discussion, it was decided that there was no way they could measure the volume of these large stones using the equipment they had, and most groups would ask for a larger graduated cylinder. Unfortunately, I had to inform them, the school didn't have any larger graduated cylinders. But it did have another piece of equipment that might be useful – a displacement can. Each group was given a displacement can, and asked how it could be used to determine the volume of their large stone.

As before, one or two groups would grasp the concept immediately, a few groups would take some leading questions to work out how it might operate, and there were inevitably one or two groups which needed to be shown explicitly how to use a displacement can and graduated cylinder to determine the volume of a stone.

Immediately, we can determine that this type of lesson does contain elements of inquiry, and although it could not be termed open inquiry (Blanchard et al., 2010), it falls somewhere between Level 1: Structured and Level 2: Guided inquiry. The teacher in this situation has given the question, and although has provided the students with equipment, has not explained how that equipment can be used to measure the volume of either stone. In this case, the data collection methods, the measurement of the volume of the stone, was left open to the student, although there was generally one way to use the equipment to do so. As shall be seen in Chapter Seven, this is a common occurrence in science lessons in my school.

Upon reflection, how I see the lesson as I have described it is an example of Brookfield's (2017) paradigmatic assumptions. I assume that carrying out the lesson as planned will lead to most of the students being able to undertake the activity, and understand the concepts behind the activity, with some support. This leads to the prescriptive assumption that all lessons should be carried out in this fashion, and the causal assumption that, since this lesson worked well in the past, that it will always work as intended. As shall be uncovered in the following sections, these assumptions are not always correct.

5.3.6.2 Teacher D – Autumn 2016

The first time I had the opportunity to be a cooperating teacher with Teacher D, I was a little taken aback with his authoritative manner in the classroom, which was in complete contrast with his laid-back personality. His style of teaching was of a more traditional variety, expecting total silence and perfect obedience. Students were not to do anything without being told what to do beforehand, and how to do it. This included handling and using laboratory equipment during a practical lesson.

As I set about gathering the equipment from the storeroom and distributing it to students[22], Teacher D began explaining what would happen in the lesson. The students had already covered the calculation to determine the volume of a cuboid shape in the previous lesson, so were to begin directly with the volume of a liquid. Teacher D drew a graduated cylinder on the board, told students what it was called, and how to use it. He then poured some water into a graduated cylinder and showed the students how to read the volume..

---

[22] It is a source of frustration to science teachers in this country that, unlike in many other countries, and in private schools in Ireland, we do not have lab technicians. Science teachers are expected to assemble the equipment needed for any experiment themselves and return it to storage afterward. While it would be theoretically possible for teachers to do this in the morning for all the lessons of that day, it may be the case that other teachers will also need that equipment that day. In addition, if there are a full day of practical lessons, it would be difficult to keep all the different pieces of equipment laid out in the laboratory as the different classes come and go. Many science teachers forgo their break and lunch to prepare laboratory equipment for subsequent lessons. Less ideally, science teachers often must physically leave the laboratory in search of equipment during a lesson, because it was not available earlier, or because they did not have time to collect it beforehand.

> What to say about today? Well, it was interesting, to say the least. That double class with [Teacher D] and the first years. The whole aim of the new Junior Cycle is that students learn by Inquiry and through investigations as much as possible - at least that's my reading of it. And today, the students were doing on of the activities that I would have thought of as one of the easiest to do investigatively - measuring the volume of a small stone, a large stone and a liquid.
>
> If this was my class, I would have supplied the students with some stones, and asked them to come up with a method of measuring the volume. Eventually some would have come up with using the displacement of liquid, so we would need graduated cylinders. They would have figured it out. The whole meniscus thing would have to be explained to them, but that would have been fine. For a large stone, again, some thinking would have been involved. But they get there in the end… (Journal Extract, 27 October 2016)

Granted, at this point, explaining how to use a graduated cylinder rather than letting the students play around with it themselves is not wrong[23]. The above extract, in fact, highlights another one of Brookfield's (2017) prescriptive assumptions which I find present in my thinking from time to time; namely the notion that because I tend to teach in a certain manner, that I think other teachers should do so too. In reality, there are some factors which should be highlighted to the students in order for them to read the volume correctly, such as taking the meniscus into account, and making sure that they read the volume of the liquid at eye level. After explaining these to the students, Teacher D told them to put some water in the graduated cylinders and measure the volume.

As I and Teacher D walked around the room, checking that students understood the process, such as it was, it appeared that everything was in order. I then distributed the small stones to each group as Teacher D settled all the students and explained how to measure the volume of the stone. This consisted of him drawing the graduated cylinder

[23] I must continually remind myself that this dissertation is not me delivering judgement on the actions of other teachers, but rather assessing their actions, to determine whether or not they are implementing inquiry in their lessons. It can, however, be difficult to separate my observations of the actions from the emotions I felt as I observed the actions.

on the board without a stone in the water, and showing the level of the water, and beside it drawing the graduated cylinder with a stone in the water, showing the fact that the level of water had risen. He then proceeded to perform the calculation on the board of subtracting one reading from another to show the volume of the stone.

> But, no. That was not the way [Teacher D] ran the class. Almost every minute detail was discussed, and diagrams drawn on the board, with bullet point steps to be followed. In absolute silence. Then, and only then, were students allowed to do the 'investigation'. (Journal Extract, 27 October 2016)

The students were then asked to proceed and determine the volume of the stone that I had provided them with. Both of us proceeded to circle the room, again to check that students had understood what was expected of them, but there were few questions.

Finally, as we moved on to the final step in the practical lesson, I proceeded to hand out the large stones and the displacement cans. While I was distributing the stones, the appropriate diagram had been drawn on the board, and the whole process explained to the students. Again, when the students were given the time to carry out the 'experiment' the teachers circulated through the room, but as before there were no questions from the students. All the students understood what was expected of them to carry out the 'experiment', as noted in my journal from that day:

> And they did it well. As you would expect, says you. They were told exactly what to do. Although, there were a few groups that had difficulty in filling the displacement cans to the spout and then moving it without spillage. But at least while the students were working, I was able to move around and discuss their problems with them. (Journal Extract, 27 October 2016)

At this point, it seems futile to consult with Blanchard et al.'s (2010) table to determine the degree to which inquiry is present in the lesson. There clearly was no inquiry present, yet, if we were to give it a level, it would be Level 0: Verification. The question in this case was provided by the teacher, the data collection methods were provided by the teacher, and the interpretation of the results was also carried out by the teacher. And all done prior to the 'experiment', which removed any hint of curiosity from the perspective of the student.

By the end of the lesson, I was confused by the actions of my colleague, and disappointed that a learning opportunity for the students had been lost. My emotions here, perhaps, warrant some further investigation. The second step of Gibbs' reflective cycle (Bassott, 2016, p. 72) asks us to describe what we were thinking and feeling. Apart from the confusion and disappointment, I will admit that there was a small amount of jealousy, an emotion I often feel when seeing another colleague's lesson in which all the students are quietly working on the assigned task. Step three of Gibbs' reflective cycle asks us to describe what was good and bad about the experience. However, in this case the different lenses (Brookfield, 2017) through which we view the lesson must be considered. From the point of view of Teacher D, all the students were working on task, and all the students learned the material that was required of them. Using the students' lens (Brookfield, 2017), however, the lesson could be seen as having removed any sense of curiosity from the student, and lacked any enjoyment for them. Viewed through the lens of personal experience (Brookfield, 2017), I can understand both viewpoints, the teachers' desire for order, and to cover the material, and the students' desire for an enjoyable lesson, one which would spark their curiosity.

5.3.6.3 Teacher D – Autumn 2017

A year later, and both I and Teacher D are back in his laboratory, teaching the same topic to a new group of first years. This time, there was a marked difference in the attitude of Teacher D from the beginning of the lesson. I don't know if it was because this was the second time he was teaching the topic under the new *Specification* or whether some outside factor played a role, but the difference in between this lesson and the previous year was marked, as I noted in my journal that evening:

> So, I figure I should probably write something about today's double with [Teacher D] and his first years. It's one of the few opportunities I actually have to work with another teacher this year, apart from [Teacher B] coming in to help me with the double 3rd years on Mondays. And, in fairness, that isn't much of an opportunity for me to see another teacher in action, that's them getting to see how I work, for the most part.

What happened today? Well, given what last year's class was like, I was expecting more of the same, to be honest. I can't remember exactly how the lesson went last year, but I'm sure that I wrote about it, given how much it stands out in my memory as how *not* to teach this topic - measuring volume of a solid and a liquid.

Alright, so I looked, and I did write about last year's lesson. Jeez. But, hey, it looks like there was an improvement. So, I'll be thankful for small mercies. It appears that even [Teacher D] is changing his teaching style as the new course becomes more… what's the word? Familiar? (Journal Extract, 2 October 2017)

Although I had expected the lesson to be a repeat of the previous year's lesson, in fact there were some marked changes. Teacher D began by drawing the equipment on the board and explaining the basics of how each piece of equipment could be used, but did not repeat the explanation of how to use the rise in the level of water in the graduated cylinder to measure the volume of the stone. There was no step-by-step calculation on the board showing the students what to do.

I started collecting equipment - I had to go to *Saotharlann* [Laboratory] 1 and 2 to find enough graduated cylinders. Someone is hoarding them somewhere, I'm convinced of it. And the box of stones and stuff. As I was doing that, [Teacher D] was recapping on the last lesson, where they talked about the volume of regular shapes. And then he started explaining what the students were going to do today, and I groaned internally. I was sure he was going to draw the equipment and give a step-by-step breakdown of exactly how to do the experiment, but all he did was talk about how a graduated cylinder can be used to measure the volume of liquid, and how we could use it to measure the volume of a stone. He then drew a displacement can on the board, and said that it could be used to measure the volume of a stone if it didn't fit in the graduated cylinder, but he was a bit vague on exactly how that could be done.

This was strange. Something was up. Gone was the clear instructions on how to subtract one volume from another. Gone was the diagram of how to set up the graduated cylinder and displacement can. Granted, more information had been provided to the students on how to measure the volumes than I think I would

> have done it, but it was definitely a step in the 'right' direction. (Journal Extract, 2 October 2017)

There was a little more confusion when the students were required to complete the experiments, and Teacher D and I spent more time questioning the students as we circulated around the laboratory when the students were carrying out the investigation. However, since Teacher D had spent less time explaining how the experiment should be run, we had the time to engage with the students on a small group basis to discuss their understanding. As described in Section 5.3.4, we were able to use similar questioning to probe the understanding of the students, and lead them towards creating their own experimental method. Given this lesson was closer to how I had envisaged the lesson would be carried out if I was teaching the topic, and that my assumptions (Brookfield, 2017) convinced me that this was the best way of doing it, I was bolstered in that belief by the fact that the students were clearly enjoying the lesson more than the students had the previous year. Although there was some confusion, and plenty of questions from the students, I had no reason to question my assumptions that an inquiry method was the most appropriate for teaching this material.

In comparison with the Level 0: Verification (Blanchard et al., 2010) lesson that had been delivered the previous year, this lesson would be classed between a Level 1: Structured and Level 2: Guided inquiry. Interestingly, although the students had less freedom of choice than in my lesson described in Section 5.3.6.1, the level of inquiry appears about the same, when Blanchard's rubric is applied. To see more of a distinction between the lessons, a more granular rubric is needed, one that more accurately reflects the fact that inquiry is a continuum, rather than four discrete stages, or levels.

What is not clear here is whether Teacher D falls under Desimone's (2009) or Guskey's (2002) model of teacher change. In retrospect, it would have been interesting to find out whether Teacher D's views about teaching were changed because of a CPD event he attended, and is therefore changing his teaching practices; or whether he is changing his teaching practices as a first step after a CPD event, and that this might result in a change in beliefs about teaching at a later stage. As will be seen in Chapter Seven, Teacher D's beliefs about inquiry-based learning over the course of this research have changed, and he now sees that students have increased enjoyment and engagement, brought about by a change in his teaching practices, which might suggest that the lesson described in this episode was more in line with Guskey's (2002) model of teacher change.

5.3.6.4 Me – Autumn 2018

For the first time in many years, I had my own first-year class to guide through the course. In fact, I had two groups[24]. Although I had been watching other teachers teach the new curriculum for several years now, and planning the curriculum with them, for the first time I would be confronted with the actual reality of having to make sense of what was being asked of me. Could I actually teach the material as I had been imaging? Would I be able to employ IBL methods successfully? Would the students find science interesting, stimulating, and engaging?

Notwithstanding the change in my own understanding of the aims of the Junior Cycle science course, which will be further discussed in Chapters Six and Seven, I also delivered the lesson on the topic of measuring volumes in Autumn 2018, this time to my own classes. Of course, the lesson was planned to proceed as I had previously discussed in Section 5.3.6.1 above, and I will not describe in full detail that procedure again. I found my lesson planning fully espousing Brookfield's (2017) causal assumptions; this lesson had worked well in the past, and it will work well this time. However, things did not go as planned, and I found the students struggled more than envisioned during the lesson.

> Monday
>
> […] I know they were missing last Thursday for their single class, but I think they'd covered enough of area and volume of regular shapes last week to move on to the volume of a liquid and irregular solids.
>
> Let's just say, it was all a bit chaotic. I started off okay, we talked about measuring the volume of a liquid, and in fairness to them, a good few had had experience of

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[24] I had arranged with the Principal before the summer break to ensure that I would be given a first-year class for the 2018-2019 school year. I was determined to try to put into action those methodologies which I had been discussing with my colleagues for the previous few years, but without actually having much first-hand experience myself, as well as seeing a cohort of students through the full journey of the three-year Junior Cycle curriculum.

> measuring liquids with measuring jugs in home ec, or just about the house at home. One or two insisted that it would be possible to use a ruler, and measure the height, width and length, no matter how hard I tried to convince them that, yes, it's possible, but not very accurate. But I told them that if that's what they wanted to do, that they should fire away, and then compare that answer with the answer they get using a graduated cylinder.
>
> But, on the whole, measuring the volume of a liquid was fine. Everyone managed. (Journal Extract, 12 November 2018)

Having covered the volume of regular solids the week before, and knowing that they had also learned about that topic in primary school, it was only fair that some students would be convinced that it would be possible to measure the volume of any object by multiplying the measurements of the three dimensions. However, what struck me was the stubbornness to which the students clung to this idea, despite me trying to show them that, while it would be possible to get an estimate of the volume, it would be difficult to measure the volume of a liquid accurately using that method.

> Moving on to the volume of a small stone, again we were back to using rulers. Fine, same answer as before. But everyone in your pairs try and come up with a more accurate method. So, I had some groups who immediately grasped the concept, put the stone into the water, and noted the rise in level of the water in the graduated cylinder. There was the pair of students […] who put the stone into an empty graduated cylinder, and measured the height of the stone in the cylinder as the volume of the stone. And [the] pair that put the stone into the water, without reading the volume of the water first, and not really bothering to read the volume of the water after either. […] both those groups took a few minutes of my time discussing with them what they were trying to do, and how they would go about doing it […]. (Journal Extract, 12 November 2018)

Again, the lesson was proceeding as I expected it to. I knew that some students would require additional guidance through questioning, and that some of the students would be creative enough to work out the correct method without requiring any assistance at all. However, when the discussion turned to a larger stone, the lesson began to veer from how I had envisioned it to proceed.

> Time to move on, and as a class, we talked about what would happen if I had a stone that wouldn't fit into my graduated cylinder? Cue the usual responses of "buy a bigger cylinder", "break the stone into smaller pieces", etc. So I showed them the displacement can, gave each pair one, and asked them to work it out.
>
> Disaster. Well, not a total disaster, but for some groups it wasn't exactly what I had imagined. C and D […] came up with the idea that they should measure the total volume of water in the displacement can, put the stone in and wait for the excess to flow out, and then measure the total volume of the remaining water. I've *never* had students come up with that idea. Totally roundabout way of doing it, of course, but it worked. What bothered me was that I had to have a quick chat with *every* pair of students to nudge them towards the correct method. Even the stronger students seemed a bit lost. Obviously some of the groups, like A and B, and E and F, only needed one or two questions before they saw what they should be doing, and I even had the opportunity to talk to them about the problems with measuring a volume smaller than $10cm^3$ with the graduated cylinders they had, but it wasn't like this when I taught this material before.
>
> Was there something I had done differently? Had they not had the same experiences as the students the last time I actually ran this lesson myself?
>
> […]
>
> D actually came to me at the end of class and admitted he didn't really understand what he was doing that day, and asked could we go over it again the next day. Which, looking back, I'm going to have to do. (Journal Extract, 12 November 2018)

I was confused and taken aback. I had taught this lesson many times, although admittedly it had been a few years previous. Every time, the students seemed to grasp the concepts more quickly than this group had. It wasn't that these students were not as able, or that I hadn't covered the material to the same extent. My prescriptive assumptions had consequences. However, there was clearly some difference between how the lessons had previously proceeded and this lesson.

I began by comparing this lesson, which was conducted with a group of 18 students, to my other first-year cohort, which consisted of 9 students. I had taught this lesson to the smaller class the previous week, and it had proceeded as I had expected.

> Like, last Thursday it was fine with 1D. Granted, there are only 9 of them, so it's much easier to keep an eye on them, and keep them on track while I interact with them individually. And of that 9, W, X, Y and Z are *very* able students. (Journal Extract, 12 November 2018)

And therein, to a certain extent, lay one problem. With a small group, it was possible to move around the laboratory, engaging with the students if they had questions and still be able to keep a close eye on all the other students as they performed the investigation. Colburn (2000) sees the maintenance of good discipline as essential to successfully using inquiry-based learning in the classroom, a notion encountered elsewhere (Poon, Tan & Tan, 2009). I had more control over the situation, to put it bluntly. With the larger class, although none of the students were misbehaving, per se, it was easier for them to become distracted from the material while I was making my way around the classroom. It enabled those students who were not fully engaged in the lesson to disengage completely until I was standing in front of them. It only at that point that they began thinking about the problem at hand. This is an important lesson to have learned, a fact highlighted by Turner, Keiffer and Salamo (2018, p. 1464): "Having a large percentage of students actively engaged during the learning process is crucial. A high level of inquiry that only includes 10% of the students may not be as effective as a moderate level of inquiry that includes 95% of the students".

And therein, I believe, is a problem. Although the students were eager to carry out the experiment, and excited by the fact that they were carrying out a hands-on activity, I believe the excitement had more to do with the fact that they were doing something practical, anything practical, more so than what they were actually investigating. As will be seen in Chapter Seven, this is a common occurrence in science lessons, as described in the literature (Nadelson, 2009). In addition, some of the students were fully prepared to wait for me to help them with the investigation, rather than trying to solve the problem themselves, which is another topic that will be discussed in Chapter Seven.

Using Gibbs' (1998) reflective cycle, when acknowledging the emotions I felt during this lesson, the principal emotion was frustration, followed by confusion. Frustration at myself, that it felt like I had wasted an entire 40-minute lesson on something that I would have to revisit. Confusion, because my assumptions about how the lesson should have progressed were clearly wrong. However, Gibbs (1998) encourages us to evaluate what was good and what was bad about the experience being studied. Similar to previously described lessons, the students were enjoying the experience. As will be discussed in Chapter Seven, the enjoyment of science is one of the principal aims of many of the teachers in my school, and although the students aren't learning exactly what we want them to learn, we do want them to have positive emotional associations with science.

Upon further reflection on the differences between the two first-year groups, I now (2019) wonder about the language aspect. The 1D class, the smaller of the two, is a transition class for those who do not have a sufficient level of Irish to take part in the complete Irish immersion programme. The '*Droichead*[25]' programme enables them to undertake their education bilingually, admittedly using more English than Irish, until they are proficient enough to move to the full Irish immersion programme, after consultation with school management and parents. Did these students understand the concepts behind the lesson more easily than their counterparts in the immersion programme, enabling them to undertake the inquiry investigation more successfully, because it had been explained to them in English? Although the students in the immersion programme are sufficiently proficient in Irish to undertake their education in the language, this is not a complete indicator of their level of comfort with the language. This is a line of thought that cannot be pursued at this time, although might be worthy of future study.

Although this lesson would again be considered between Level 1: Structured and Level 2: Guided in Blanchard et al.'s (2010) rubric, did the students really learn what had been expected of them? The short answer is no. Not all students achieved what had been

[25] Bridge

expected of them for the lesson. The long answer, if I was inclined to hedge, is that it would depend on the learning intentions of the lesson. If the intention of the lesson was that “students be able to describe how to measure the volume of a stone using a displacement can”, then not every student fulfilled this aim. Indeed, one student admitted as much. However, it may have been possible that one of the learning intentions of the lesson was “students will be able to investigate the use of a novel piece of laboratory equipment”, in which case it is more likely that this learning intention would have been achieved by the students. A more in-depth discussion on the importance of learning intentions in IBL lessons will also take place in Chapter Seven.

5.4 Discussion

When is 'inquiry' inquiry? For me, as a science teacher, this journey has forced me to evaluate whether I am actually 'an IBL teacher'. First, it is clear that, from the literature available, there is more than one way in which inquiry can be interpreted. As the NSES (NRC, 1996) states, as long as there are some of the five features of inquiry present in a lesson, then the lesson can be considered an inquiry lesson, even if it is only a 'partial' inquiry. In addition, each feature of inquiry has several variations, and it is therefore not a case of whether a feature of inquiry is present, but to what extent it is present in a lesson. It would be incorrect, therefore, to conclude that inquiry is present, or is not present, based on one single interpretation of any one definition of inquiry.

It can be interpreted that each of the variations of inquiry can be found in my lessons, as well as in the methods of assessment we make use of in the science department. As described in Section 5.3.2, even when it is not planned that a lesson take place in an inquiry manner, some of the features of inquiry are still present. Section 5.3.3 described some of the methods of assessment that the science department is using, and again I would argue that some of the features of inquiry are present in the examination described. When inquiry is planned as a feature of a lesson, the interpretation of the features of inquiry is important, as Sections 5.3.4 and Sections 5.3.5 outline. The extent to which a lesson 'is inquiry' depends on the amount of direction the teacher provides, and how they provide it, although in both cases, I argue that inquiry is present in how I conduct the lessons.

