Exploring the Development of Irish Pre-service Science Teachers’ Scientific Inquiry Orientations using a Pedagogical Content Knowledge Lens within a Targeted Learning Community

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Abstract
This current study reports on the findings from a two year longitudinal exploratory case study. A qualitative dominant mixed methods approach was used to establish the orientations of a cohort of Irish pre-service teachers (PSTs) towards the practice of scientific inquiry as they transitioned through their initial teacher education (ITE). A pedagogical content knowledge (PCK) lens was used to capture and portray the orientations towards scientific inquiry in order to examine whether such orientations were embedded within the PSTs’ PCK.

Phase one began by introducing a cohort of PSTs (n=35) to the theoretical construct of PCK using a lens that has gained significant attention in the research literature, known as content representation (CoRe). A CoRe represents group PCK and in phase one a CoRe was developed before and after a six week teaching practicum experience to identify exemplars of inquiry orientations. The results of this phase, including some classroom observations, revealed their orientations towards inquiry practice were lacking. This resulted in the author making a slight adaptation to the CoRe in phase two to include a greater inquiry focus. The results of phase two suggest that as the cohort (n=12, due to dropout) engaged in CoRe workshops they began to develop their inquiry orientations due in part to the interactive discursive environment that the CoRe workshop presents. The PSTs were involving themselves in a professional learning community (PLC) but was theory put into practice? In phase three the developing espoused orientations towards scientific inquiry appeared to have transitioned into classroom practice through the analysis of classroom observations, interviews, lesson plans and a survey. This survey was also distributed to PSTs not involved in the study (n=29) and in-service teachers (n=94) for comparative purposes. The findings have shown that the average action of scientific inquiry were significantly higher for the PSTs involved in the study which allows the author to suggest the following conclusion: The PSTs’ exposure to the adapted PCK lens has appeared to enhance their orientations towards scientific inquiry through their social construction of knowledge within a structured PLC. They were in a sense engaged in an “inquiry” into their understanding of scientific inquiry and were able to develop their own “living educational theory” (Whitehead 1989, p.7) of what