Engaging on reflection on my lessons has uncovered some insights into my practice, both reassuring and uncomfortable. Ghaye's (2011) strengths-based reflective practice allows us as teachers to reflect on the positives of a situation, rather than always looking for something negative to improve. For example, the lesson described in section 5.3.2 could have been reflected upon as a case of a teacher being under-prepared for a lesson; or of a teacher exhibiting an occasion where the behaviour of a class group influences their lesson planning. However, by focussing on the positive aspects of the lesson, where the teachers amended their plan for the lesson, and conducted a class that was both enjoyable and fruitful, both for teachers and students, we could engage in "selfaffirmation" (Ghaye, 2011, p. 78) by acknowledging our strengths and self-efficacy as teachers. A similar case may be made in the lesson described in section 5.3.4. Engaging with students who are usually disinterested and unengaged in small-group or one-to-one situations generally provides a more productive experience for all parties.

Nonetheless, reflection on practice cannot be one-sided, and there is a need to reflect on those areas which could be improved, as section 5.3.6 highlights. My assumptions, paradigmatic, prescriptive and causal (Brookfield, 2017, p. 32) had led me to believe that the way I had envisioned conducting a class was the best way, that other teachers should conduct their lessons in the same way, and that because it had been successful in the past it would be a success every time I carried out that lesson. However, I was to be proven wrong on both counts, as the lessons described in that section illustrate.

This chapter was originally written in the Spring/Summer of 2017 as a stand-alone paper. It was amended, and re-written several times, including the addition of the further lessons in Section 5.3.6 to show a progression in teaching practice, where a teacher teaches the same lesson year after year. However, each re-visiting, with the passage of time, as I read and re-read this chapter and the source materials upon which it is based, with a greater understanding of action research, reflection, self-study, inquiry-based learning and the expectations placed on us by the new *Specification*, gives me the opportunity to uncover greater understanding of my own practice, inquiry-based learning and action research. In this manner, the constant re-visiting of this chapter serves as an example of Cochran-Smith and Lytle's (2004, p. 635) "dialectic… the reciprocal, recursive, and symbiotic relationships of research and practice".

The question I therefore ask of myself, at this final stage of the research journey, is 'what do I think inquiry is?'. I began the research, as described in Section 5.3.1 with an incomplete understanding. Although this process has clarified matters for me, I am no closer to being able to give a concise answer to the question 'what is inquiry?'. I can begin by stating what inquiry definitely does not look like in the classroom. If I am lecturing, providing information without asking the students to participate in a dialogue, and the students are simply rote learning information without engaging with it, that is not inquiry. Similarly, if I am simply providing the students with a complete 'cook-book' approach to experiments, including lists of equipment, how equipment is used, sample calculations and precise instructions on data analysis, along with expected conclusions, that is not inquiry. I would consider nearly anything else to be arguably within the realms of inquiry, even if it is only a minutely partial inquiry.

I would argue that inquiry can be incorporated into most lessons, some of which have been illustrated in this chapter. By providing a small amount of information, and then asking students to make predictions for similar situations based on that information. By teaching a part of a topic, and waiting for students to make connections with previous topics, or notice patterns emerging in the information. By giving students a piece of equipment and asking them to determine how it is used. By providing enough information for them to carry out an experiment, but have to determine for themselves precisely how the data is collected, or how the data is analysed. By not always answering their questions with a direct answer, but with more questions. Or, much to the frustration of my Leaving Certificate Physics or Chemistry students over the past few years, simply asking 'why?'; why do they think something happens, or doesn't happen; why was this scientific explanation seen as valid at the time, and why did it change; why do we carry out particular steps in an experiment. And to follow up their answers with another 'but, why?', until different students provide their opinions, and together we come to a satisfactory conclusion.

It doesn't matter, usually, if they are the correct answers, or methods, or conclusions. The aim is having the students actively engaging with the material at hand, by forcing them to think about what is happening in front of them, or the abstract concepts I am trying to explain. For me, especially in the Junior Cycle, having the students learning the scientific concepts precisely has become less important than encouraging the students to use reason, and to think logically. If it has the added benefit of my students enjoying the process of learning science, and having a general appreciation for science in their everyday lives, I consider that a job well done. It might not be inquiry-based learning, in the strictest sense. Perhaps a student-centred approach might be a more appropriate label.

Chapter 6: The ISE Project in My School

6.1 Introduction

This short chapter is being included to serve two purposes. Its minor purpose is to provide some additional context to Chapter Four, as it provides a description of how I and other science teachers in my school were engaging with the ISE project and the resources that could have been provided to schools, had the webinars continued into second and third cycles. However, the primary purpose of providing this chapter is to serve as a prologue to the discussion that will take place in Chapter Seven.

This chapter, therefore, outlines how I attempted to include the other science teachers in my school in the ISE project, by sharing the resources and learning from the project, and arranging for Erasmus+ training abroad. I also provide a description of how we used ISE eTools in our practice, including lessons that we created on the ISE Lesson Authoring Tool. I conclude the chapter by discussing the responses the teachers provided on their experiences of the ISE project, both the training undergone and the use of eTools in classes, when completing an ISE questionnaire.

6.2 Erasmus+ Training and The ISE Lesson Authoring Tool

The European Commission provides funding each year for teachers and students to visit other countries, both to learn and to experience other European cultures. This funding is available through various channels depending on the type of learning being undertaken, and on the nature of the project for which the funding is being sought. For school teachers who wish to attend courses in another European country, funding is available which will cover the course fees, costs of travel and accommodation, as well as additional funds for the participating school to cover additional costs which may be incurred, such as employing substitute teachers. This funding is known as Key Action 1 and falls under the remit of the Erasmus+ programme, which was allocated a budget of almost €15 billion, spanning the years 2014-2020.

As previously described, my involvement in the ISE project included implementing IBL in my lessons with my science classes. In addition, one of the deliverables expected of the participants was to complete a European Development plan, ideally including submitting it as part of an Erasmus+ funding application. The 2014 application I submitted for funding on behalf of my school was successful, and the school received a large grant towards enabling teachers to attend training courses in other European countries.

The plan, as devised, envisaged the science teachers attending training organised by the ISE project. In addition, a number of teachers in other subject departments would attend training courses with an emphasis on incorporating ICT into their lessons. However, as this was the first year of the Erasmus+ funding mechanism, succeeding the former Comenius and Grundvig funding models, there were some delays in the judging process. This resulted in notification of a project's success or failure not being issued until late July 2014, and final contracts were not issued until September 2014. This was too late for teachers to organise attendance at training courses taking place throughout the summer months. There was some concern as to whether the project we had envisaged, due to take place over the 2014-2015 academic year, would be able to proceed as planned, as teachers would not have had the opportunity to attend the necessary training courses.

However, it was decided to proceed with a slightly reduced project. The dates of the project were amended to run the full calendar year, from January to December 2015, and a training course was organised by DCU, on behalf of the ISE project, in Estoril, Portugal over the February mid-term break. This course was specifically organised for Irish secondary schools taking part in the ISE project, and the Portuguese partner, NUCLIO, also invited some local Portuguese teachers to take part. Of the six science teachers in my school at the time, five travelled to take part in the course.

Given that the course was being organised for a specific purpose, it could be tailored to suit the needs of the participating teachers. NUCLIO, as an organisation, is predominantly involved in the provision of astronomy-related teacher training courses, and are regularly involved with EU-funded projects with a focus on inquiry-based learning, such as ISE. This included creating sample IBL lessons for participants in the ISE project. NUCLIO have also been involved with some projects investigating the incorporation of ICT into science lessons, such as GO-LAB and Digital Schools of Europe. Given that the new Junior Cycle specification would contain material relating to astronomy, with which many teachers would have had little experience in teaching, it suited the participants to attend a course which placed an emphasis on astronomy, as well as providing information on incorporating IBL and ICT in our science lessons.

Over the course of the week, therefore, the participating teachers learned some basic astronomy; we had hands-on experience in using Stellarium, a planetarium computer programme, and SalsaJ, and learned how we could embed these software programmes into our lessons; we had the opportunity to experience the use of a telescope to view some astronomical objects; and we were shown how to make use of freely available databases of astronomical images to conduct investigations into the solar atmosphere, comets and meteoroids. In addition to the astronomy aspect, the participants also had the opportunity to have several productive sessions discussing inquiry-based learning; how teachers might begin the process of implementing IBL in their lessons; and share the experience teachers might have had in the past, including any difficulties encountered by teachers in using this methodology with their students.

6.2.1 The GO-LAB Project

As mentioned, NUCLIO engages with a range of different EU-funded projects with a focus on science education. One of the projects in which NUCLIO was a partner was the Go-Lab

Project (www.golabz.eu), which ran from 2012 to 2016. This project aimed to engage secondary school students with inquiry-based learning, by developing an online portal where teachers could find simulations and online laboratory tools, as well as developing an online 'Authoring Platform' in which these simulations and labs could be combined with other apps to create "Inquiry Learning Spaces" (ILS), to guide students through the stages of an inquiry lesson.

One session during the training course was devoted to showing the participants the GO-LAB project website, shown in Figure 6.1, giving us a brief overview of how to create an Inquiry Learning Space, and allowing us time to create accounts on the GO-LAB authoring platform and experiment with creating an ILS for our own school context. The participating teachers from my school immediately saw the benefit of having a computer-based system for guiding students through an inquiry lesson.

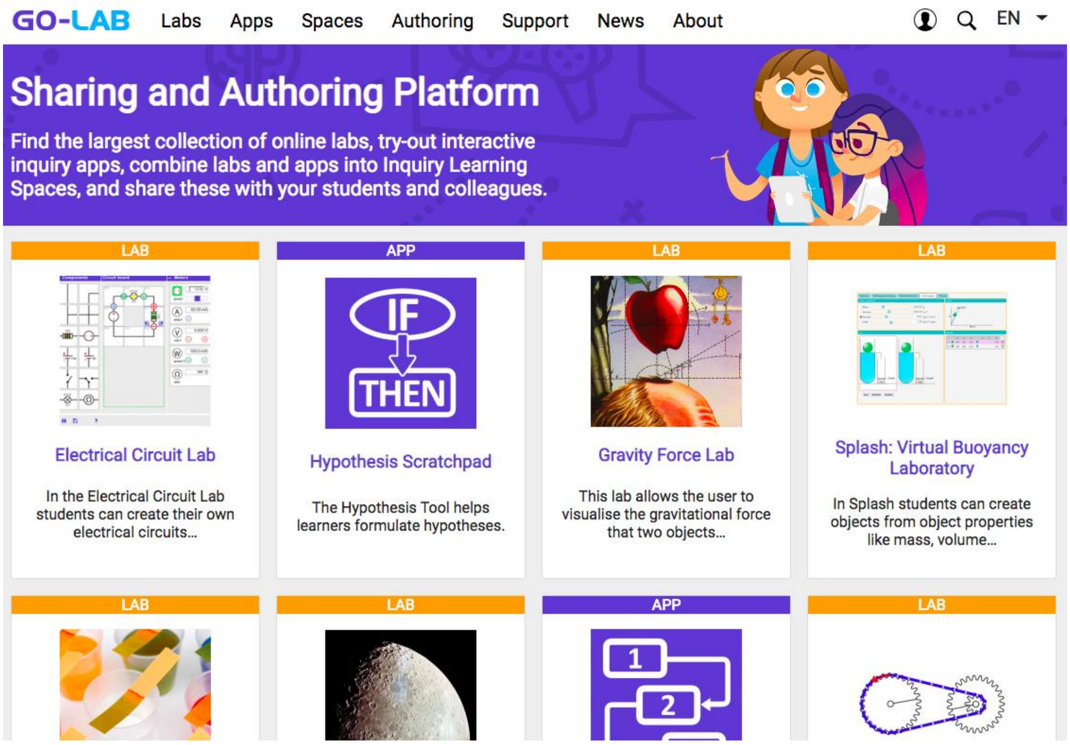

Figure 6.1: Screenshot of GO-LAB Project website (www.golabz.eu)

Traditionally, a lesson would rely on the teacher to monitor engagement and learning, and provide feedback to each student as they progress through the lesson. Providing the students with a physical worksheet to help guide the student through the lesson could reduce the workload on the teacher. However, the teacher would still be required to provide assistance to students, ensuring they type website URLs correctly, checking that they complete each section of the work, and providing feedback. Another drawback of a physical worksheet is that there is no restriction on the student skipping through the majority of the worksheet to the last section, in order for them to be “finished” with the work as quickly as possible. The use of an online ILS, however, meant that students could be provided with step-by step instructions on how to progress through the lesson. In addition, checks could be integrated into the lesson, which would require them to complete each stage in turn before they could move on to the next step.

As the GO-LAB project was concerned with inquiry learning, the stages on the ILS authoring tool were designed to encourage students to attempt activities in an order that would lead to increased understanding of the material, as shown in Figure 6.2, and allow them to experience scientific thinking and scientific processes in a structured, guided learning environment.

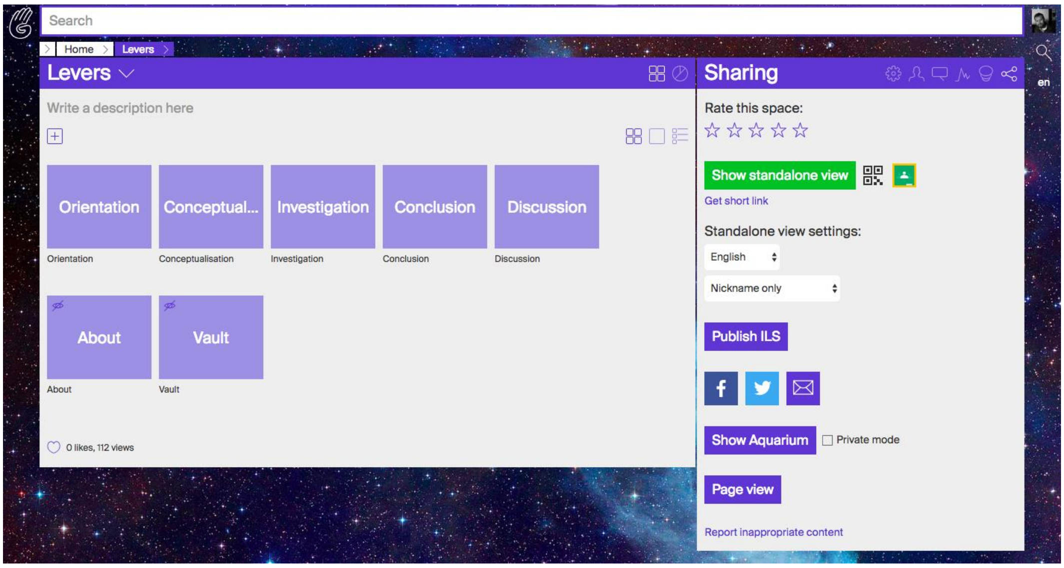

Figure 6.2: Screenshot of GO-LAB ILS Construction

Links, activities and video could be embedded into the ILS, thereby facilitating their use. The students’ progress through the lesson could be tracked, and their responses to any activities and questions could be recorded. In addition, any ILS that a teacher creates could be shared with other teachers, reducing the amount of preparatory work that any one teacher would have to undertake. The teachers from my school were excited to experiment with using GO-LAB Learning Spaces in their lessons.

6.2.2 ISE Lesson Authoring Tool

A second feature of the training course in Portugal was specifically about the ISE project. As previously discussed, the ISE project aimed to encourage teachers to implement IBL in their lessons, specifically through increasing the use of technology in the classroom. So far in the project, until February 2015, this had consisted of providing the participating teachers with a copy of Vernier Logger Pro and pointing teachers towards some online simulations and tools that might be of interest, or use. A "community portal' (portal.opendiscoveryspace.eu/en/ise) was launched during the winter of 2014-2015, where groups of teachers could form communities based on common language and interest, in which they could share ideas and resources. However, the portal at that point was somewhat slow and cumbersome to use, and there was very little activity taking place thereon.

The participants in the training course in Portugal, however, were introduced to a feature which would incentivise teachers' use of the community portal to a greater extent. Accessed through the community portal was the ISE Lesson Authoring Tool. This would allow teachers to create interactive, guided lessons based on the five-stage inquiry model used by the ISE project, as described in Chapter Two. Students would be able to log onto the platform and undertake an inquiry lesson, with preliminary information, instructions, multiple choice questions and online simulations all embedded into one online platform. Student progress through the lesson would be tracked, and their responses to the questions posed at the end of every section would be recorded. In addition, students would not be able to progress to subsequent sections without having completed all the questions and activities.

In essence, this is very similar to the creation and use of an ILS by the GO-LAB project. The principal and execution are the same, with only some subtle differences between the two platforms. This online tool provided a framework for teachers to see how a lesson could be broken down into the five stages of inquiry, as adopted by the ISE project. Exemplars of best practice were created by the ISE partners, and these lessons were made available on the Lesson Authoring Tool. Each lesson consisted of several aspects: embedded video material to spark interest in the lesson, questions to guide the students in their thought processes, directions for students in practical issues such as recording data, links to online simulations and interactive resources, and multiple-choice assessment questions to gauge the students' understanding. By using the ISE Lesson Authoring Tool, it is possible to build a lesson on the online platform, give the students access to it, and allow them to work through the lesson, answering the questions and designing and carrying out an investigation at their own pace. Teachers participating in the training course in Portugal were also instructed in how to use the Lesson Authoring Tool to clone the provided lessons and adapt them for their own use.

Given that the teachers had been so enthusiastic about the GO-LAB platform during our time in Portugal, we were eager to make use of the ISE Lesson Authoring Tool in our own practice once we returned.

6.2.3 Using the Lesson Authoring Tool in School

However, of the five teachers that attended the training in Portugal, only two made active use of the Lesson Authoring Tool by creating lessons that suited our purposes, myself and Teacher A. Given that the Lesson Authoring Tool is available to any teacher that wanted to experiment, two of the other teachers, Teachers B and G, made use of the lessons we had created, by cloning them for their own use, and running a lesson based on them, giving a total of four teachers that made use of the lessons on the Lesson Authoring Tool[26]. One teacher did not make use of the Lesson Authoring Tool, either to create lessons, or to use existing lessons in their class, which will be discussed shortly.

In all, the teachers in my school created several lessons from scratch, and cloned lessons that others had created, translating them into Irish for our own students. In implementing them with our students, we discovered that there were very few difficulties in using these lessons to implement inquiry-based learning. Creating lessons on the Lesson Authoring Tool meant that we had a framework around which we could design the activities we wanted our students to carry out.

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[26] Part of the research reported on in this section was presented at the New Perspectives on Science Education conference in Florence, Italy in March 2016 (O Coileáin & Crotty, 2016).

The five-stage model of inquiry used by the ISE, as described in Section 2.3.2.5 and designed into the Lesson Authoring Tool, meant that it was clear what kind of activities we should include. We could create lessons that exactly suited the curriculum for our students. We could embed the kind of online simulations that we frequently used with our classes, although this time also provide prompts and questions to guide the students, as shown in Figure 6.3.

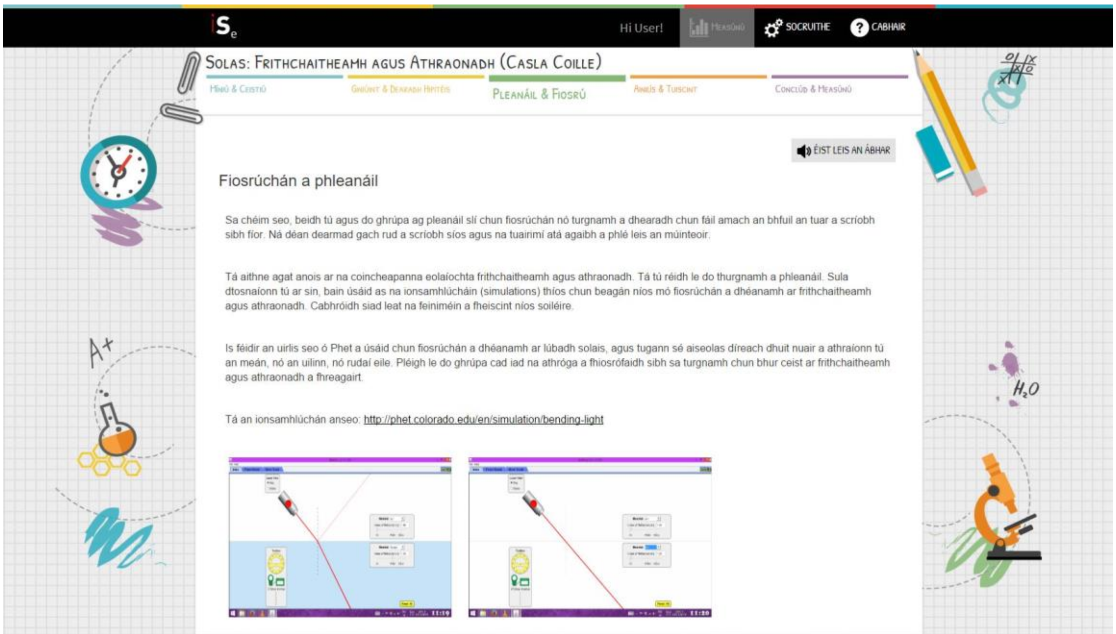

Figure 6.3: Screenshot of Planning & Investigating stage of lesson

At the end of each stage in the process, students were required to answer multiple-choice questions before they could progress to the next section, ensuring that students carried out all the steps in the inquiry process. An example is shown in Figure 6.4.

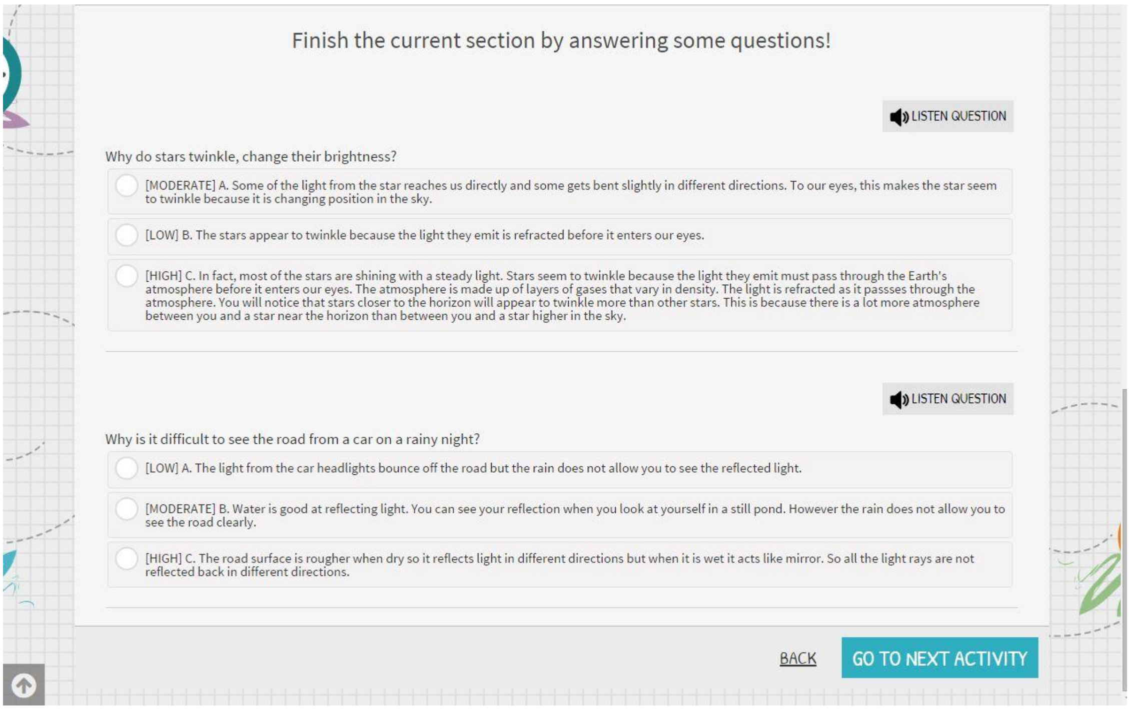

Figure 6.4: Example of multiple-choice questions

In addition, given that each student had 'logged in' with a nickname at the beginning of their lesson, their activity and progress could be tracked, both in terms of time spent in each section, and the answers given to the questions, as can be seen in Figure 6.5.

Student Name	Orienting & Asking Questions	Hypothesis Generation & Design	Planning & Investigation	Analysis & Interpretation	Conclusion & Evaluation	Overall
noiselesspurse19	0:7:9	0:7:30	0:25:54	0:1:43	0:1:6	0:43:22
Soup & Piccolo	0:6:1	0:4:0	0:28:23	0:2:34	0:0:56	0:41:54
[redacted]	0:7:23	0:6:30	0:21:37	0:2:1	0:0:54	0:38:25
[redacted]	0:6:6	0:7:3	0:20:26	0:2:12	0:2:27	0:38:14
[redacted]	0:5:29	0:3:37	0:1:23	0:1:29	0:1:55	0:13:53
[redacted]	0:7:18	0:6:8	0:14:55	0:2:3	0:0:48	0:31:12
jarjarisbeststarwarscharacter	0:4:45	0:2:29	0:5:17	0:27:18	0:0:7	0:39:56

Figure 6.5: Example of student time tracking through lesson

As the ISE Lesson Authoring Tool developed, the sample IBL lessons provided by the ISE project changed from word documents to ready-made lessons on the Authoring Tool. However, some challenges applied to using the sample lessons with our students, as well as some new challenges. Since these lessons were being created by teachers across Europe, many of them did not align with the Irish curriculum, although the Lesson Authoring Tool facilitated the process of altering lessons to make them more suitable. Even those lessons which were aligned with the curriculum would still need some amending to make them more personalised to the specific class group. The principal problem we encountered with some of the demonstrators, however, was that they introduced new tools and technologies with which our students were not familiar, and therefore extensive direction was needed in order for the students to make full use of that technology, as shown in Figure 6.6.

The lamp bulb should be 10 cm above the tabletop. It should be the same distance from each of the model homes. Do not turn on the lamp until instructed to do so in Step 7.

4. Position Probe 1 in the model solar home with no thermal mass and Probe 2 in the model solar home with the thermal mass. In both cases, pass half of the probe through the hole provided. Make sure the probe is not in direct light from the lamp.
5. Connect the Temperature Probes. Start the Vernier data-collection program and open the file "11 Solar Homes" from the *Middle School Science with Computers* folder (or follow this link: http://tools.inspiringscience.eu/author/resource/uuid/f877bff4)
6. You will be collecting data for 80 continuous minutes. During the first 40 minutes, the light will be on. After 40 minutes have passed, the light will be turned off and the windows of the model solar homes will be covered. Data will be collected for 40 more minutes with the light off.
7. Click ▶ Collect to start data collection. Turn the light on after the first set of temperature readings appears on the screen.
8. After 40 minutes, turn the light off and cover the window of each model solar home with a piece of cardboard. Data collection will end when a total of 80 minutes has passed.
9. Determine the maximum temperature reached in each of the model solar homes.

a. Click the Examine button, [x=].
b. Move the mouse pointer to the highest point on Curve 1.
c. The temperature at this point is displayed. Record the Probe 1 (no thermal mass) maximum temperature.
d. Move the mouse pointer to the highest point on Curve 2.
e. Record the Probe 2 (with thermal mass) maximum temperature.

10. Move the mouse pointer to the 80 minute line. Record the two temperatures at 80 minutes.
11. Print copies of the graph as directed by your teacher.

Record your data in the table below:

Figure 6.6: Directions for students from lesson on solar energy

Figure 6.6 shows one example of directions for the students. Although, as an adult, I understand the importance of providing clear directions, the experience of the teachers in my school was that, faced with a wall of text, many students simply ignore it. This observation was not limited to the junior students with which we implemented these ISE lessons. Anecdotally, many teachers of senior students will complain about the inability of their students to read through instructions and follow them sequentially. Our solution was simple. Any lesson we implemented would only include software with which the students were already familiar, or tools which were simple enough for the students to use without in-depth, step-by-step instructions. Many of the simulations from the PhET[27] website fell into this category, such as the activity shown in Figure 6.7.

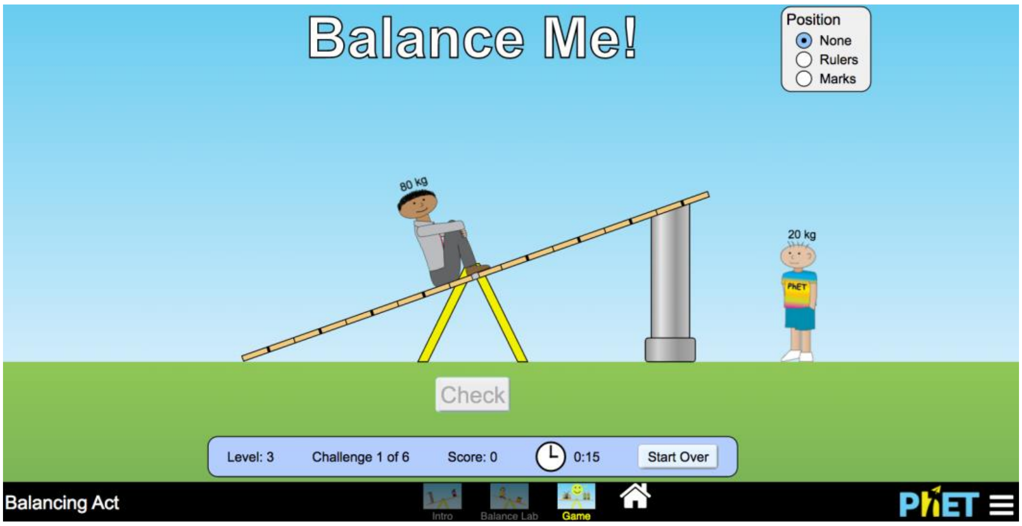

Figure 6.7: Screenshot of 'Balancing Act' PhET activity

A second difficulty that arises when providing the students with such level of direction, as shown in Figure 6.6, is that the lesson may claim to be an inquiry lesson, but in reality is no higher than a Level 0: Confirmatory lesson (Blanchard et al., 2010; Smithenry, 2010). It can, however, be difficult to strike a balance between providing enough direction so that the students can successfully complete the lesson, and providing so much direction that the 'investigation' becomes no more than a cookbook exercise, as experienced in the lesson described in Section 5.3.6.2. Therefore, we tended to take the viewpoint that we provide the minimum amount of guidance as written text, which would allow most students to complete the lesson as a structured or guided inquiry lesson. Students who required additional assistance would engage the teacher, who could provide further guidance to allow the student to progress, without providing excessive direct instruction.

6.2.4 Feedback on ISE Training and ISE Lesson Authoring Tool

In order to gauge the level of engagement the teachers had with the materials and tools presented to them during the training course, the participating teachers were asked to

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[27] The PhET Interactive Simulations project is a collection of interactive simulations created by the University of Colorado, Boulder. They can be found at phet.colorado.edu

complete a short online survey, approximately one year after completing the training. This information, along with conversations between the teachers regarding their use of the Lesson Authoring Tool, was compiled into a report for the ISE project. This report is included in Appendix D. This report was intended to provide the ISE with information regarding teacher opinions and attitudes on implementing lessons from the Lesson Authoring Tool in their schools. Some of the main points raised during the collection of this data can be grouped under several themes, as follows.

6.2.4.1 Understanding of IBL

Teachers were happy with the training course provided in Portugal by the ISE project, in conjunction with NUCLIO. When asked about their initial expectations of the course, some of the responses included "Looking forward to learning about Inquiry-Based learning" and "Learning about new ways to teach the material", and some teachers were more interested in incorporating technology into their lessons such as "Finding new ways to use computers in class" or "looking forward to learning about how ICT can be integrated into my teaching", responses which echo some of the expectations of teachers undertaking the webinar series described in Chapter Four. Many of the teachers described themselves as increasingly energised and motivated after the training course, and armed with a better understanding of IBL, were more confident in attempting IBL in their classrooms.

6.2.4.2 Benefits of ISE Lesson Authoring Tool

Teachers were interested to make use of the ISE Lesson Authoring Tool. One teacher specifically mentioned that the Lesson Authoring Tool helped them with planning inquiry lessons insofar as "It made it clear what was expected of the teacher and students in planning each stage of a lesson. The online lesson authoring tool helped greatly with this". By facilitating their adoption of IBL, some teachers found that it gave "student [sic] the opportunity to be more engaged with the material" and more specifically that it "Really engages the weaker students". Two responses highlighted the ability of the platform to monitor the students' activity and progress to be especially useful, "so that I can tell who is spending too little time on each section during the lesson". As I had felt myself, the provision of directions to the students allowing the students to proceed at their own pace, rather than the teacher leading the entire class was a great benefit: "It gives the student the opportunity to work at their own pace"; additionally, "Having a computer-based lesson is much more effective than handing out printed directions", giving the additional advantage that eTools could be embedded into the lesson, rather than the students being provided with a URL that they needed to type into the browser themselves. Teachers found the inclusion of the multiple-choice questions at the end of each section also allowed them to monitor student progress, something that "was also a great benefit compared to a traditional lesson".

The greatest benefit the teachers found to the ISE portal, and the Lesson Authoring Tool, however, was that we did not need to create every lesson from the beginning. It was possible for one teacher to create a lesson, and these lessons "could be cloned, and altered to suit" any teacher's situation. Apart from the lessons that we created ourselves, it was possible for us to find lessons created by other teachers around Europe, or by the ISE, clone them, and translate them into Irish for our students. One teacher's response was openly enthusiastic about this aspect, stating "Being able to modify lessons provided, or create our own was a very exciting experience".

6.2.4.3 Difficulties in Implementing ISE Lessons

However, teachers found that there were several drawbacks to using lessons on the ISE Lesson Authoring Tool. The most common observation was in relation to the amount of written directions provided to the students, as I had observed in Section 6.2.3. One teacher observed: "the students were not very interested in reading through all the directions", especially if the lesson was "text-heavy". In addition, "often some students just ignored the directions and went straight to the questions at the bottom of the page", in an effort to work through the lesson as quickly as possible. Another reason observed for students to skip ahead in the lesson included their becoming distracted by "an app or practical activity further along" the page, causing them to skip the instructional material beforehand. However, this resulted in their not gaining "an understanding of the material this way".

Another teacher found that the greatest difficulty was in asking the students to type the URL of the lesson correctly, something they found "was sometimes difficult". This resulted in a loss of ‘instructional time’, as “getting all the students to the lesson took a significant amount of time at the beginning of the class”. More time would be lost when the lesson took place over more than one class period. In returning to the ISE lesson, “very often the students couldn't remember their password, so they had to create a new account and start over from the beginning of the lesson”, although this is perhaps less to do with the ISE platform specifically, and more related to teenage behaviour.

As I had envisaged in Section 6.2.3, one difficulty related to the lack of consistency between the curricula of the different countries taking part. Notwithstanding the claim made in the previous section, that it was helpful that we could clone lessons made by any other teacher, it was, in reality, difficult to find lessons that aligned with the learning objectives of the Irish science curriculum. This was expressly addressed in two responses by the teachers in my school. One response bemoaned the fact that “Some of the learning scenarios were not applicable to our situation”, and another stated that “A lot of the demonstrators provided did no correlate with the learning outcomes specified by the science curriculum in Ireland”. In two of the responses to the questionnaire, teachers referred to “time constraints”, and felt they did not have adequate time to engage with the lessons on the Lesson Authoring Tool. This was also a common topic in conversation we had about using these ISE lessons. Teachers felt that the less aligned the lesson objectives were with the outcomes described in the curriculum, the less likely they were to execute the lessons with their students.

The final challenge in implementing ISE lessons related to the provision of ICT in the school. At the time, our school had two computer laboratories, each with approximately 30 PC computers. Given the number of class groups in the school, it was difficult to access the computer laboratories when we wanted to. Since the computer laboratories were regularly scheduled for use by subjects such as computing or design and communication at times when our junior classes had science, many of our junior science classes did not have access to the computer laboratories at all, and we did not have the opportunity to implement the ISE lessons with these class groups.

One viable solution, we felt, was if the school invested in a set of one-to-one tablet or laptop devices, such as iPads or Chromebooks, which could be used in rooms other than the computer laboratories. This would provide the same functionality as a computer laboratory, but without the need for a dedicated physical space, something our school was lacking. Alternatively, as many schools in Ireland have been experimenting with over the past few years, we could become a one-to-one device school, with each student investing in their own device[28]. This would solve an additional issue for us, as science teachers. It would mean that we could use the devices in the science laboratory, rather than being tied to the computer laboratories. We would no longer be limited to performing experiments in online simulations, but could also perform physical investigations, whilst making use of the ISE platform to guide the lessons. Data logging and graphing software could be installed on the devices, and attached to the data logging tools provided by Vernier, as described in Chapter Four. However, as this suggestion was one that would require long-term planning and evaluation, it was not immediately acted upon.

[28] Anecdotally, the number of 1:1 schools is increasing every year, but no statistics are published. Conversely, some schools which experimented with 1:1 devices are moving away from this model. The decision was reached, however, that all first-year students commencing September 2018 would have their own iPad devices on a 1:1 basis.

6.3 Discussion

The feedback on the training course itself was positive, and the teachers were glad to have taken part. Personally, in addition to the new knowledge and skills we have developed over the week, it was enjoyable to spend time with my colleagues outside of a school setting, and we appreciated the opportunity to get to know one another better on a personal level. Teachers professed that they felt they better understood the concept of inquiry-based learning, and were more confident in implementing it in their classrooms. The provision of an IBL framework in the form of the Lesson Authoring Tool greatly facilitated this process. In addition, using the web-based platform removed some of the barriers to using inquiry and eTools in the classroom, as described previously. Had the school been a one-to-one device school, it was possible that adoption of the Lesson Authoring Tool to guide students through inquiry lessons might have been more widespread.

In reality, however, over the course of the 2015-2016 school year, use of the lessons designed on the ISE platform began to wane. In addition to the difficulties outlined previously, a new challenge appeared. The new specification for the Junior Cycle science course was published in the Winter of 2015/Spring of 2016, and the first cohort of students with whom we would be implementing this new curriculum would begin their post-primary education in September 2016. Teacher attention was therefore absorbed by the new CPD being offered by the JCT, and in understanding and planning for the new *Specification*.

Chapter 7: Teachers' Experience of Implementing the Junior Cycle Specification

7.1 Introduction

This chapter describes and discusses the final stage of the research underpinning this dissertation. I begin by outlining the research questions this section of the research seeks to investigate. I then analyse the responses provided by the teachers to the questionnaire and interviews undertaken during the 2017-2018 school year. I end the chapter with a summary of the understanding gained from the teachers' responses.

7.1.1 Research Questions

The publication of the Junior Cycle *Specification* in 2015/2016, and subsequent introduction for students beginning their post-primary education in September 2016 envisaged a change in how teachers approached the teaching of science. Part of this change was that teachers were expected to make more use of inquiry-based learning in their lessons. The rationale behind the use of IBL in science is that it can increase both student interest in science and student achievement. However, little formal school-wide training was offered to teachers relating to the new *Specification* before its introduction, and none specifically relating to inquiry-based learning. The primary focus of this chapter is the question

III. In a time of curriculum reform, how do science teachers in my school view their practice?

As explained in Chapter One, various sub-questions emerged during the research process. Therefore, this chapter intends to investigate these questions in this chapter, thereby contributing to my understanding of the main question:

vi. With the introduction of the Junior Cycle, have the science teachers seen a change in their practice?
vii. What do the teachers think inquiry-based learning is?
viii. Have the teachers seen any effect on the students – either in their interest or learning?

7.2 Teacher Experience of the New Specification

In order to determine the extent to which the science teachers in my school felt that the *Specification* impacted upon their practice, and to what extent they felt that their practice had changed in response, the teachers were asked to complete an online survey consisting of four questions:

- Do you think your teaching has changed since the introduction of the new Junior Cycle? If so, could you please give some detail.
- What is your understanding of Inquiry-Based Learning?
- Do you use inquiry, or inquiry strategies in the classroom? Could you provide some examples?
- If you use inquiry in the classroom, do you feel there has been any effect on the students' learning, or their interest in science?

The responses provided by the teachers are given in Appendix E. One additional question was asked, which was not envisioned would form part of this research:

- Is there anything that the school / other teachers / external organisations could do, to support your teaching in the new Junior Cycle science classroom?

The responses to this question are included in Appendix E, originally for the sake of completeness, although these responses also proved interesting. Several months were allowed to lapse before the teachers were then asked to take part in a semi-structured interview, loosely based on the above questions, but giving the teachers the opportunity to expand on their thoughts, and on the responses previously provided to the questionnaire. Transcripts of the interviews are not included in an appendix, as their provision would make the individual teachers readily identifiable.

Thematic Analysis (Braun & Clarke, 2006; 2012) was carried out, using a deductive approach in order to answer the research questions posed in Section 7.1.1, as described in Section 3.5.5. Initially, given that I was searching for specific information, codes used in the analysis included change in practice; IBL; interest; learning. Some of the codes used initially were found to be too broad, and further iterations of the coding process divided these initial codes into more granular codes, such as 'IBL definition'; 'IBL in practice';

‘better understanding’; ‘less rote learning’; ‘more interest’; ‘more freedom’; ‘skills – social’; ‘skills – science’; ‘skills vs content’.

In conducting the analysis, expected themes emerged. These include how teachers have changed their practice in response to the curricular change; their understanding of inquiry; the changed roles of teachers and students when implementing inquiry; whether they feel their students are more or less interested in science; and whether they feel their students are learning more, or better.

However, during the analysis, it was noted that several teachers voiced opinions on the same topics in the course of their interviews. Codes such as ‘time’, ‘uncertainty’, ‘exam focus’ and ‘balance’ were used across the transcripts and questionnaire responses. These additional codes contributed to additional themes and sub-themes, such as the aim of science education at lower post-primary level; the role and impact of assessment in lower post-primary science education; exam preparation or focus as experienced by the teacher and student; and the fact that the perceived interest of students in science depends on student academic ability and the activity in question.

7.2.1 Change in Teacher Practice

All of the teachers reported that their teaching practices had changed in some way since the introduction of the Junior Cycle, in both their responses to the questionnaire and during the interview. Teachers who had more experience of teaching the old Junior Certificate course reported more of a change compared to more newly-qualified teachers, as, for example, Teacher B admitted to in her written answer to the questionnaire “That being said, I have only been teaching for three years”. Although Teacher F was only in her first year of teaching, she could compare her experience with that of having been a student, when she observed that “teachers are more open minded in their styles of teaching […] achieve learning outcomes in different ways.”

During her interview, Teacher B elaborated on that point when she said “that’s the only comparison that I can make, is to compare those that have just completed the old course, the Junior Cert course, and I’ve now done, say, this is my second year of teaching the new course”. However, most teachers included some comparison between the way they were teaching the third-year[29] students and the first- and second-year students, with Teacher C stating during his interview that "we are doing kind of more projects and things which we weren't doing with the third years, so yeah, there is definitely more activities based learning, there is less just going straight through the book". This shift in emphasis from learning content to learning critical thinking skills was echoed by Teacher D during his interview, when he described his teaching practice "Certainly it has changed, it's not 'take down notes, learn, do an exam', it's 'what do you think of this', 'why are we doing this', 'what did you learn', 'what could you possibly apply this to in the future', etc.".

However, it appears that the experience of Initial Teacher Education also had an impact on the amount of change required in a teacher's practice. Teacher B, in her response to the questionnaire highlighted the fact that "during my teacher training much emphasis was placed on inquiry-based learning and using a variety of activities and technologies in the classroom", and as such, the introduction of the Junior Cycle did not result in as large a change in her teaching practice as it may have for other teachers. This resonates with my own experience. Having undertaken a concurrent Science Education degree, in which a large emphasis was placed on inquiry-based learning, my own teaching style, described in Chapter Five, did not undergo such a radical shift in the move to the Junior Cycle.

In contrast, Teacher E, who undertook a similar concurrent teaching degree as I did, in the same university at approximately the same time, did not experience the same emphasis on inquiry-based learning during his teacher training. One of his statements during the interview was telling, when he admitted that his teaching style "is different. It's probably not as different as it should be, in that it's taking time to adjust". This indicates that he feels he is not placing enough emphasis on student investigations and questioning, and that the change required is difficult. Although, for him, there hasn't been a large change in his teaching practice, it is not that he was teaching with inquiry methods already embedded into his practice, but that he recognises that there is a need for change, and conscious of the effort required to make the change.

[29] At the time of the interview, the third-year students were still completing the old Junior Certificate course, and were to be the last students to do so.

The implementation of the new *Specification* (DES, 2015) was credited with allowing the teachers the freedom to explore more, and to experiment with various ways of teaching topics. In their responses to the questionnaire, some teachers highlighted how the lack of clarity in the *Specification* allowed them greater flexibility. Teacher A described how "When approaching the topic with my Junior Cycle class I tend to explore more different ways in which to teach the topic… open nature of the Junior Cycle *Specification* gives me the freedom…"; and Teacher B stated that "the new syllabus is much less prescribed and so I have the freedom to go as in depth into a topic as I deem necessary, teach/demonstrate a concept in a manner entirely up to myself, allocate more or less time to a topic at my own discretion".

During her interview, Teacher B expanded on her thoughts on the topic, outlining how "you have the freedom to go online, see what interesting, funny ways of doing something are out there, and then choosing what one might work best, and they might enjoy more, […] rather than trying to cover what you think might come up, for an exam". Similarly, the move away from a focus on terminal examinations towards allowing students the freedom to undertake their own investigations was highlighted by other teachers, as this excerpt from Teacher E's interview shows: "with third years, it's… you're under pressure to get a certain amount of things done, and it's just chalk and talk… there's very little time and room for manoeuvre when it comes to inquiry-based learning. […] but the first years, I haven't got second years, the first years this year, I have done a good bit where I've given the responsibility to them, and given them a chance to do it". It would appear, from these answers, that the original designers of the *Specification* were correct in allowing teachers the flexibility to explore topics that interested them, and allow teachers the freedom in deciding how they wanted to teach topics.

However, Teacher D, in his interview, expressed a note of caution about the freedom allowed by the open nature of the *Specification*, observing "obviously the change in, I suppose we can't really call it a syllabus, but a directional… […] I suppose piece of literature, where, you know there is a loose… eh, we're still learning, I suppose, but there's loose interpretations of each […] learning objectives". Although it might not be obvious from the quotation used here, but the tone used by Teacher D as he spoke indicated that he was worried that, as time progressed, and we implemented the

Specification with successive year groups, that we would come to realise that our "loose interpretations" of the 'learning objectives' were incorrect, and that they would have to be revised. Anecdotally, and from personal experience, this is still a cause of worry amongst science teachers, as we approach the first time the Junior Cycle science *Specification* will be examined, in June 2019.

7.2.2 Teacher Understanding of Inquiry

When asked to give their understanding of inquiry in the classroom, teachers responded in a variety of ways. The answers provided on the questionnaire to the specific question resulted in most teachers giving responses that touched on some of the aspects of what inquiry entails. Teacher A gave their understand of inquiry as "Giving students the opportunity to discover things for themselves, to learn through investigations and inquiry as opposed to being told", and Teacher F gave a similar response "My understanding is that students must use their own initiative to figure something new out for themselves". Similarly, Teacher D outlines his understanding, "That the students would discover the subject more with support from teachers rather than the teacher giving them the answers or rote learning"; and Teacher C describes his understanding of inquiry-based learning as "It is where the student has to solve some kind of a problem or decide how to approach a situation without being told if it is the right way to complete the task".

The responses to the same question when asked during the interview stage, highlighted a similar broad understanding. During his interview, Teacher E explained his understanding of inquiry-based learning to be "it's when you give… certain guidance, or a task, and they go out and they do their own learning, and they learn from it, and they come to their own conclusions from it". Teacher D also developed on his understanding of what inquiry-based learning is, as the following quotation from the interview transcript shows "It's the ability of the student to work within a framework where they are able to… nearly… you know, teach themselves the material, or even learn the skills in which to do, and to figure out, the end result".

However, these responses to both the questionnaire and during the interviews suggest that the majority of teachers see the aim of inquiry-based learning as being a methodology in which the students learn science content as much as they learn science skills. However, to a certain extent, this contradicts what teachers say when they talk about what the students learn, as will be discussed in later sections.

A common feature found in many of the responses to both the questionnaire, and during the interviews, was the concept of the teacher directing the students' learning. For example, Teacher E, during his interview specifically stated that he "Now, as I said, you end up having to give a lot of help, a lot of scaffolding along the way". In contrast, Teacher C implied that guiding the students' learning was taking place, rather than stating it explicitly when he wrote "They are free to implement their plan (with some teacher input)". Clearly, teachers are aware that students will not have the capacity immediately to begin designing their own experiments, or even composing their own hypotheses from the beginning, and that some students will require a certain level of support throughout the Junior Cycle course.

One criticism that may be levelled at all of these accounts of IBL is that they are loose descriptions of generic discovery learning, or that they display a lack of understanding of the differences between inquiry-based learning and other forms of discovery learning. However, I would argue that most teachers would not have engaged with the literature surrounding IBL before attempting to implement some inquiry methods in their own classrooms. The CPD provided to science teachers by the JCT alluded to inquiry, and to teachers allowing the students the freedom to undertake their own investigations, but did not provide teachers with an in-depth description of IBL, the features of IBL, or the fact that different levels of IBL exist. Therefore, it should not be unexpected that teachers are unaware of the nuances surrounding the concept of IBL, and its place within the spectrum of investigative learning methodologies

Indeed, only one teacher referred to the fact that inquiry requires the presence of certain features to be considered inquiry, as opposed to general discovery learning. In her response to the questionnaire, Teacher B wrote "I remember from college that this involves a specific number of features such as students posing their own questions, planning investigations, researching themselves, sharing their findings, critiquing one another and probably a lot more features I can't remember!". Considering, as described in Section 7.2.1, that Teacher B is the only other teacher, apart from me, who had a ‘formal’ introduction to IBL during her initial teacher training, it might be expected that she was aware of the fact that there are specific features that are required to be present for a lesson to be considered an inquiry lesson. However, we should not be surprised when teachers who have not had such an academic introduction to inquiry-based learning tend to conflate the different styles of discovery learning under one umbrella term.

Similarly, only one teacher, Teacher A, made reference to the fact that there were different levels of inquiry, a fact that was emphasised when she asked during her interview “But I think it also depends on how many steps I give them to follow… back to whatever, there’s different levels of inquiry, isn’t there? Semi-led, and… yeah…”. Again, I would argue that criticism should not be levelled at teachers for their lack of understanding of the fact that levels of inquiry exist, and that the extent to which inquiry is present in their lessons depends on the amount of freedom afforded to students to direct the lesson.

7.2.2.1 Examples of teacher use of inquiry

Given the opportunity to describe how they implement inquiry strategies in the classroom, the teachers gave examples of their practice that indicate that their understanding of inquiry is, perhaps, deeper than displayed in the previous section. When asked to describe some examples of how they implement inquiry in the classroom, it seems that some of them, at least, have an understanding of the features of inquiry, and the different ways in which it can be implemented in the classroom. For example, Teacher B wrote in response to the questionnaire that, in her classroom, inquiry means that “students have the freedom to choose their own method to carry out an experiment and not follow written steps provided by the teacher… students of the new JC come up with their own hypothesis and this hypothesis does not need to be the same for everyone”. It can be seen from this response that the teacher understands that allowing the students to develop a method for carrying out an experiment provided by the teacher is a separate concept from the student creating their own hypothesis to be tested.

The introduction of the Classroom Based Assessment (CBA) into the Junior Cycle, in which students are given the freedom to develop their own questions to be investigated, had a profound effect on some of the teachers' understanding on IBL. Teacher C, for example, described one example of how he undertakes inquiry in his lessons: "it is that, that they aren't told exactly what to do, that they are… there's more questions, like that thing we did, the *MRB* [CBA], isn't it? That they have a question that they kind of research, that they kind of find out how to approach, how to do it, rather than just being told a, b, c", again showing that the students are given the independence to carry out an investigation as they want, rather than the teacher providing the method for undertaking practical work.

The descriptions of inquiry in the classroom provided by the teachers can be divided into two groups; namely, the actions undertaken, or the roles filled, by the teacher during the lesson, and the actions the students undertook. Many teachers referred to the idea of not giving the students the answers to questions they may have, but rather allowing the students to conduct their own investigations, and determine the answers themselves. Teacher A, in response to the questionnaire, for example described her role as "I do my best to pose a question to the class and let them come to their own conclusion", and expanded on her thoughts during the interview, saying "but usually I kinda pose a question before I give them anything, any equipment, which tends to help a little bit, so they get… they kind of… [sigh]… already thinking about the topic before they have equipment to try and work out whatever the question is…". Teacher A, it may be interpreted, sees the role of the teacher as a guide, prompting students to think about what they want to investigate, but keeping the questions posed by the students within the parameters of the topic at hand.

This concept of the teacher as a guide is echoed by a number of other teachers. Teacher D explicitly uses the terms guide and guiding during his interview when he described how his role is "to guide them, we're guiding the students, essentially, to learn some of the stuff, or to figure it out, or to understanding what they're learning". In a more oblique manner, Teacher E voices a similar idea "it didn't come to the case where I just threw theory at them, and said 'go, do that, and whatever you come up with, that's what you come up with', I was… with them along the way", as does Teacher F when she says "instead of telling students the answer I try to help them to figure it out, by giving them hints or by providing them with the necessary equipment to find an answer/explanation".

These responses reinforce the fact that the concept of guidance, in the form of hints, probing questions and provision of the correct experimental equipment, seems to be a central idea to what the teachers see themselves doing in an inquiry lesson.

However, it appears that some of the teachers are finding a balance between student autonomy and teacher guidance. For example, Teacher E describes how he views the teacher as someone who checks the understanding of the students at various points during an investigation, to ensure that students are not picking up misconceptions "at the beginning of the year, we did a lot of work on, say the scientific method, and the experiments and that, and, if the result wasn't making sense, I was telling them… And we looked through it, and we saw what they were doing wrong, and by the end of it they all came to the same answer… they all came to the right answer". This can be an important role to fulfil, as will be discussed in a later section.

Teacher D, some of whose teaching practices were described previously in Section 5.3.6, found a balance between giving complete autonomy to students, and directing their learning. During the interview he outlined his thoughts on the role of the teacher during investigations, stating "The teacher needs to be in control of the direction of the learning of the student", and that to facilitate this process, for both teacher and student, that "You don't need to give them carte blanche, take any piece of equipment they want in the lab, you can give them a choice of maybe one or two". Part of the response provided by Teacher C during his interview also relates to student autonomy when he describes how "I'd say definitely give them more, give the students more kinda scope, instead of… I suppose moving away from the recipe, the *modh oibre*, and just trying to give different approaches to things, that gives them a bit more scope for… not individual, but independent, eh, learning".

In their descriptions of their lessons, to more fully describe their understanding of inquiry and how they use it in the classrooms, the teachers also described some of the roles fulfilled, and activities carried, out by the students. Teacher A, for example, described how "working in groups students had to find some specific information about their assigned planet (mass, temperature, gravity, size...). This information was then brought together, and students were tasked with comparing the different bits of information and as a class we came up with a picture of our solar system", which highlights a point made in Section 2.3.2 that inquiry in the classroom doesn't necessarily require a practical, experimental activity. Although most of the teachers did equate experimental and investigative work with inquiry, some of the teachers viewed the research element as being just as important a stage in the investigative process as the physical execution of the experiment, such as Teacher D: "the information I gave was enough, but not too much, so they actually had to go and do a little bit of research on actually what… what scientific method they were going to use, how they were going to design it, and all the rest of it", with the aim that the experiments are "directed primarily, and designed primarily by the students".

Many teachers reported that they often asked students to determine how to use a piece of scientific equipment to carry out a task, as I had described with the displacement can in Section 5.3.6 previously. Teacher B also uses the same piece of equipment as a "simple example of inquiry that I've always used during measurement in physics is providing students with equipment, a problem and getting them to figure out how to use the equipment themselves (opisometre, displacement can)", as does Teacher C "eg. forces - giving them some equipment and asking them to see if they can use it to determine the effects of friction on movement, or the connection between mass and weight. In Mass, Volume etc, give them the equipment and see if they can discover how to measure volume of an irregular object". Using Blanchard et al.'s (2010) or Smithenry's (2010) definition of the levels of inquiry, using this tactic of providing the students with the equipment, and asking them to answer a question posed by the teacher, in this case 'what is the volume of the stone', a lesson could be viewed as a Level 1 or Level 2 inquiry lesson, depending on the level of guidance and direction provided by the teacher to the individual students.

Sometimes the teacher provided the students with a piece of equipment, and did not provide a question to be answered, but rather let the students experiment for themselves and determine what question can be answered with the equipment provided. This example, also from Teacher C, refers to electronics kits that are often used by schools, consisting of batteries, solar panels, buzzers, bulbs and other pieces of equipment in easy-to-use, durable casings: "it's just that they were given the material, and allowed to go off and explore, and it's kinda the way you'd expect those sets to be used… it's like a Lego box set, you just kinda go and do it, em, now they obviously had to come up with some kind of thing as well, like a 'show something' but…". In situations like these, the level of inquiry can be increased to Level 3: Open Inquiry, if the conditions allow.

The majority of teachers also referred to their desire that the students engage with critiquing their own work and the work of other students and that they communicate their thoughts effectively. Group discussion, both small-group and plenary, seems a common occurrence in science classrooms for many teachers. Teacher B gives one example of how she encourages the students to engage with reflection on their own and other students' work: "if students carry out an investigation in the classroom I like the students to compare and contrast groups' results, their methods, identify what was good about their methods and how they could be improved". Teacher C also gives an example whereby a deliberately vague question posed by the teacher can lead to class discussion: "Also, give them a metre stick and ask them to find out how big the room is, without saying what exactly I'm looking for - some will do volume, some length, some area. It makes for a good discussion". The benefits, he says are that "in those kind of things, really, is that they get different answers, and you have an opportunity at the end to explain, or to kind of discuss, so you can sit down and go 'why did you do that?'".

7.2.3 Student Enjoyment

All teachers reported an increase in student interest in science. As previously mentioned, I and the other teachers use the term 'interest' loosely here, synonymous with 'enjoyment' or 'engagement', not in the strict sense as employed by educational psychologists. As in the previous section, the written responses to the questionnaire proved the most succinct. For example, Teacher B stated "I certainly feel a greater level of enjoyment for the subject from the students […] there is undoubtedly more enthusiasm for the subject…", and Teacher F concurs: "I think they have more of an interest in science and are more confident in their own abilities to find something new out". The freedom and independence provided by the new *Specification* was obviously a factor for Teacher C's students improvement in attitude too: "Definitely, you can see the difference in the students' attitudes to the tasks as they know that they can try what they want to and they enjoy the challenge”.

Similar responses were received from the teachers during the interviews. This tallies well with the literature, insofar as student interest is increased when an inquiry approach is utilised. Teacher D was surprised by the increase in enjoyment: “some people really surprised me, I think just the interest, maybe they weren’t able to articulate it before, because it was all rote based, and they never got a chance”; Teacher E not only reported an increase in interest in his own classes: “So, they’re really enthusiastic about it, they’re really enjoying it. So, yeah, I think they are more engaged to what’s going on”, but also in his observation of other teachers’ lessons too: “I’m obviously sitting in on D’s class and F’s class, and they seem to be enjoying what’s going on”. However, Teacher B used a phrasing which echoed almost exactly the words I found myself using to parents at a first-year parent-teacher meeting “They’re definitely more open to it, they don’t groan coming in, like my first and second years do not groan coming into the classroom, the way some of the others did, that have just completed the old Junior Cert”.

However, several caveats arose to qualify the answers given on the question of interest. Several teachers highlighted the idea that, no matter how engaging the lesson, you will never have all of the students enthused and interested. As an example, Teacher D stated that “There’s always going to be people in the class that just don’t like science, and are not that way inclined… If they don’t like woodwork, or country music… People have preferences. We cannot expect people to be forced into a funnel, you know, just to shine, you know. Not everybody will”. The suggestion that some students will just not be interested in science was also echoed by Teacher A: “but I don’t, like, every student in a 30-student class is never going to be interested in science, and that’s just, a fact”. In addition to personal preferences for subjects, several other factors were suggested by teachers that have an impact on the interest of the students during science lessons, and these will be discussed separately.

7.2.3.1 Student Interest Depends on Activity

Not unexpectedly, and as research (Bryan et al., 2011; Odom et al., 2011) shows, interest in science differs when comparing lessons in which practical activities were taking place, and those without. Teacher A, for example, states that “Students are certainly more interested during classes where there are practical activities”. Teacher E similarly states that his students are “really enthusiastic about it, they’re really enjoying it. So, yeah, I think they are more engaged to what’s going on”, as previously quoted, but adds a caveat, when he admits that “Em, well, as I was saying that, something crossed my mind… I’ve only first years, and first years tend to be enthusiastic about everything anyway!” and continues with the admission that the enthusiasm emoted by his students is not evident in all lessons.

The fact that student interest depends on the topic being studied is also discussed by the teachers. Teacher D admits that some topics are more interesting for the students when he says “they really lit up… yeah of course, I think they’re more excited, but it depends on what we’re covering, and if it’s inquiry-based or is it… or we’re giving them notes, you know, so like it’s a… it depends on what part of the course we’re doing…”, which not only underlines the fact that not all students are going to find all parts of the science course equally interesting, but that students are distinctly uninterested by writing notes, or by the teacher using PowerPoint presentations too often, as Teacher E admits “When you’re going through PowerPoints with them, you can see they’re bored out of their head. You know, they’re… they say death by PowerPoint”.

It was not a surprise, therefore, to find teachers report that students prefer, and are interested in, undertaking practical work; they similarly dislike copying notes, and teachers being overly reliant on PowerPoint. These statements agree with work carried out by Odom et al. (2011) and Bryan et al. (2011). Overall, the teachers’ perceptions of student interest, engagement and enjoyment align with the findings of Krapp and Prenzel (2011) when they state that “students’ interest is not equally high for all topics or activities related to a particular subject” (p. 37).

7.2.3.2 Student Interest Depends on Ability

Unexpectedly, several teachers distinguished between the perceived interest of students of high academic ability, when compared to academically weaker students. Teacher B was clear in her opinion that academically weaker students showed “more enthusiasm for the subject… is particularly obvious in those who wouldn't be considered academically the strongest students”. This increase in student interest is especially evident when she compares their attitude to the attitude displayed by academically weaker students under the old course: “Those doing the new Junior Cycle where I have more freedom to teach by inquiry seem to quite like and be enthused by the subject even if they don't attain the best grades. Whereas weaker students to whom I've taught the old Junior Cert to, appeared to dislike the subject, put little effort into groupwork and be very eager to drop to ordinary level”. Teacher E agrees that there seems to be more enthusiasm amongst academically less able students: “You can see it with the weaker students, they’re a lot more active, and engaged in their own learning”.

However, the literature does not engage with this topic to a great extent. Although several teachers commented on the higher perceived levels of interest amongst the weaker students in particular, only one attempted to explain this phenomenon. Teacher A stated that “As long as, when they get a class test, their marks are relatively good, and they’re happy with those marks, because I think that’s often what disengages students, is failing constantly; em, they just, they can’t be interested in that kind of subject, and I understand… there’s no… if you fail constantly at something, you’re not going to want to do it”. Perhaps the increase in interest is especially evident in those students who traditionally would have turned off science at an early stage. This disengagement may be due to difficulties in understanding complex concepts, and being required to rote learn material of which they had little understanding, resulting in low grades in exams, which would decrease interest in the subject. As part of the change of emphasis in the new course away from rote learning, and towards broad understanding, which will be discussed in the following section, it appears that weaker students are performing better on class tests, which results in more enjoyment in the subject.

In contrast, again surprisingly, a number of teachers commented on the lack of enthusiasm displayed by academically stronger students. Some teachers opine that academically stronger students are struggling with the more open nature of the new course. Teacher B comments that “The more academically able students, I think that they would prefer a more structured approach… and I find they’re still doing well, but they don’t like ambiguity… and I’m aware of that. They want the information, they want a template, they want to know what’s coming up on the exam…”. This discomfort experienced by the stronger students is echoed by Teacher C, who found that "Some of the less academic students really enjoy jumping right in whereas others who always get high grades don't always like the uncertainty of the activity, which is also good preparation for them".

Teacher C elaborates on this thought by providing an anecdote from one lesson, where the students were learning about measurement: "and straight away the ones who would be… the more intelligent ones I suppose, straight away ask the question 'what do you mean, how big?'… [in response] 'No questions, five minutes, come back to me'. Whereas the other ones are already gone off with the *méadar slat* [meter stick] and they're trying to measure the desk, and the… you know, they didn't know what they were doing, but they were having fun, and they were at least able to use a ruler, whereas the more… the high functioning ones [laughs] are sitting there, like 'what do you mean?' They couldn't do it without further instruction from… or at least a definite question, or a proper question, I suppose… It is, yeah, it is interesting, I think". He highlights the difficulties academically stronger students seem to have with more open forms of inquiry as "a similar kind of thing, in that if you don't have that 'think outside the box' attitude, that it tends to be the very smart ones that need to be just told… and then they're going to do it… is it… it's a different kind of intelligence, isn't it?".

Again, there is a lack of research conducted on the relationship between student ability or aptitude and interest or enjoyment. Clark's (1982) analysis of studies conducted in the 1950s, 60s and 70s is the only 'recent' paper I could find which reports a relationship between student ability and enjoyment. He found that students "tend to report enjoying the instructional method from which they learn the least" (Clark, 1982, p. 99). In this case, lower ability students tend to enjoy more permissive methods, but learn from more direct instruction, and higher ability students enjoy direct instruction but tend to learn more from open approaches, which allows them to stretch their abilities. However, more recent research (McRobbie & Fraser, 1993) found no correlation between student aptitude and attitude towards science.

Nonetheless, it may be suggested that the anxiety prompted by the seeming lack of structure in the new Junior Cycle course, and during lessons during which more open investigations are taking place, take its toll on stronger students. Teacher A surmised that "they were getting very stressed about what's going to be on the exam, what sort of questions, how do I… especially the stronger students, because they want to get an A, because they're used to getting As". In this case, I could suggest that the interest or enjoyment of the students is being negatively influenced by anxiety and lack of control, a finding which would correlate with more recent research (George, 2000; Green, Martin & Marsh, 2007). Although students express better attitudes towards open inquiry activities (Jiang & McComas, 2015), they preferred traditional exams rather than open evaluation situations (Stefanou & Parkes, 2003), and the uncertainty introduced by the new course, expressed previously, and which will be discussed in more detail in Section 7.2.6.2, impacts on the enjoyment of science of some of the stronger students.

7.2.4 Student Learning

When discussing the impact on student learning and achievement, the nature of the Junior Cycle *Specification* leads to more mixed views. Teacher E sums up one of the benefits of the freedom of the new Junior Cycle, coupled with the use of inquiry techniques in his lessons, when discussing the students investigating drinking water compared to sports drinks: "you give them a question, and they have to go out then and put together a plan to discover what the answer to the question is. But along that journey they're learning as well, you know, about osmosis, respiration, all different things as well. So, they're learning things for themselves, rather than you just…". The flexibility of the Junior Cycle allows for several topics to be woven together into one overarching theme, allowing the students to see the connections between the different topics they are learning about. This, Teacher E believes, leads to increased engagement with the subject, which in turn leads to better learning: "if you're interested, you're going to… I think you learn a lot better."

However, when asked to discuss whether students were learning better, or more effectively, the responses from the teachers tended to be somewhat more cautious. Teacher D, for example stated that "they're looking for this, that and the other, they don't know what they're going with, that's… they're not really… they're not really learning, they're not really swinging towards the learning outcomes". The idea that the students were not necessarily learning the outcomes which were expected of them was also mentioned by Teacher A: “em… they’re not always… I suppose they’re always learning something, they’re not always learning what I had set out for them to learn…”. Teacher C was concerned that some students didn’t learn anything by undertaking practical activities: “you have… you can’t just let one thing guide that, cos there’s other ones who will be completely lost and won’t have picked up anything from the… the inquiry”.

I feel that at this point, a caveat is in order. With such little detail, such a broad range of different approaches to inquiry possible, and especially given the differences in teacher understanding of inquiry discussed in the previous section, it can be difficult to determine exactly why the teachers feel that their students might not be learning, or not progressing towards the learning outcomes they had envisioned for the lesson. Similarly, in describing some of the responses, I believe that teachers are conflating the influence of the Junior Cycle course, and its open nature, with their experience of implementing inquiry techniques into their lessons. It is, of course, impossible to tell from this remove whether teachers who reported implementing inquiry-based learning in their lessons did so successfully, or merely attempted some inquiry techniques. However, the responses are interesting in their own right, not necessarily as a reflection of teacher experiences of implementing inquiry.

However, some of the teachers did provide more information. Part of the difficulty can stem from the students becoming distracted by the fact that they were undertaking practical activities. Teacher A was explicit on this point: “but they are not always focused on the desired learning/the purpose of the task”, and about the fact that it tends to be the less academically able students who fall into this behaviour most often: “Weaker students tend to be more just like ‘oh my god we have stuff in front of us that we can play with or do whatever’ and they forget whatever you’ve told them they need to be doing, so it takes more management in that regard…”.

In a slightly different vein, Teacher D similarly highlights classroom management as an additional factor that needs to be considered when implementing inquiry activities: “I know, like, some of them, the lads sitting down the back there are just playing around, and they won’t be learning anything, whereas other groups will be focused on something…". As discussed in Section 5.3.6, this was one aspect with which I have had experience, and felt that the same difficulties arose during an inquiry lesson of my own. In both these cases, it is wilful disregard for the learning outcomes of the lesson, and for the task that has been set for the students, rather than excitement overcoming the students' better judgement, as Teacher A experienced in the previous paragraph. Without proper classroom management, it is impossible to ensure that all students are on task.

However, it appears some students do respond to the increase in autonomy for their own learning. Teacher E outlines: "the first years this year, I have done a good bit where I've given the responsibility to them, and given them a chance to do it. Em… how it's worked out, at times it's gone very well. Sometimes they struggle a little bit with the personal responsibility, but I definitely feel that if I'm doing chalk and talk, I'm taking on the majority of the work, and then when it comes to seeing how much they've learned, em, a lot of them are sitting there, pretending they know what's going on, and they don't". Evidently, Teacher E sees a benefit to students engaging in practical investigative activities when compared with traditional didactic teaching methodologies.

In order to ensure that all students are achieving the same learning outcomes during practical activities, it helps if the students are clear about the link between that practical activity and the material discussed before or after the activity, as Teacher A points out: "Those students who see the link between the practical activities and the discussions/group work that follow or precede them seem to have more of a continued interest as to what we will be investigating next". Teacher C similarly finds it useful to continuously direct the students attention to the desired learning outcomes, to ensure that all students remain on task: "unless you kind of bring it all together at a certain point, you do have to stop and get everyone to focus on one aspect otherwise it's completely, yeah, you get all different ranges of, of understanding, of interest, you know some kids are brilliant at that kind of stuff, but I suppose if you don't have a focus, could be very misleading or misguided".

Teacher A similarly points out that although "they're not always… I suppose they're always learning something, they're not always learning what I had set out for them to learn…". Putnam and Borko (2000, p. 9) discuss this exact situation, in stating "This dilemma is analogous to one faced by the classroom teacher who wants to empower children to build upon their own thinking while simultaneously ensuring that they learn expected subject-matter content." We, as teachers, want our students to be independent learners, and to be able to undertake scientific investigations to enable them to construct their own knowledge, but often the investigations lead to scientific misconceptions, or inaccuracies.

This entire section can probably be best summarised by one comment made by Teacher D, when he replied "really, I'd be lying to you if I said they were or weren't…" learning better. This response should not come as a surprise. The literature is divided, and often contradictory on whether students learn science content better through inquiry-based learning. As described in Section 2.3.3, although many studies have shown that students learn better by inquiry methods (Alfieri et al., 2011; Furtak et al., 2012; Jiang & McComas, 2015; Marshall & Alston, 2014; Marshall et al., 2017; Minner et al., 2010), care must be taken with this information. Jiang and McComas (2015), for example, found that guided inquiry leads to higher student achievement, but that open inquiry does not lead to better outcomes. Similarly, Teig et al. (2018) found that using inquiry to a certain extent in the classroom can improve outcomes, but that increasing the amount of inquiry used in the classroom beyond a certain frequency can actually have a detrimental effect. Kirschner et al.'s (2006) seminal criticism of open discovery methods gives a fuller description of the case against open constructivist techniques, which was outlined in Section 2.3.4.

However, this dissertation is not designed to test the efficacy of inquiry-based learning in *Gaelscoil* science classrooms, and tempting as it may be, I can't engage in a deeper analysis of why teachers felt that their students were learning better.

7.2.4.1 Student learning and ability

Again, unexpectedly, the teachers differentiated between the perceived ability of their students when gauging the level of learning. Several teachers found that the weaker students had gained more in the move to the new course. Teacher E, for example, finds that the weaker students are more aware: "Whereas, if you're giving them the ownership, and they actually have to do the work themselves, the weaker students are a lot more clued into what's going on". This is in stark contrast to the observations of Teacher A, who found that "Sometimes I feel that inquiry-based learning is lost on some of the weaker students (particularly if they are in a group with stronger students) as they can hide in the group or are sometimes distracted by the equipment or practical element and do not understand the importance/relevance of the results". This point is mirrored in Clark's (1982) analysis of open discovery learning methods. Weaker students prefer more open learning situations because they "could find considerable anonymity in this setting" (p.99).

7.2.4.2 Skills-based vs Content-Based

In explaining whether the teachers felt that students were learning better under the new *Specification* compared to the old Junior Certificate syllabus, many teachers made a distinction between scientific concepts and scientific skills. It appears that teachers perceive a shift away from a content-based curriculum, towards a more skills-based curriculum in the new Junior Cycle course. Teacher D described how his students "mightn't have rote-learned as many facts, figures, and eh… normal, back to the old course; but they certainly are more quick to deal with research, and actual real science going forward", signifying that although the students are not learning scientific concepts, they do have a greater understanding of science as a methodology, and the scientific skills that are required to undertake scientific investigations. He later elaborates on that point by stating that the students are "nearly learning more skills in which to be a scientist, than learning the science and working backwards, if you know what I mean". Similarly, Teacher B points to the *Specification* as the driver of this shift away from learning content towards learning skills: "they don't want us to… have our students rote learning, or learning things off, and em, to get them to think outside the box, and to analyse and to pose questions and to use their, the principles that they've learned, to apply them to a wide range of things".

It appears that several of the teachers feel that the emphasis placed on scientific process skills does have a positive outcome for students. Teacher C, for example, sees an additional emphasis on the skills-based aspect of the new *Specification*: "See, you know the way we do put all this focus on that… on the holistic… and then… wellbeing, and it is all about that at the end of the day they are here to learn but they're also here to develop all sorts of skills”. Teacher A describes an improvement in the ability of the students to undertake more open inquiry activities in the classroom, with less teacher support: “but, that said, with our first year group, we started with the scientific method, and variables, and a fair test, and I have to say that I could give my… they’re now my second years, I could give them any investigative question… measure the distance between x and y, or whatever it happens to be, and they would be able to design an experiment, most of them would be able to design an experiment that’s fair, and they would be able to identify the variables for me; whereas I could do the same exercise with my third years, and they would need an awful lot more spoon-feeding”.

Teacher D sees that this improvement in science skills is something that will benefit students in the long-term: “And once you learn the basic skills, and it’s the same with science for the Junior, for the new Junior Cycle; they will have skills, I’ve no doubt, in fourth or fifth year, when they start… even in third year when they start, if they were asked even to do another, next year they’re going to do another *MRB* [CBA], they will be far more critical of why they’re doing things, as opposed to getting it done, and getting the mark in, and I believe their skillset, science skillset will have definitely increased”.

However, there is a tension between the conclusions the students draw from their investigations, or indeed how they conduct the investigation to begin with, and the body of accepted scientific knowledge, which they are trying to ‘discover’ for themselves. Teacher C points to the difficulty in carrying out an investigation, when students are unsure of the ‘correct way’ of proceeding “obviously you have to give the caveat that there is no correct answer, but, yeah, yeah, some might obviously think that they have done something wrong when they see other groups doing something”. Teacher A raises a similar point, when trying to connect the discoveries made by students during an investigation with the content they should be learning “I think inquiry-based learning lends itself to understanding, it’s very hard to go from an inquiry-based approach aimed towards understanding back to ‘well, actually you’re right, but now learn these specific words in the way that I’m writing it’; I think that kinda says to them ‘all… everything you did is great, but actually this is what I want you to learn’…”.

This tension is especially evident when teachers compare the learning of the students during class time, with what might be expected of them on the terminal examination at the end of their third year. Teacher A, for example, worries that "as long as the exam – the questions that are written reflect that type of learning, we'll be fine, but if they're looking for… word for word definitions of things, that's not what we've been teaching… because, well, I don't think people need word for word definitions because, we now have google [laughs]". This emphasis on examinations is a common theme amongst science teachers, and their thoughts on the topic will be more fully discussed in Section 7.2.6.2.

7.2.5 The Aims of Junior Cycle Science

One unexpected theme that emerged during the interview process was teachers' understanding of the aims of lower post-primary science education. Teachers refer to the change from rote learning without understanding, to understanding the broader concepts in science. Teacher A opines in her written response to the questionnaire that "I think that my emphasis has shifted towards broad understanding and away from rote learning (I hope!)"; she elaborates on this point further during her interview: "I think the things we've covered, they know pretty well, and they seem to have a better understanding of concepts, rather than just rote learning of… facts, I suppose…". Teacher D similarly sees the *Specification* as shifting the focus away from rote learning of facts: "trying to get the students to understand why they are doing what they are doing and the logic behind it more than just asking them to learn something outright".

'Doing the right thing' or 'getting the right answer' seemed to be a common concept in the teacher responses. It appears that the science teachers want their students to understand that there is no 'one right way' of doing things in science. Teacher C states that "more investigative activities rather than the old style of reading the instructions and copying them… the emphasis is more on the scientific method than doing the right thing every time", and Teacher A makes a similar argument "They don't get the idea – there is no wrong result, as long as you've done… as long as you can defend your experiment and how you did it, your result is whatever it happens to be. And if we can teach that, and the value in mistakes, I think we're onto a winner".

Some teachers referred to the fact that we are trying to engage students in science, a motivation which has several benefits. First, teachers view it as a means of encouraging students to pursue science subjects for the Leaving Certificate, and for them to see science as a valid career choice, as Teacher B explained "I think you should be, em, bringing them up to a standard and a level where they still want to learn more about physics, and they still want to learn more about chemistry, and then they go on from there, and not ruling it out". However, Teacher D sees students struggling with the Leaving Certificate science courses, as "they basically go back to rote learning for biology, you know?". Teacher A similarly sees students as "possibly more likely to choose science at Leaving Cert level? But they might just get a shock to the system when they get there. Because Leaving Cert is hard. Even at ordinary level, Leaving Cert is *hard*. And takes an awful lot of work". This difficulty, moving from the freedom allowed by the Junior Cycle to the highly prescriptive Leaving Certificate course is also highlighted by Teacher D, who sees an increase in students numbers taking science subjects for the Leaving Certificate only "if the biology and physics and chemistry courses change the same way".

A second benefit to the increase in student enjoyment and understanding of science is so that they see its value in their everyday lives. Teacher B states that, for her, the aim of science "from first to third year, I think it's really about getting the students to enjoy science, realise the importance of it in their everyday life, in society, in sports that they watch on tv, like, it penetrates through every walk of life…". Students should, at the end of their three years in Junior Cycle science, have encountered scientific concepts in such a wide variety of settings, linked to their everyday lives, that they should appreciate that science is everywhere in their lives, even if they do not choose to progress with the study of science at Leaving Certificate level, or beyond.

7.2.5.1 Developing Other Skills

Teachers report themselves as placing a greater emphasis on developing students' communication skills in the Junior Cycle, as Teacher B highlights: "I place a lot of emphasis of communication in science". But in addition to communication skills, teachers see students interacting with each other having additional benefits. For example, Teacher C also acts a 'class tutor' to one of the first year classes: "So now, with my own group especially, I'm really kind of conscious that, with those things like, you know, giving them *trealamh* [equipment] and saying 'off yez go', I can see the social aspect as well of things like that…". He sees that students undertaking group work and communicating with each other has benefits in addition to merely improving their communication skills. Conscious of what he learned in his time as a teacher in Korea, he also sees the social aspect of students communicating with one another, and acts upon it when appropriate: "It is a different kind of ball game now, really, cos you can see 'okay, she's not mixing'… just get them, change the groups a bit more, you know I'm maybe a bit more interested in that now".

It may be that, as a relatively recently qualified teacher, Teacher C was encountering these situations for the first time. It may be that the other teachers who were interviewed accept that part of our roles as science teachers, or teachers of any subject, is to promote and encourage students' social skills, and did not deem it worthy of remark. A second skill identified by Teacher C, which we science teachers struggle with, is the students' lack of knowledge surrounding graphs; the ability to draw and read graphs is a core skill in science, as well as other subjects. Teacher C outlines how he has "always had that kind of thing with other groups as well, in that I was really pissed off at times when I realised they couldn't do graphs, in second, third year, I was like 'what have you been doing? How can you still not be able to do a graph?' and I didn't get that, so I was taking time out to do graphs, because I thought that was a valuable skill, and then it mightn't have been technically on the course at that point, but I was… I felt that I was right to help, I thought that was something that you will need to do, it might be one of those things that's overlooked in a lot of subjects, it's just expected that you can draw a graph."

Clearly, the teachers feel that the aim of Junior Cycle science is to give students a broad understanding of science, it's importance in their everyday lives, and an interest in science, both within and without the classroom. Some teachers hope that this increase in interest and understanding will lead to greater uptake of science subjects at Leaving Certificate level, although some concern was expressed at the differences between the Junior Cycle, and the flexibility it affords when compared to the rigid structure of the Leaving Certificate. In implementing the Junior Cycle, it appears that teachers place more value in the students understanding that making mistakes can be a valuable learning experience, and that the students appreciate the importance of offering their justifiable opinions. However, teachers expressed the opinion that the rote learning of scientific facts has lost some of its importance to them, although this will be further discussed in subsequent sections.

7.2.6 Challenges Encountered

In implementing the Junior Cycle, several difficulties and challenges were encountered by the teachers. Many of them relate to the flexible nature of the *Specification*, and the openness of the learning outcomes. The difficulties tended to fall into two main categories, those related to time constraints in implementing the *Specification*, and the flexibility of the *Specification* in relation to examinations and assessment, which includes the depth of treatment of topics. In addition, teachers referred to the difficulties in moving from a didactic approach to a more inquiry-focussed methodology, and their struggle to find a balance between the two.

7.2.6.1 Time

The teachers all report difficulties in determining the level of detail required in the new course, how much time should be allocated to the different topics to ensure full course coverage within the three years, and uncertainty regarding the assessment process. Teacher E, for example, states: "Yep, I've only first year, so I don't know how time constraints are going to come into it, that's the biggest concern I have; that there is so much to cover, with so little time, where you give them the responsibility with inquiry-based learning, and you have a certain amount of topics to cover, or a certain amount of content to cover, you can be worried about time". Teacher A talks about her class's progress through the learning outcomes on the *Specification*: "We're covering a lot of them. But they're so broad. They're just so broad. So either it's the biggest course in the history of… or…". The openness of the learning outcomes on the *Specification*, which can be an advantage in allowing the teachers to cater for the different interests of the students, become a liability when the entire course needs to be covered within the three years of the Junior Cycle.

Other teachers were also concerned about the time it takes to undertake inquiry investigations in the classroom, and the impact it would have on the course as a whole. As Teacher D states, "and there's a lot of time wasted, and we only have a certain amount of time, and… at the end of the day, we do have to cover a certain amount of material. So there's a balance, I think, between, yes, there's of course there's a… there's an argument to be made for letting them just discover themselves, but let them discover for themselves within a certain framework, or parameter". Similarly, in discussing the use of inquiry methods in the classroom, Teacher A compares her teaching to explanations of inquiry she found online "cos I know a lot of the videos we watched are about, like, weeks-long inquiry-based projects, and I haven't, I certainly haven't gotten to that… I pose a question, and they've answered it by the end of class, cos the idea of giving them that much freedom… again, your weaker students would be god-knows where by the end of two or three weeks".

Teacher A also expressed concern about the openness of the new *Specification*, but specifically in relation to the terminal exam at the end of third year. Since teachers are unsure as to the depth of treatment, they are taking as much time with topics as they see fit, until "but all of that said, I won't really know until next year… [laughs]… when there is an exam, and suddenly I'll find out that all of that freedom was just a myth, and actually, we need to learn a whole course in six months…". This focus on the terminal examination is also a common theme amongst the teachers, and is explored further in the next section.

7.2.6.2 Exam Focus

Although most teachers had described themselves as giving students a broad understanding of science, and an appreciation of and interest in science in Section 7.2.5, teachers are still cognisant of the fact that there is a terminal examination of the Junior Cycle course at the end of third year. Teacher A is explicit in her understanding of this fact: "And unfortunately, like I know we're not supposed to teach to an examination and I'd love not to have to teach to an examination but if there's going to be an examination, then our job is to prepare them for that. You can't say both at the same time". Teacher B similarly tries to disregard the examination when choosing topics and methodologies for teaching content in class "choosing what one might work best, and they might enjoy more, rather than what's… rather than trying to cover what you think might come up, for an exam".

However, given that teachers feel that there is more of an emphasis on skills acquisition rather than learning content in the new course, some express anxiety that the examination will not reflect their understanding. Teacher A hopes that “again, as long as the examination at the end is open enough”, her students should do well. Teacher B finds herself “trusting the system that whatever way you’ve carried out an investigation, that they’ve learned a general set of skills, that they should be able to apply in any context; that’s what one’s hoping will happen with the new Junior cert Cycle…”, and that the idea they have instilled in their students, that as long as they can justify the approach to an investigation there is no wrong answer, will be an acceptable argument on the examination.

Some of the pressure on teachers in relation to examinations comes from the students themselves. Some students, especially the stronger ones, have expressed concern to Teacher E about how the new course will be examined, because “they might be a bit more anxious, in this type of exam”. Similarly, students expressed dismay to Teacher D that he wasn’t giving them the answers, only more hints and questions “they actually couldn’t understand why I wasn’t giving them the answers, because they had been conditioned, even in primary school to be given information to learn, and then reproduce…”. Students have learned from an early age that information the teacher provides is to be learned and regurgitated, even if it is not completely understood. Teacher B had a similar experience with her students “but come three months later, if they don’t have some formal notes written down, some formal, em, scripted notes, old-fashioned style diagrams, and definitions written in their copybook, they panic a little bit, and so from that point of view, em, I suppose we are coming back to the summative sort of, eh, assessment again, which we’re trying to get away from, but we haven’t gotten away from, because the Junior Cycle is still going to be a summative exam in the end”. Although teachers recognise that they are not meant to be teaching towards an exam, they are still conscious, as are their students, that an exam is awaiting them at the end of the three-year course. It can be difficult for both students and teachers to ignore that fact.

For this reason, several teachers find themselves being more didactic in their teaching methodologies due to the presence of a terminal examination. Teacher D, for example finds that: “And I think, I’m guilty of it myself, falling into just giving them the, basically, the answers, and making things easier on yourself as a teacher to get through, to make sure the learning outcome is achieved, is… is you just being part of a system that basically ends up in a one full exam". He goes on to admit that "Sometimes they do rote learn, no actually denying that we are still teaching a little bit in the old way; because, I don't know, and I think many of the teachers I've spoken to also believe they do need a certain amount of information in which they can actually go back and study, cos there is an exam still at the end of the year".

However, it should be noted that, as previously described, a combination of inquiry and didactic methods have been found to be the most beneficial for students, and that there is no right or wrong amount of either method, as long as there is a combination, as most teachers have discovered for themselves. This is the topic of discussion in the next section.

7.2.6.3 Striking a Balance

Despite the emphasis placed on skills and broad understanding in the Junior Cycle, and due in part to the presence of a terminal examination, some teachers do still see the role of learning of concrete scientific facts and concepts in Junior Cycle science. Teacher B, for example, is clear on this point "I think, from first to third, it should be about giving them an enjoyment of it, an appreciation of it, as well as learning very fundamental, important aspects". For example, her argument is that "you still have to teach the facts", as "you still have to teach the fundamentals in order to give them a solid foundation, I think, in order to build them up then, to be able to pose their questions, and become more scientifically minded; that doesn't come immediately". Once the students have a solid grounding, they become more adept at inquiry. Teacher B similarly views rote learning as something that should not be completely discarded. She states that "there's no point saying 'rote learning is terrible' or, because science fundamentally from year one is based on learning terminology and having to understand what a certain word is defined as, what, you know, cytoplasm is, you know, you can't… you can only explain that to somebody, you can't get them to figure out what cytoplasm is; you know, they have to learn that, so there's still quite an element of teaching the facts". I, and most teachers, would have to agree with her on this point. There are certain ideas and concepts that a student will never be able to deduce for themselves through an inquiry method. Without state-of-the-art equipment, and at least a basic understanding of certain scientific concepts, no post-primary student would deduce elements of, for example, cell biology, chemical bonding or evolutionary theory. Some topics require that students be taught certain concepts.

Other teachers agree with this idea. Teacher E states that “But I think it shouldn’t just be inquiry, it should probably combine the two. And when I think of it, that is what I actually am doing. I am doing PowerPoints with them, I’m doing also, I’m doing inquiry with them as well… I think you have to find the balance between the two”. Teacher C is of the same opinion “I wouldn’t be 100% on either side, I would be somewhere in the middle”, as is Teacher B, “so I think a combination of both works well, particularly in the Junior cert years; a combination of old-style supplemented by inquiry-based”, as previously stated. As discussed in Section 2.3, certain sections of the literature agree (Mayer, 2004; Teig et al., 2018).

Some teachers admit to struggling with finding a balance between the two, however. Teacher E, previously (see Section 7.2.1) admitted the change was taking time “It’s probably not as different as it should be, in that it’s taking time to adjust”. Similarly, Teacher D states that he is having difficulty in moving away from entirely direct teaching methods: “I was a bit sceptical at the start with it, but after doing the *MRB* [CBA], and talking to them, it’s so exciting for them, and like, it’s such a great chance for them to express themselves, so I’m very much into that”. It was interesting that, after being required to undertake an inquiry element in his classroom teaching, Teacher D expressed an interest in using inquiry in his practice. This is similar to Guskey’s (2002) model of teacher change. As Guskey pointed out, sometimes it is better to try something, which leads to a change in personal beliefs, rather than waiting for a change in personal beliefs to bring about a change in classroom practices.

7.2.7 What Support do the Teachers Want?

As mentioned at the beginning of Section 7.2, the teachers were asked one additional question on their questionnaire, which was not envisaged to form part of the research: “Is there anything that the school / other teachers / external organisations could do, to support your teaching in the new Junior Cycle science classroom?” This question was asked from my own point of view, to determine whether we, as a subject department, could ask school management to arrange, or whether it might be in our interests to work together as a group of teachers to put a structure in place for the following academic year. However, the information provided in response to this question, I believe, warrants some discussion at this point.

Teacher A responded with a request for more technology: "I think that technology in the classroom would help with some group projects and also allow teachers to explore some of the resources available online", before expressing the opinion, as she did during the interview, that the difficulties of booking a computer laboratory in the school, and wasting time moving the class and logging onto computers, discouraged her from doing so on a regular basis. This was a common complaint from teachers in response to our experimentation with the ISE Lesson Authoring Tool, as described in Section 6.2.4. Given that one of the Key Skills of the Junior Cycle (NCCA, 2012) includes the use of "digital technology to communicate", to "access content" and to "develop numeracy skills", it is not unreasonable to assume that teachers teaching the new Junior Cycle courses would expect reasonable access to digital technologies for their students. However, I expect that the iPad roll-out in September 2018 addressed this concern, for Teacher A's first-year students at the least.

Two teachers expressed an interest in more workshops and training; both Teacher B and Teacher C. In both cases, they expressed an interest in subject-specific workshops, where practical ideas could be shared amongst the teachers. I found this thought interesting, especially given the responses from the teachers who attended the series of webinars I organised, as described in Chapter Four. As Teacher B stated, "It's too easy for teachers to teach a topic they know the way they've always taught it rather than explore new ways of doing it". Teacher B went further and voiced the opinion that the teachers could attend different workshops, and "share their knowledge through a combination of team-teaching and classroom observation", an idea Teacher D also suggested. The concepts of team-teaching and observation to share professional practice are powerful but underutilised in Irish contexts. As Teacher B stated, "I think it could be advantageous in two ways. Given the high percentage of newly qualified teachers in [my school], they would greatly benefit from observing different teaching styles/classroom strategies before settling on their own style. Secondly those newly qualified teachers are probably a wealth of information regarding the new Junior Cycle given that some of them will have taught no differently before now and could in fact help their subject departments transition over to the new Junior Cycle". This would address the concerns of Teacher F, who felt that more communication between the members of the science department was required to share ideas and best practice. Again, what is most requested from teachers is the opportunity to share ideas with one another, and to learn from one another.

7.3 Discussion

Having taught the new Junior Cycle course for two years, all teachers reported a change in their teaching practice. However, the degree of change seemed to depend on two factors. Teachers who had been teaching longer found a greater difference in their teaching, when comparing the Junior Certificate classes with the Junior Cycle classes, or felt that there should be a greater difference, but that the change was difficult, and would come in time. Teachers who had not been teaching as long found that there was less of a difference. Similarly, the amount of change in teacher's practice depended on the extent to which they were exposed to inquiry-based learning during their initial teacher education (ITE). Those who had encountered IBL during their teacher training expressing the opinion that their teaching style had not undergone as big a change as those who did not encounter IBL during their ITE.

In describing their understanding of IBL, teachers tended to view inquiry in a general light, and display an understanding that inquiry-based learning is about giving the students the opportunity to undertake investigations in order to discover scientific concepts for themselves. However, the teachers often conflate the concept of inquiry-based learning with other general discovery learning methods. Similarly, most teachers are unaware that there are specific features required for a lesson to be considered an IBL lesson, such as the students asking questions, giving priority to evidence, and communicating findings as discussed in Section 2.3. In addition, most teachers seem unaware that there are various levels of inquiry, corresponding to the amount of freedom awarded to the students, and the amount of guidance given by the teacher to the students.

However, teachers are conscious of the role they fulfil in an inquiry setting. All teachers discussed the topic of teacher direction, either in terms of hints, questions or providing the necessary equipment to undertake the experiment at the right time. What was interesting was the number of teachers who used the same example of how they do inquiry in the classroom. In this case, it was by describing the situation where they give a piece of equipment to the students, and ask the students to answer a question using the equipment. This mirrors exactly one of the teaching episodes I described in Section 5.3.6, where I ask students to measure the volume of an irregular object using a displacement can.

All teachers reported an increase in student interest or enjoyment in science, as expected. This is especially evident in lessons which contain a practical element, as the literature would suggest (Bryan et al., 2011; Odom et al., 2011). Teachers report the increase in interest to be especially noticeable in students who would be considered academically weaker, as Clark (1982) noted; however, higher achieving students reportedly exhibited more frustration and uncertainty. This may be due to a reduction in the amount of material that is required to be learned by rote, with classroom assessment being more oriented towards displaying a broad understanding of scientific concepts and methods. It may also be due in part to the uncertainty around expectations of students during open inquiry activities, and the nature of assessment in the new Junior Cycle course.

Teachers were of a mixed opinion when describing how well the students learned under the Junior Cycle. At this point, it may be possible that the teachers are conflating their introduction of more inquiry-based learning techniques into their classrooms and the change in the structure of the course content. It is not possible to determine the reasons for the teachers' beliefs regarding how well the students were learning, nor should their comments be taken as an accurate reflection of student progress and achievement. However, a common response from the teachers was that students tended to become distracted during practical activities, especially when the activity allowed for greater student freedom of choice. Teachers were especially aware that such activities often lead to student confusion, and to the acquisition of misconceptions.

The teachers did report, however, that the students seemed to be learning less scientific content, and but were more comfortable and understanding of scientific skills and processes. Most teachers confirmed that their students were more proficient in constructing hypotheses, designing and carrying out experiments, and coming to conclusions based on those experiments, although, as noted, those conclusions did not always equate to the scientific facts the teachers had planned for the activity.

Overall, teachers felt that the implementation of the Junior Cycle course lead them to move the emphasis they place in their lessons from the learning of scientific facts and concepts towards the students learning a set of scientific skills, along with a broader understanding of science, the nature of science and its impact on the students' lives. Teachers also felt, for the most part, that part of the aims of the Junior Cycle was to instil an interest and enthusiasm for science in their students, so that they might be encouraged to continue studying science for the Leaving Certificate, and beyond. This is, in fact, a stated aim of the Junior Cycle science *Specification*, as well as a number of other international documents and reports, such as the Rocard Report (2007), the NSES (1996) and the NGSS (2013), as previously described in Section 2.3.

However, most teachers felt that students still required knowledge of a basic set of scientific facts and information. Teachers found that a balance was required between the students learning science content and science skills, and that this required a combination of direct teaching and investigative activities in their classrooms. Teachers reported an appreciation for the flexibility and freedom afforded to them by the Junior Cycle *Specification*. The lack of detail in the *Specification* allowed them the choice in depth of treatment, and choice in how best to approach different topics with their students. However, this flexibility had two main drawbacks. The lack of detail made teachers uncertain as to the length of time they could spend on each topic, with several teachers expressing concern that they would not have enough time to complete the entire course. In addition, teachers were unsure as to the nature of the assessment at the end of the third year of the course. Although they expressed an understanding that they should not 'teach to the exam', the lack of information made choosing to spend time on inquiry activities over content acquisition increased the teachers' anxiety that they might be doing the students a disservice.

7.4 Postscript

The data gathering process upon which this chapter was based was carried out in the 2017-2018 academic year, before the teachers had completed teaching two full years of a three-year programme. It is therefore, perhaps, unsurprising that so much of the narrative regarding the implementation of the new Junior Cycle contains an undercurrent of uncertainty.

I can only offer anecdotal evidence, and my own personal experience, but the two years that have elapsed since the interviews in this chapter has seen a softening of attitudes towards the Junior Cycle, and an acceptance of the new course. This may be because, as time has progressed, and the teachers have gained experience with the flexibility of the *Specification*, they have come to appreciate the level of choice offered to students and teachers in choosing topics that interest them to investigate and research. It may be that, as we undertake an additional day of JCT training each year, as described in Section 2.2.3, that we come to understand the *Specification* better, and more clearly grasp what is we are expected to cover when teaching the course. It may be that, since the sample Junior Cycle examination paper was published in October 2018, and then the first time the new course was examined in June 2019, the teachers have become more confident that they are not disadvantaging their students by placing too much or too little emphasis on certain parts of the course above others, or spending too much time on practical investigations rather than content acquisition. It is quite probably a combination of these and other factors.

What is noteworthy, in speaking with my colleagues and other teachers at CPD events, is that teachers have come to appreciate the benefits of the Junior Cycle above the previous Junior Certificate system. We now recognise that the enjoyment their students display towards the subject far outweigh the uncertainty that was involved in the initial years of teaching a new curriculum. The change in practice required to accommodate the openness and flexibility of the new *Specification* has taken time, and will take longer for some, but it is happening.

Chapter 8: Overall Discussion & Implications

This dissertation has outlined the professional and personal journey I have undertaken to understand my own practice and how IBL is integrated within that practice. I have also come to better appreciate how, both collaboratively and individually, my colleagues and I have come to interpret and implemented the new Junior Cycle science specification in our practice. This process has illustrated aspects of how I and my colleagues view our practice, how the implementation of the new Junior Cycle curriculum has impacted our teaching, and the benefits, for both teacher and students, of attempting new methodologies in the classroom.

Over the course of the project, as the focus of the research changed, so too have the research questions. The primary research questions, as outlined in Chapter One were:

I. How can I improve the provision of CPD for science teachers who teach *as Gaeilge*?
II. Can I claim to be using inquiry in my practice?
III. In a time of curriculum reform, how do science teachers in my school view their practice?

The aims of the research, in terms of research questions I, II and III above, can be seen as being comprised of the smaller research questions asked in each chapter, which I list for the sake of convenience below.

Chapter Four: How can I improve the provision of CPD for science teachers who teach *as Gaeilge*?

i. How can webinars be used to support the introduction of inquiry-based learning in Irish-language science classrooms?
ii. Do teachers who teach through the medium of Irish attach importance to undertaking their CPD *as Gaeilge*?
iii. What are the benefits and drawbacks to providing CPD opportunities via webinar, rather than face-to-face?

Chapter Five: Can I claim to be using inquiry in my practice?

iv. What does inquiry in the classroom look like in my practice?
v. Do our assessment approaches support the introduction of inquiry?

Chapter Seven: In a time of curriculum reform, how do science teachers in my school view their practice?

vi. With the introduction of the Junior Cycle, have the science teachers seen a change in their practice?
vii. What do the teachers think inquiry-based learning is?
viii. Have the teachers seen any effect on the students – either in their interest or learning?

Each of these questions have been addressed in the appropriate chapters. However, given the broad, seemingly disparate nature of the various aspects of the research, I decided to utilise Denzin and Lincoln's (2000; 2005) notion of *bricolage* in order to draw the various aspects of the research into a coherent whole. In subsequent sections, I will attempt to weave the various threads from each chapter together. To facilitate visualising how the questions and sub-questions are interrelated, I repeat a version of Figure 1.1 on the following page. However, Figure 8.1 has been amended to include the overarching idea of the journey this dissertation represents, which is to illustrate how IBL can be interpreted and implemented by science teachers in a *Gaelscoil* setting, in a time of curriculum change.

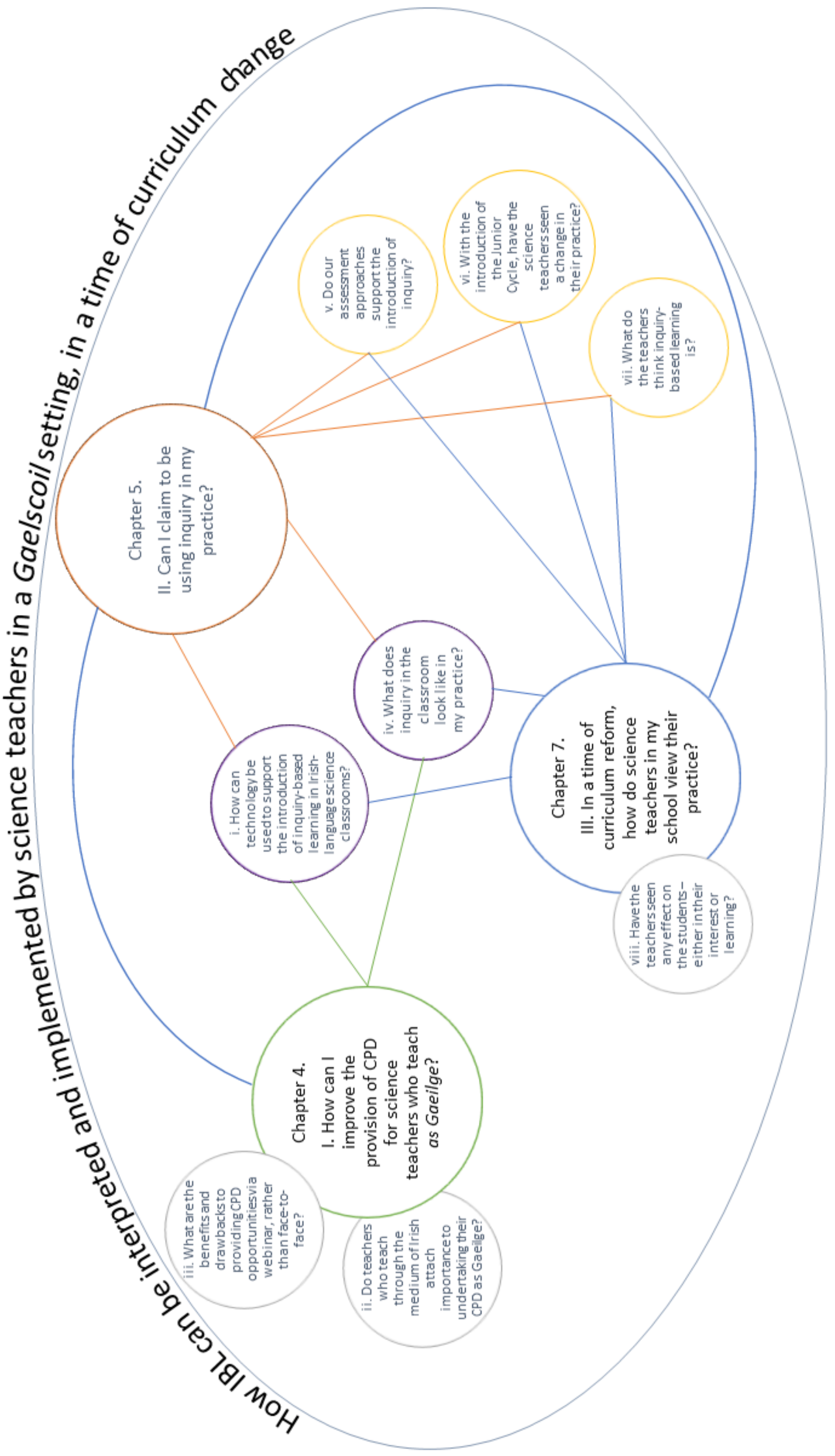

Figure 8.1: Amended Graphical Representation of the Relationships between Research Questions

8.1 CPD for teachers

The research project began by arranging webinars to deliver CPD *as Gaeilge* to teachers who teach through the Irish language. As part of the ISE project, these webinars would educate teachers on IBL, and describe how incorporating technology into their practice could facilitate their adoption of inquiry. However, my experience in organising the webinars was that it was difficult, and frustrating, to recruit teachers to take part. In hindsight, although the webinars were conducted, in as far as practicable, following best practice for webinars (Zoumenou et al., 2015), the CPD developed didn't follow recommendations for designing effective CPD (Cordingley et al., 2015; Desimone, 2009; Guskey, 2000; 2002). It was probably not long enough, consisting of only three hours of interaction, and there were very few opportunities for follow-up activities. The content provided was not concrete enough for teachers, who expect to experience CPD that will directly impact their day-to-day practices. This was not surprising, as I did not have a firm view of IBL at this point, and would have struggled to give concrete examples of how I implement inquiry in my practice. Most importantly, from the point of the teachers, perhaps, was that there was not enough teacher activity, and teacher interaction.

Teachers, in engaging in CPD, wanted to have time for informal discussion, sharing ideas, and building a network of other teachers who experience the same difficulties they do. Unfortunately, the webinar approach to CPD doesn't easily allow for such participant interactions (Glogowska et al., 2011; McBrien, Jones & Cheng, 2009; Ng, 2007; Yates, 2014), especially when technical difficulties arise. For this reason, I believe, that teachers indicated they would have happily partaken in this CPD if it had been offered on a face-to-face basis, rather than via webinar, as it would have facilitated this construction of a *Gaelscoil* science teacher network. The *Gaelscoil* aspect of this teacher CPD was critical, however. Most teachers indicated that the fact that the CPD was being offered in Irish was a very important aspect of their deciding to participate in the webinar series. However, given the geographical spread of Irish-language post-primary schools, it would be difficult, if not unfeasible, to arrange face-to-face CPD events *as Gaeilge*. Although webinars can overcome geographical limitations, and facilitate attendance at CPD in other ways, do these benefits outweigh the drawbacks, such as lack of interaction and technical difficulties? Further investigation is required on this point.

A second aspect of facilitating the integration of IBL in teacher practice is how technology can be used in the classroom, the benefits of which are discussed in the literature (Hmelo-Silver et al., 2007; Mäeots & Pedaste 2014; Rutten et al., 2015; van Joolingen et al., 2007). The development of the ISE Lesson Authoring Tool allowed the teachers in my school to better understand the sequence of an IBL lesson, and facilitated their planning of inquiry lessons. The fact that this platform also allowed for students to log in, and be guided through the inquiry lesson, while utilising embedded online simulations was seen as being of great benefit to the teachers who made use of it. Teachers could take the time to interact with students individually or in small groups, without being overly concerned about other students' progress through the lesson, as the teachers could include instructions and guidance in the lesson. Conversely, the inclusion of multiple-choice questions at the end of every section ensured that students couldn't progress directly to the end of the lesson, and claim that they had finished the lesson without completing all of the sections. In addition, the fact that other teachers' lessons created on the Lesson Authoring Tool could be cloned, amended as required and implemented, without much difficulty, decreased the workload on individual teachers. Although there were some criticisms and difficulties, overall the ISE Lesson Authoring Tool was seen as 'A Good Thing' by the teachers in my school, in supporting their use of inquiry in the classroom.

In summation, it appears that the provision of CPD in Irish, although appreciated, is both difficult, and probably not completely necessary. However, technology can greatly facilitate the implementation of IBL into science teachers' classrooms, both in terms of CPD to educate teachers on IBL, and in supporting their individual classroom practices.

8.2 Inquiry in Practice

This aspect of the research stemmed from my experience in delivering the webinars *as Gaeilge* to science teachers. As preparation and delivery of the series of webinars progressed, I found myself increasingly uncomfortable with the role I was filling. By delivering this series of webinars, I was implicitly presenting myself as an 'expert' on inquiry-based learning (Boud & Hager, 2012; Dadds, 1997). I found myself describing the benefits of implementing IBL into science teaching, and how it can be undertaken, but I was growing increasingly concerned that I was claiming to act in a way that did not reflect my actual teaching practices. By reflecting on my practice, I could investigate to what extent I was incorporating IBL into my classroom, and what that inquiry looked like.

Having undertaken this process of reflection, I still struggle somewhat to describe how I implement inquiry in my classroom. At its simplest, it is about making the students active participants in their learning. This may be related to one of the variations of the features of inquiry, such as allowing the students the choice in deciding what question to ask when carrying out an experiment; or how to carry out the investigation; deciding on how to analyse data they have collected; or drawing their own conclusions from that data. However, my understanding of how I implement inquiry in my practice goes somewhat beyond how practical investigations are carried out. I see inquiry in my practice as being more than simply providing information when a 'content lesson' is being delivered. I ask questions of the students, I urge them to give their opinions, and to defend those opinions using scientific knowledge. No student is forced to answer a question; similarly, few answers given are 'wrong'. If a student has engaged with the concepts being discussed, and answered the question with some degree of thought, they are encouraged for their effort.

Can I therefore say that I am teaching by inquiry? I think so, or I am, at least, incorporating aspects of inquiry into most of my lessons. Cognisant of the fact that there are different levels of inquiry, I would class many of my lessons as Level 1: Structured or Level 2: Guided inquiry. I have rarely 'progressed' to fully open inquiry, but feel no guilt in not attempting this level of inquiry more often than is required. My lack of guilt in this case is justified, as research shows that open inquiry doesn't lead to better learning (Furtak et al., 2012;

Kirschner et al., 2006). In addition, I feel no guilt at not incorporating inquiry into all my lessons, as recent research has shown that there is a curvilinear relationship between student achievement and the frequency of using inquiry (Teig et al., 2018). Guided inquiry can be beneficial, but direct instruction is better for teaching students facts, and it is important to find the balance between the two.

That said, in recent years I find myself leaning away from the previous emphasis on the learning of facts in science, and find myself more concerned with the students learning how to reason and think logically. The openness of the *Specification* allows for students to investigate topics that most interest them. It follows that not all students will encounter the same concepts, and that within a class there will be a difference in content 'learned' by different students. My assessment practices have therefore had to change to accommodate this variation. Less emphasis is placed on recall questions relating to science content, and more questions are included that test students' general understanding of science topics and scientific processes, and challenge their scientific reasoning abilities.

This reflective process was simultaneously both more difficult and easier than envisioned, due to the lack of an agreed-upon definition for IBL in the literature (e.g. Abd-el-Khalick, 2004; Anderson, 2002; Banchi & Bell, 2008; Blanchard et al., 2010; Cairns & Areepattamannil, 2019; Capps et al., 2012; Crawford, 2000; Creemers & Kyriakides, 2006; Furtak et al., 2012; Kirschner et al., 2006; Rutten et al., 2015; Smithenry, 2010). Although the ability to clearly state that IBL was or was not present in a lesson based on a concrete definition would have facilitated the process; the fact that this wasn't possible was an advantage in the end. By engaging with the fact that specific features of inquiry do exist, but that they all have variations, and that the presence of these variations, to a greater or lesser extent, can mean that a lesson is classed as inquiry, meant that I could claim that inquiry is present in many of my lessons.

However, this claim results from a very broad understanding of inquiry as a somewhat nebulous entity, although it is a view of inquiry that is shared amongst other teachers, as will be described in the following section. Rather than seeing IBL as a very distinct set of actions, undertaken either by the teacher or the student during a lesson, the wide description of variations in the features of inquiry mean that almost any lesson could be considered to contain aspects of IBL. I recognise, of course, that the presence of features of IBL, or inquiry activities, in a lesson does not make it an inquiry lesson (Turner et al., 2018, p. 1462), but I feel that this distinction may be an abstraction to many teachers in practice.

However, this poses a difficulty faced, and acknowledged, by academia already. The myriad approaches to inquiry can make studying IBL and its effects on students an almost impossible undertaking. Given that a teacher could argue that inquiry is present in their lessons, carrying out large-scale studies on the effects of inquiry *as practiced by teachers* would contain as many variants of inquiry as there would be participating teachers.

Another difficulty relates to providing training for teachers in how to use IBL in their classrooms. If a succinct description of IBL is provided to teachers, or if one model of IBL is used, it may become too prescriptive for teachers, who will feel constrained by their lack of understanding of the fluidity and flexibility of inquiry. If too open a description is used, then teachers may find that interpreting the description is too much of an undertaking. If the examples provided to illustrate IBL aren’t concrete enough for them to use in the classroom, or not applicable in their situation, they may feel disinclined to attempt any implementation of IBL.

8.3 Teacher Growth & Curriculum Change

When asked if the teachers found any change in their practice in teaching the new course, many reported they are using more questioning in the classroom, getting the students to undertake more activities, and being less prescriptive when carrying out experiments. They felt that they were using more inquiry in the classroom, although that is a subjective perspective. Judging from their responses, many teachers feel that they understand what inquiry is, and like myself, feel that they do sometimes implement inquiry in their own lessons. In fact, their understanding of what inquiry looks like in the classroom is very much like mine.

We see inquiry as generally involving the students in the decision-making process, and giving them more autonomy in the classroom, as can be seen from Chapters Five and Seven. Very often, teachers referred to allowing students the freedom to decide how to carry out an experiment; getting students to work out how to use a piece of equipment to solve a problem; and providing less instructions for students when carrying out an experiment. This can range from being less explicit in the question that is being asked of them when conducting an experiment, to the use of questioning rather than the provision of information when the student asks questions. Although many of these features can be seen in the definitions provided by the literature, or are a variation of those features, they would tend to point to the lessons *containing* aspects of inquiry, rather than *being* inquiry-based lessons, again mirroring my own understanding, as described in the previous section.

What is interesting is that these views on IBL do correspond with two of the definitions described in Chapter Two, from the NSES (NRC, 1993, p. 23), and Marshall et al. (2017, p. 789). The NSES described inquiry in terms of a succession of verbs, i.e. activities that the students would carry out. Marshall et al. similarly stated that the students would carry out scientific practices, but his important contribution here is his insistence that it takes place *before* explanations are provided to the students. I would argue that the teachers', and my, understanding of inquiry is in line with how it might be defined in the literature.

In relation to student learning, we see some slight variation in the answers. Teachers felt that the students were learning, but it might not always be exactly the things the teachers wanted them to. Certainly, students became more proficient in those skills associated with independent investigations, such as experimental design, data gathering and analysis, and general laboratory skills. Occasionally, some students were distracted by the fact that they were carrying out practical activities. Others were comfortable carrying out practical investigations, but sometimes their work resulted in misconceptions. Teachers were cognisant of this fact, and took steps to rectify any erroneous conclusions students developed during investigations. Generally teachers felt that students had a better understanding of the scientific topics that were encountered, as well as a deeper appreciation of science processes, and the importance of science to their everyday lives.

Most teachers found that the students were enjoying science more. The fact that less emphasis was being placed on students rote learning material tended to increase student enthusiasm for the subject, as did the fact that many teachers no longer felt the need for the students to copy pages of notes into their notebooks. Students also enjoyed the increase in the amount of practical activities and investigations. The flexibility of the *Specification* allowed the students a greater sense of independence in choosing their own topics of investigation, and fostered a sense of curiosity in them.

However, when it came to practical activities, teachers had an interesting point, worthy of further investigation. The less able students greatly enjoyed the practical activities, no matter whether they were guided, structured, etc. However, when it came to more open forms of investigation, the more able students struggled with the autonomy. The type of student that likes learning pages of notes and following directions to get 'the right answer' doesn't like the independence offered by inquiry lessons. The fact that there are few studies on this topic is intriguing.

In fact, a lot of the teachers recognised that one of the primary aims of junior science was to create a sense of enjoyment in the students, to make them eager to learn more about science. This is partly to encourage them to choose to study science subjects at Leaving Cert level, and beyond. But we do also want them to understand the importance of science in their everyday lives, as well as having an appreciation for how science is carried out.

We can see that the amount of change teachers reported in their teaching style depended on several factors, such as how long the teacher had been teaching, and their experience during teacher training. To a certain extent, these ideas are linked, with more recently trained teachers possibly being more likely to have had an introduction to IBL during ITE than those who have been teaching for longer. In addition, it appears that teacher training, in relation to the emphasis placed on IBL, varies from one university to another, and even within the same university, from one course to another. Similarly, some teachers reported a small change in their teaching style, but acknowledge that more change is required, and that it will come in time.

Some teachers were slightly worried about the uncertainty created by the new course, and the lack of detail in the *Specification*. Teachers were concerned about the lack of clarity surrounding the depth of treatment of the different topics, and the impact this would have on the amount of time spent on the various topics. Additionally, teachers were worried about assessment, and how the terminal examination at the end of the third year would examine student learning. We were confident that no definitions would be asked, nor would it be possible to ask students about specific experiments they had carried out, since no two science classrooms would be covering the same topics to the same depth, or conducting the same investigations. This resulted in more than a little teacher discomfort. Indeed, it is only in October 2018 that these initial thoughts on assessment in the new course were confirmed, when the sample paper for the Junior Cycle science examination was published.

The final interesting point to note was teachers views towards *what* students were meant to be learning as part of the Junior Cycle science course. The old course placed almost exclusive emphasis on the learning of science content, with little regard for students learning practical science skills, apart from the Coursework B component as described in Chapter Five. The teachers in my school, and I, have noticed, however, a shift away from the learning of science content towards a skills-based curriculum. Despite this, the teachers place a firm importance on the learning of science facts as well as science process skills in their lessons. The key, for them, is striking a balance between the two.

8.4 Conclusion

I believe that this research makes an original contribution to the knowledge base surrounding the implementation of new teaching methodologies in science classrooms, and specifically inquiry-based learning. As a first-person account of how professional knowledge can be shared amongst teachers in a school, and with other teachers outside the school, it is a rarity in the academic literature. Similarly, as an account of action research and teacher self-study, describing the teaching practices of a science teacher from their point of view and in the researcher-practitioner's own voice, it is uncommon. Finally, as an account of how a *Gaelscoil* implements curriculum changes, promotes teacher collaboration and cooperation, it offers unique insights into post-primary science classrooms in Ireland today.

This research illustrates some of the benefits of implementing inquiry-based learning in science classrooms, leading to increased enjoyment of science, fostering a sense of curiosity and independence in students, and promoting scientific literacy and science process skills. The research also indicates that teachers' interpretation of IBL often does not align directly with any one definition of inquiry. However, their descriptions of how they integrate IBL into their practices echo the features of inquiry, and their variations, found in some of the literature (Marshall et al., 2017; NRC, 1993). In addition, I offer an insight into how some teachers implement their interpretation of inquiry in their own practice, and how reflecting on that implementation can in turn deepen their understanding of that practice. The provision of CPD can facilitate the integration of new teaching methodologies into classrooms, as can the use of technology. If the CPD is provided *as Gaeilge,* that is appreciated by the participants, but of more importance is teacher interaction, and concrete examples of IBL in practice. However, the adoption of new approaches can be slow, and sometimes a change in teacher beliefs come after a new teaching strategy has been attempted. The dissertation furthermore highlights some of the uncertainty experienced by science teachers when adopting a new curriculum, but also indicates that subject content matter acquisition is no longer a primary aim of Junior Cycle science; rather the enjoyment of science, and appreciation of science is a principal objective of science teachers in my school.

8.5 Limitations & Scope for Further Research

Despite having forewarned about some of the limitations of the research, I find myself retrospectively regretting not having undertaken some of the research in a slightly different way. This has also raised a number of additional avenues that could warrant further exploration.

For example, it would have been enlightening to understand more of the *Gaelscoil* science teachers' motivations for undertaking the series of webinars, despite stating that they would have been willing to do so in their local Education Centre. What would have been especially useful would have been to discover the reasons teachers had for *not* participating in the course. In addition, when the teachers stated that they had implemented, or planned on implementing, inquiry-based learning in their classrooms after having undertaken the course, it would have been helpful if I had asked them to describe what they did, in order to assess their understanding or interpretation of IBL.

Clearly, utilising technology, such as video recording or audio recording of my lessons while investigating the presence of IBL in my lessons would have been a major assistance. This would have allowed me a more in-depth view of my teaching practices, rather than relying on my memory of the events, even if it was only until that evening. Obviously, as humans, we do not have perfect recall, and although my reflective journals are an *honest* account of my lessons, they are not necessarily an objectively *accurate* account of what transpired.

I had originally planned for the *Gaelscoil* aspect of the research to take a more central role. Although Chapter Four focussed on the language, very little else appears to be unique to a minority-language immersion school. In retrospect, I should have included some questions on the questionnaire, and in the interview, for the teachers in my school, to determine whether they felt the language of education in the school had an impact on their students' learning. I feel, personally, that although we aim for scientific literacy, and for the students to be able to participate in science argumentation, the language does have an impact. Part of the reason is the lack of scientific articles published in Irish that would be suitable for junior level post-primary students, which would enable the students to develop their abilities in judging scientific arguments. Similarly, I would argue that students of their age engaging in scientific debate in their second language would be a difficulty, for some at least. However, there is no way of investigating such claims without having undertaken research specifically.

Similarly, in the context of the science teachers in my school learning from one another, and subconsciously or otherwise influencing each other's practice, nothing less than a complete audio-visual recording of our time in school would have given the necessary depth of detail into how our discussions shaped our views. These not only included formal, subject-department meetings, where we planned the curriculum and the assessment for our students, but also the minute hallway discussions, the moments at tea break where we happened to chat about the upcoming lessons and topics, and the times when one teacher aimlessly walked into another teachers' room 'just to see what was going on'.

This culture of openness and collegiality between the science teachers in my school also highlights a limitation of this research, namely a lack of generalisability. Clearly, the development of my understanding of my own practice is just that; my personal practice, how I behave as a teacher, and how I have come to understand that behaviour. This aspect of the research is not generalisable across the teaching profession. However, this understanding, as well as the views expressed by the other science teachers throughout previous chapters, is shaped by our shared professional practice. The willingness of the teachers to discuss problems and issues, to look to other teachers for ideas and suggestions, and to accept their colleagues into their classrooms during lessons is less common than it should be, perhaps. The culture of each school is unique, and it may be that conducting similar research in a different school setting would produce results that are at odds with those in this research.

It is in the informal encounters, I believe, and through teacher discussion, that the most profound effects to our personal practices take place. As Dadds (1997, p. 33) pointed out, each of us has "a potential 'expert' within", but we consistently defer to the external expert. Boud and Hager (2012) call for a re-thinking of the current delivery model of CPD, with a move towards a model that includes "participation, construction and becoming". Indeed, in Section 7.2.7, I outlined some of the supports that the teachers sought in developing facilitating the change from the Junior Certificate to the Junior Cycle, which included responses such as team-teaching and peer observation. I could also include here the less-utilised modes of teacher CPD, as outlined previously by Guskey (2000; 2005) and others, such as study groups, curriculum development and school development initiatives. This *participation* in in knowledge-sharing practices between teachers would allow for greater *construction* of such knowledge. This could lead to us *becoming* the potential 'expert' we all have within, and become more confident in our choices as reflective educational practitioners.

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Appendix A: Timeline of Project (Approximate)

<table>
<tr><th></th><th>ISE Project</th><th>Irish Webinars</th><th>My Personal Practice</th><th colspan="2">Me & My School (including context)</th></tr>
<tr><td>Spring 2014: Jan - Mar</td><td>Cycle 1 of webinars</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Summer 2014: Apr - Jun</td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Autumn 2014: Sep - Oct</td><td></td><td>Planning for Irish ISE webinars</td><td></td><td colspan="2"></td></tr>
<tr><td>Winter 2014: Nov - Dec</td><td></td><td>Planning for Irish ISE webinars</td><td></td><td colspan="2"></td></tr>
<tr><td>Spring 2015: Jan - Mar</td><td>Cycle 2 of webinars</td><td>January/February – cycle 1 webinars held</td><td></td><td colspan="2">February – ISE training in Portugal</td></tr>
<tr><td>Summer 2015: Apr - Jun</td><td></td><td>Cycle 1 feedback</td><td></td><td></td><td rowspan="4">Using lessons on ISE platform</td></tr>
<tr><td>Autumn 2015: Sep - Oct</td><td></td><td>Planning for cycle 2</td><td></td><td></td></tr>
<tr><td>Winter 2015: Nov - Dec</td><td></td><td>Planning for cycle 2</td><td></td><td>New Junior Cycle Science Specification</td></tr>
<tr><td>Spring 2016: Jan - Mar</td><td></td><td>January – cycle 2 begins.
Cycle 2 ends.</td><td rowspan="2">Investigating my own practice</td><td></td></tr>
<tr><td>Summer 2016: Apr - Jun</td><td>July – end of ISE project</td><td></td><td colspan="2">Feedback on training and using ISE Lesson Authoring Tool</td></tr>
</table>

Autumn 2016: Sep - Oct				First cohort of new Junior Cycle - science
Winter 2016: Nov - Dec				
Spring 2017: Jan - Mar				
Summer 2017: Apr - Jun				
Autumn 2017: Sep - Oct				Second cohort of new Junior Cycle - science
Winter 2017: Nov - Dec				Teacher Questionnaire
Spring 2018: Jan - Mar				First CBA carried out
Summer 2018: Apr - Jun				Teacher Interviews
Autumn 2018: Sep - Oct				Third cohort of new Junior Cycle - science
Winter 2018: Nov - Dec				Sample Assessment Published
Spring 2019: Jan - Mar				
Summer 2019: Apr - Jun				First Junior Cycle Science Examination

Appendix B: Science Teachers in My School

Name	**Me**	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Attended Training in Portugal?	Yes	Yes	Yes	No	No	Yes	No	Yes
Implemented Lesson Authoring Tool?	Yes	Yes	Yes	N/A	N/A	No	N/A	Yes
Answered Questionnaire on ISE Training?	Yes	Yes	Yes	N/A	N/A	Yes	N/A	Had left teaching
Answered Questionnaire on Inquiry?	N/A	Yes	Yes	Yes	Yes	No	Yes	Had left teaching
Interviewed?	N/A	Yes	Yes	Yes	Yes	Yes	No	Had left teaching

Appendix C: Irish Webinar Feedback

I had originally intended to provide the results to the questionnaire in tabular form, so that responses to one question could be cross-referenced against the responses to other questions, such as the number of webinars attended, or what the participant originally expected from the series of webinars. However, such granularity is unwarranted, and the responses will simply be collated by question, anonymously.

Ten respondents are given, although I assume a teacher (or more than one) completed the survey more than once. However, I don't see this having an impact on the results, given that I am not interested in the qualitative data, and the set of results a comment appears in doesn't impact the interest in the content of a comment.

Ar fhreastal tú ar na seimineáir ghréasáin?

Did you attend the webinars?

Níor fhreastal mé ar aon cheann	*No webinars*	1
D'fhreastal mé ar ceann amháin	*One webinar*	2
D'fhreastal mé ar dhá cheann	*Two webinars*	2
D'fhreastal mé ar trí cinn	*Three webinars*	6

People who indicated they did not attend any webinars were directed to a new page and asked if they would be interested in being contacted when another series was being organised. The one respondent above indicated they would be interested.

Cad leis a bhí súil agat agus tú ag dul i mbun an chúrsa seo?

What were you expecting when you signed up for the course?

- Foghlaim conas ISE a úsáid sa seomra ranga. Roinnt smaointe a fháil ar ISE
    - *Learning how to use IBL [sic] in the classroom. Get a few ideas about IBL [sic]*
- Bhí mé ag súil le buaileadh le múinteoirí eile leis na suimeanna múinteoireachta céanna. Bhi mé ag iarraidh cur le mo chuid tuisceana ar IBL
    - *I was looking forward to meeting other teachers with the same teaching interests. I wanted to add to my understanding of IBL*
- Ní raibh me ach ag eist, agus ag leamh, ach bhi an eolas an-cabhrach. GRMA.

  - *I was only listening, and reading, but the information was very helpful. Thanks.*
- Bhí mé ag súil le dul i dteagmháil le múinteoirí meánscoile eile agus a bheidh a phlé leo úsáid acmhainní sa seomra ranga
  - *I was looking forward to getting in touch with other secondary teachers and discussing with them how resources are used in the classroom*
- Breis eolas ar cúsaí teicnólaíochta
  - *More information on technology*
- Bhí mé ag iarrraidh aithne a chur ar mhúinteoirí eile agus tuilleadh a fháil amach faoi IBL
  - *I wanted to get to know other teachers and learn more about IBL*
- Áiseanna teagaisc a bhailiú.
  - *Collecting teaching resources*
- Bhí sé i gceist agam tuilleadh áiseanna eolaíochta a fháil trí mheán na Gaeilge agus nasc a dhéanamh le múinteoirí eolaíochta eile timpeall na tíre.
  - *I intended to get more science resources in Irish and make connections with other science teachers around the country*
- Eolas/acmhainní dírithe ar múinteoirí eolaíochta ag múineadh trí Gaeilge
  - *Information/resources directed at science teachers teaching through Irish*

Ar clúdaíodh na h-ábhair lena raibh tú ag súil?

Did the course cover what you expected?

- Chlúdaigh
  - *It covered*
- Sea
  - *Yes*
- Cinnte, agus cúpla rud eile.
  - *Certainly, and a few more things*
- Clúdaíodh agus roinnt ábhair eile
  - *It covered, and more subjects*
- Clúdaíodh
  - *It covered*
- Chlúdaíodh.
  - *It covered*
- Chlúdaigh, bhí an-chuid áiseanna, smaointí srl curtha ar fáil dúinn.
  - *It covered, there was a lot of resources, ideas etc provided to us*
- Ní rabhas in ann freastal ar na léachtanna, nílim cinnte
  - *I couldn’t attend the lectures, I’m not sure*

I do thuairim, an raibh an cúrsa:

In your opinion, was the course:

Ro-ghearr	*Too short*	4
An fad ceart	*Right length*	5
Ro-fhada	*Too long*	1

Caighdeán Cur i Láthair

Quality of presentation

Mí-shásúil	*Unsatisfactory*	0
D'fhéadfadh sé bheith níos fearr	*Could be better*	0
Sásúil	*Satisfactory*	0
An-mhaith	*Very good*	10

Caighdeán Gaeilge an Láithreoir

Quality of the presenter's Irish

Mí-shásúil	*Unsatisfactory*	0
D'fhéadfadh sé bheith níos fearr	*Could be better*	0
Sásúil	*Satisfactory*	0
An-mhaith	*Very good*	10

Caighdeán Eolais faoi IBL

Quality of the information about IBL

Mí-shásúil	*Unsatisfactory*	0
D'fhéadfadh sé bheith níos fearr	*Could be better*	0
Sásúil	*Satisfactory*	2
An-mhaith	*Very good*	8

Caighdeán Eolais faoi Maoiniú Erasmus+

Quality of the information about Erasmus+ Funding

Mí-shásúil	*Unsatisfactory*	0
D'fhéadfadh sé bheith níos fearr	*Could be better*	1
Sásúil	*Satisfactory*	3
An-mhaith	*Very good*	6

Soiléireacht na Ríomhphostanna

Clarity of emails

Mí-shásúil	*Unsatisfactory*	0
D'fhéadfadh sé bheith níos fearr	*Could be better*	0
Sásúil	*Satisfactory*	1
An-mhaith	*Very good*	9

Caighdeán Leanúntas

Quality of follow-up

Mí-shásúil	*Unsatisfactory*	0
D'fhéadfadh sé bheith níos fearr	*Could be better*	0
Sásúil	*Satisfactory*	4
An-mhaith	*Very good*	6

Dá mbeadh an cúrsa seo curtha ár fáil as Béarla, an dóigh leat go mbeadh sé roghnaithe agat?

If this course had been offered through English, would you have chosen to attend?

Roghnóinn	*I would have chosen*	5
Ní Roghnóinn	*I wouldn't have chosen*	4
Eile	*Other*	1

Eile: b'fhearr liom gan freastail ar i mBéarla, ach muna raibh rogha agam - déanfainn i mBéarla é

> *Other: I would prefer not to attend in English, but if I didn't have the choice I would have done it in English.*

Cé chomh tábhachtach a bhí sé duit go raibh an cúrsa seo á ofráil trí Ghaeilge?

How important was it for you that the course was offered through Irish?

Ní raibh sé tábhachtach	*It wasn't important*	0
Ní dhearna sé aon difríocht	*It made no difference*	1
Bhí sé an-tábhachtach	*It was very important*	9

Dá mbeadh an cúrsa seo curtha ár fáil "adhaigh ar adhaigh" (e.g. i do Ionad Oideachas áitiúil), an dóigh leat go mbeadh sé roghnaithe agat?

If this course had been offered on a "face-to-face" basis (e.g. in your local Education Centre), do you think you would have chosen to attend?

Bheadh	*I would*	8
Ní bheadh	*I wouldn't*	2
Eile	*Other*	0

Cé chomh tábhachtach a bhí sé duit go raibh an chúrsa seo á ofráil arlíne?

How important was it for you that this course was being offered online?

Ní raibh sé tábhachtach	*It wasn't important*	1
Ní dhearna sé aon difríocht	*It made no difference*	1
Bhí sé an-tábhachtach	*It was very important*	8

Cé chomh dóchúil atá sé go n-úsáidfidh tú modhanna IBL i do chuid ceachtanna, tar éis duit an chúrsa seo a dhéanamh?

How likely is it that you will use IBL methods in your lessons, now that you have undertaken this course?

Níor smaoinigh mé ar ó chríochnaigh an chúrsa	*I haven't thought of it since the course finished*	0
Dóchúlacht íseal	*Low probability*	0
Seans mhaith	*Good chance*	0
Cinnte	*Certainly*	3
Tá sé déanta agam cheana féin	*I've already done it*	6
Eile	*Other*	1

Cé chomh dóchúil atá sé go n-úsáidfidh tú eUirlisí i do chuid ceachtanna, tar éis duit an chúrsa seo a dhéanamh?

How likely is it that you will use eTools in your lessons, now that you have undertaken this course?

Níor smaoinigh mé ar ó chríochnaigh an chúrsa	*I haven't thought of it since the course finished*	0
Dóchúlacht íseal	*Low probability*	1
Seans mhaith	*Good chance*	2
Cinnte	*Certainly*	4
Tá sé déanta agam cheana féin	*I've already done it*	3
Eile	*Other*	0

Cad iad na moltaí a dhéanfá chun na timthriail don chúrsa seo atá le teacht a fheabhsú?

What recommendations do you have to improve future cycles of this course?

- B'fhéidir níos mó samplaí de conas a n-úsáidtear ISE i ceachtanna difriúil
  - *More examples of how IBL is used in different lessons*
- níos mó samplaí de IBL agus é i bhfeidhm
  - *More examples of IBL in practice*
- B'féidir index, nó liosta, chun bheith níós easca an eolas a aimsiú.
  - *Maybe an index, or list, to make it easier to find information*
- Chuirfinn níos mó ceardlann ar fáil agus dhéanfainn iarracht go mbeadh níos mó teagmháil ann idir na rannpháirtíochta.
  - *I would provide more workshops and I would make more of an effort to ensure that there is more contact between the participants*
- b'féidir é a ofráil níos minic, m.sh. am gach mí, no mar sin, chun deis plé na abhar. Bhí sé deachai dom caint ar an Luain, ach bhí mé ábalta eist.
  - *Maybe offer it more often, eg once a month, or so, to give a chance to discuss the material. It was difficult for me to talk on a Monday, but I could listen.*
- Teastas a mholadh do na daoine a ghlacann páirt mar ansin b'fhéidir go mairfidh siad ar feadh na 3 seisiúin
  - *A certificate be provided for those that take part because people might last for the three sessions*
- Bh'fhearr liom dá mbeadh webinar amháin, níos faide ann seachas cúpla Webinar
  - *I would prefer if there was one webinar, longer rather than a few webinars*

An molfá an cúrsa seo do mhúinteoirí eile?

Would you recommend this course to other teachers?

B'fhéidir	*Maybe*	1
Mholfainn	*I would recommend*	9
Ní mholfainn	*I wouldn't recommend*	0
Eile	*Other*	0

Dá mbeadh seisiúin bhreise ag teastáil uait ar aon ghnéith ar leith (m.sh. an Uirlis Creatlach Foghlama do chuid ISE), ar mhiste leat iad a lua anseo:

If you wanted an additional session on any particular topic (e.g. using the ISE Lesson Authoring Tool), please mention it here:

- Uimhirheacht, agus measnú chun foghlama, agus IBL a úsáid chun na nótaí agus achmain gaeilge a eagrú
    - *Numeracy, and assessment for learning, and using IBL to organise notes and Irish resources*

Appendix D: ISE Practice Reflection Workshop Report

This report is the original report sent to DCU, for inclusion in their national report to ISE. However, it has been edited to remove any identifying material.

Country City/Region	Ireland
Working Language	Irish
Format (live, online, hybrid) (standalone, collocated)	Live, standalone
Organising Institute	DCU
Coordinator Name	Dr. Yvonne Crotty
Total Number of Schools involved	1
Total Number of Teachers involved	7
Total Number of Students involved	300
Main Statements/ Key Messages from the Group Discussions/ the Learning Cafés	**Experiences of Teachers' Involvement in the ISE Activities;** The teachers felt that the ISE course explaining what Inquiry Based learning was, and how it could be applied in their situation was very energising, and motivating. Some of the teachers expressed the opinion that the now had a greater understanding of what IBL is, and felt that they were confident enough to try implementing it in their classrooms, especially using the ISE tools and lesson scenarios provided. Several of the teachers expressed an interest in the fact that lessons provided by ISE could be cloned, and altered to suit their situation. In the case of this school, that meant translating the lesson into the Irish language.

	Perceived Experiences / Influence of the ISE Activities on Students; Students seem to be more engaged during a lesson using the ISE lessons. As long as the directions given during the lesson were clear, the students were happy to remain on-task, and working. Some of the students were unhappy at having to read through so much text though. There was a small cohort that each time would just skim through the directions, and answer the questions at the bottom of the page. They seemed to equate completing the lesson with answering all of the questions without actually engaging with the material being presented. **Expected Influence of the ISE Activities on School Settings and Curriculum;** Teachers expressed more confidence in applying IBL in their classrooms. Teachers also expressed more confidence in using ICT during lessons, such as some of the eTools demonstrated. It seemed to be much easier to explain some concepts using the simulations that can be found online, rather than in an abstract way in the classroom. **Challenges and Improvements of the ISE Approach.** Getting time in the computer laboratories seemed to be a constant issue. More access to computers would alleviate this. As more schools contemplate asking each student to invest in an iPad, it was discussed whether this would be a solution, but as many of the simulations and virtual laboratories used run on flash, this would not solve the problem.

Questionnaire Results

1. **Question 1** (Quantitative Data)**: Teachers' ICT Level of Experience**

1	2	3	4	5	0
		1	2	1	

2. **Question 2** (Quantitative Data & Qualitative data)**: How often teachers use e-Learning tools Inquiry-based Approaches**

Never	Everyday	Once a week	Once a month	N/A	Other
		1	3		

3. **Question 3** (Quantitative Data & Qualitative data)**: How often teachers use inquiry-based learning approaches**

Never	Everyday	Once a week	Once a month	N/A	Other
1		2	1		

4. **Question 4 (**Qualitative Data)**: Initial Expectations**

- Looking forward to learning about Inquiry-Based learning
- Using eTools in classroom
- Learning about new ways to teach the material
- Finding new ways to use computers in class
- Ways of keeping students interested / motivated
- That students would be more engaged with the subject material than in a standard classroom scenario.
- I was looking forward to learning about how ICT can be integrated into my teaching.

5. **Question 5 (**Quantitative Data)**: Fulfillment of Initial Expectations**

1	2	3	4	5	0
			1	3	

6. **Question 6** (Quantitative Data)**: Previous experience with ISE tools**

Never seen	Knew /never used	Already used	N/A
2	2		

7. **Question 7** (Quantitative & Qualitative Data)**: Teachers' Reactions**

	Yes	No
motivating	4	
relevant	4	
useful	4	
easy to use	4	

8. **Question 8** (Quantitative & Qualitative Data)**: Teachers' Practice supported by ISE Solutions**

	1	2	3	4	5	0
Pedagogical model				2	2	
Learning scenarios		3	1			
e-Learning tools			1	2	1	

- Using the ISE tools is a good way of implementing Inquiry Based Learning in the classroom. Having a framework to create IBL lessons is very useful
- I like how the student's progress through the lesson is monitored, so that I can tell who is spending too little time on each section during the lesson.
- I already used the inquiry model in my classroom, but found the e learning tools very useful, especially in achieving and monitoring individual levels of understanding.

- The IBL model helped in planning lessons using an inquiry framework. It made it clear what was expected of the teacher and students in planning each stage of a lesson. The online lesson authoring tool helped greatly with this.
- Some of the learning scenarios were not applicable to our situation.
- It worked very well when possible but sometimes had to use other methods due to time constraints

9. **Question 9** (Quantitative Data)**: ISE tools and curriculum content**

Yes	No
4	

10. **Question 10** (Qualitative Data)**: Strong Points of the ISE activities**

- I liked the fact that students could work through the lessons by themselves, without the teacher having to lead the entire class at the same pace. It gives the student the opportunity to work at their own pace.
- Having a computer-based lesson is much more effective than handing out printed directions. The eTools can be embedded in the lesson, rather than the students having to type in a link
- Gives student the opportunity to be more engaged with the material.
- Really engages the weaker students.
- Being able to modify lessons provided, or create our own was a very exciting experience.
- Being able to monitor the learning of the students as they progressed through the lesson, using the multiple-choice questions, was also a great benefit compared to a traditional lesson.

11. **Question 11** (Qualitative Data)**: Difficulties/Obstacles when introducing ISE Activities in the Classroom**

- Asking students to input the url for the lesson was sometimes difficult. Very often the students input the url incorrectly, or tried searching for it. Generally, getting all the students to the lesson took a significant amount of time at the beginning of the class.

- On the e learning scenarios you need to be very conscious that students read everything and follow the steps as they have a tendency to jump ahead especially if there is an app or practical activity further along but they do not gain an understanding of the material this way.
- Also, when we needed to stop a lesson, and go back to it, very often the students couldn't remember their password, so they had to create a new account and start over from the beginning of the lesson
- Some of the lessons were very text-heavy, and the students were not very interested in reading through all the directions. Very often some students just ignored the directions and went straight to the questions at the bottom of the page. On the other hand, some of the lessons gave very unclear directions as to what was expected of them, and the students were unsure as to what was expected of them.
- Lack of ICT facilities and time constraints.

12. Question 12 (Qualitative Data)**: Suggestions for Improvements**

- A lot of the demonstrators provided did no correlate with the learning outcomes specified by the science curriculum in Ireland. Therefore, they could not easily be integrated into the teaching of the students. Since they were "extra" material, it was sometimes not feasible to deliver those lessons to our students.
- Often, trying to create lessons or clone existing lessons was very slow. The portal seemed slow and clunky to use.

13. Question 13 (Quantitative Data)**: Regular Integration of the ISE Approach in the School Practice**

Never	Everyday	Once a week	Once a month	N/A	Other
			3		**1**

Appendix E: Results of Teacher Questionnaire

The questions, and responses, are provided verbatim. Typos and grammatical errors have not been corrected.

Question 1

Do you think your teaching has changed since the introduction of the new Junior Cycle? If so, could you please give some detail.

A Yes. I think that when I compare how I teach the same topic with my current third year group (or any previous Junior Certificate groups) it is significantly more structured/limited than the way in which I now approach topics with my current second year group. When approaching the topic with my Junior Cycle class I tend to explore more different ways in which to teach the topic, I feel that the very open nature of the Junior Cycle specification gives me the freedom to do this. I tend to spend more time on class and small group discussion and less on note taking, I think that my emphasis has shifted towards broad understanding and away from rote learning (I hope!).

B My teaching has changed a moderate amount since the introduction of the new Junior Cycle. For one thing, the new syllabus is much less prescribed and so I have the freedom to go as in depth into a topic as I deem necessary, teach/demonstrate a concept in a manner entirely up to myself, allocate more or less time to a topic at my own discretion. That being said, I have only been teaching for three years and during my teacher training much emphasis was placed on inquiry based learning and using a variety of activities and technologies in the classroom. Therefore I don't think I've been teaching for long enough in what might be considered the traditional manner and any change in teaching style as a result of the new JC is probably not too dramatic.

C Yes, there are more student-led activities now where they have more freedom to choose topics of research, and there are more investigative activities rather than the old style of reading the instructions and copying them. They now have to decide how they are going to tackle a problem and then implement that plan and the emphasis is more on the scientific method than doing the right thing every time.

D I believe I am trying to get the students to understand why they are doing what they are doing and the logic behind it more than just just asking them to learn something outright.

F Yes, I think teachers are more open minded in their styles of teaching. It has become more acceptable to achieve learning outcomes in different ways.

Question 2

What is your understanding of Inquiry Based Learning?

A Giving students the opportunity to discover things for themselves, to learn through investigations and inquiry as opposed to being told.

B Teaching in a way that allows students to develop a deeper understanding of whatever topic it is they are learning about. I remember from college that this involves a specific number of features such as students posing their own questions, planning investigations, researching themselves, sharing their findings, critiquing one another and probably a lot more features I can't remember!

C It is where the student has to solve some kind of a problem or decide how to approach a situation without being told if it is the right way to complete the task. They are free to implement their plan (with some teacher input) and can learn as much from their failures as from getting the 'right answer'.

D That the students would discover the subject more with support from teachers rather than the teacher giving them the answers or rote learning

F My understanding is that students must use their own initiative to figure something new out for themselves.

Question 3

Do you use Inquiry, or Inquiry strategies in the classroom? Could you provide some examples?

A Yes. I do my best to pose a question to the class and let them come to their own conclusion.

Planets - working in groups students had to find some specific information about their assigned planet (mass, temperature, gravity, size...). This information was then brought together and students were tasked with comparing the different bits of information and as a class we came up with a picture of our solar system. (Not as inquiry based as some of the more practical activities, but the students did acquire skills of analysis and comparison, and the members of each group were capable of discussing their chosen/given planet)

Mass/Weight - students had mass scale and a newton meter and had to measure multiple items (of their choosing) and write down the relevant mass and force. At the end I led a class discussion to come to a conclusion on the relationship between mass and weight.

B I would say that my teaching style incorporates aspects of Inquiry in the classroom but is not exclusively inquiry based. For example I place a lot of emphasis of communication in science, if students carry out an investigation in the classroom I like the students to compare and contrast groups' results, their methods, identify what was good about their methods and how they could be improved. This is particularly effective when students have the freedom to choose their own method to carry out an experiment and not follow written steps provided by the teacher. Rather than providing titles for experiments, students of the new JC come up with their own hypothesis and this hypothesis does not need to be the same for everyone.

Another simple example of inquiry that I've always used during measurement in physics is providing students with equipment, a problem and getting them to figure out how to use the equipment themselves (opisometre, displacement can).

The new astronomy course lends itself well to students' own research. The students love the topic, it's so vast and new discoveries are occurring the whole time so for the past two years I've focused on this as a topic for research and presentation.

C Yes, eg. forces - giving them some equipment and asking them to see if they can use it to determine the effects of friction on movement, or the connection between mass and weight.

In Mass, Volume etc, give them the equipment and see if they can discover how to measure volume of an irregular object. Also, give them a metre stick and ask them to find out how big the room is, without saying what exactly I'm looking for - some will do volume, some length, some area. It makes for a good discussion.

For Separating Mixtures, we have a 'murder mystery' activity that involves a number of substances that have to be separated in order to solve the mystery.

D I ask the students to research projects and to follow the scientific method which we have looked at in dept. They then apply their new skills to a task or designing experiment like they did in their MRB.

F Yes, instead of telling students the answer I try to help them to figure it out, by giving them hints or by providing them with the necessary equipment to find an answer/explanation.

Question 4

If you use Inquiry in the classroom, do you feel there has been any effect on the students' learning, or their interest in science?

A Students are certainly more interested during classes where there are practical activities, but they are not always focused on the desired learning/the purpose of the task. Those students who see the link between the practical activities and the discussions/group work that follow or preceed them seem to have more of a continued interest as to what we will be investigating next.

Sometimes I feel that inquiry based learning is lost on some of the weaker students (particularly if they are in a group with stronger students) as they can hide in the group or are sometimes distracted by the equipment or practical element and do not understand the importance.relevance of the results.

B Compared to when I was in school and science was taught using the "chalk and talk" method and investigations were theoretical rather than practical, I certainly feel a greater level of enjoyment for the subject from the students. But even more recently, when I think of the students who I have taught the old Junior Cert to, and those who are experiencing the new the Junior Cycle there is undoubtedly more enthusiasm for the subject in the latter group. This is particularly obvious in those who wouldn't be considered academically the strongest students. Those doing the new Junior Cycle where I have more freedom to teach by inquiry seem to quite like and be enthused by the subject even if they don't attain the best grades. Whereas weaker students to whom I've taught the old junior cert to, appeared to dislike the subject, put little effort into groupwork and be very eager to drop to ordinary level.

C Definitely, you can see the difference in the students' attitudes to the tasks as they know that they can try what they want to and they enjoy the challenge. Some of the less academic students really enjoy jumping right in whereas others who always get high grades don't always like the uncertainty of the activity, which is also good preparation for them.

D I feel it certainly get the students thinking more about why instead of just following the teachers lead.

F I think they have more of an interest in science and are more confident in their own abilities to find something new out.

Question 5

Is there anything that the school / other teachers / external organisations could do, to support your teaching in the new Junior Cycle science classroom?

A I think that technology in the classroom would help with some group projects and also allow teachers to explore some of the resources available online and their uses within the classroom. Sometimes it can be hard to get students to do a short project or bit of group research when this involves booking a computer room and moving the whole class. This wastes time and sometimes discourages me from undertake these types of tasks.

B To date I have found that of all the workshops/training that I have received regarding the new Junior Cycle, those that have been subject specific have been the best. They have been focused and practical and highly useful in my day to day teaching. I think it would be beneficial to have say 10 inservice days for a range of scientific topics that teachers could attend. It would be great to see how a topic that we're already familiar with should be taught. It's too easy for teachers to teach a topic they know the way they've always taught it rather than explore new ways of doing it.

Both the school and other teachers could help facilitate/promote these inservice days. I understand how difficult it is for school management to release its whole science department for ten full days, but different teachers could attend different inservice days and share their knowledge through a combination of team-teaching and classroom observation (plato's cave!!). It would just take a willingness from both the school and other teachers.

The whole idea in general of observing other teachers in action is perhaps not the most popular but I believe it to be essential, especially starting out as a teacher.

Having a mentor(s) or shadowing a colleague isn't a new concept in the professional world but it's not formally in place in our school. I think it could be advantageous in two ways. Given the high percentage of newly qualified teachers in [my school], they would greatly benefit from observing different teaching styles/classroom strategies before settling on their own style. Secondly those newly qualified teachers are probably a wealth of information regarding the new Junior Cycle given that some of them will have taught no differently before now and could in fact help their subject departments transition over to the new Junior Cycle.

C More workshops with practical ideas from external organisations and the school could provide more materials for use in the lab.

D Maybe some team teaching with teachers already familiar with teaching the junior cycle.

F I think communication between the science department is essential, because while teachers don't need to teach topics the exact same ways, if teachers are talking about what they've done then each teacher can put their own spin on the topic. It can be hard to always think of a new way to teach a topic but if teachers help one another it makes things easier.

Appendix F: Minutes of Subject Department Meeting

<table>
<tr><td>An Roinn Eolaíochta</td><td>Cruinniú Ábhar</td></tr>
<tr><td>Dáta</td><td>8 Samhain 2016</td></tr>
<tr><td>Comhordaitheoir na Roinne</td><td>[Teacher D]</td></tr>
<tr><td>I Láthair</td><td>[Teacher A], [Teacher B], Colm, [Teacher E]</td></tr>
<tr><td>Leithscéil</td><td>[Teacher C]</td></tr>
<tr><td>Miontuairiscí an Chruinniú Dheireanach</td><td>Glacadh leo</td></tr>
<tr><td>Nithe ag Eirí Astu</td><td></td></tr>
<tr><td>Cúrsaí Scoile</td><td>Scrúduithe an Gheimridh:

Scrúdú Bliain 1 – uair amháin
Easaontas/difríochtaí idir ábhar múinte ag múinteoirí difriúla – eg tréithe nithe beo: 7 sean-tréithe vs 5 tréithe i leabhair eile
Ar an scrúdú go mbeadh ceisteanna ar:

Nithe Beo
Micreascóp – páirteanna an micreascóp, conas é a úsáid
Na Cealla – cill plandaí vs cill ainmhí
Ach ní bheidh an turgnamh
Bonus points má tá eolas acu faoi rudaí breise sa chill eg Mitochondria, Golgi, etc
Damhna, staideanna damhna, athruithe staide
Tomhas – fad, achar, toirt, mais
Cannaí forsceite, toirt cloch mór, beag agus leacht
Aonaid agus uirlisí
Fearas saotharlainne, sábháilteacht saotharlainne, siombail guaise / siombail baoile
An Ghrianchóras
Sainmhínithe ar téarmaíocht – tá siad seo le cinntiú idir na múinteoirí roimhré
Seo pictiúr don ghrianchóras….
Lipéidigh iad
Cuir na plainéidí i ord ó mór go beag
Etc rud éigin
</td></tr>
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An modh eolaíochta

cén fáth a leantar céimeanna áirithe…. ?
tabhair turgnamh dóibh… ceann cumtha go huafásach, agus iarr orthu moltaí a thabhairt chun é a fheabhsú….

Más gá a thuilleadh a chuir leis chun an t-am a úsáid

Léamhthuiscint
Turgnamh a chumadh
Nó pictiúr a tharraingt don ghrianchóras (Ná bí buartha faoi scála)

Le béim ar dearadh – dathanna – something
Le rudaí ar leith á lorg

Crios astaróideach, nó scamall Oort
Bonus points más féidir fithis coiméad éigin a tharraingt?

Scrúdú Bliain 2 – uair amháin

Teas
Fuaim
Struchtúr an Adamh
Córas Análaithe

Go leor béim ar na turgnaimh teasa
Ní bheidh na eocharfhocail san áireamh
</td></tr>
<tr><td>Cúrsaí Scoláirí</td><td></td></tr>
<tr><td>Litearthacht & Uimhearthacht</td><td></td></tr>
<tr><td>Pleanáil</td><td></td></tr>
<tr><td>Aon Ghnó Eile</td><td></td></tr>
</table>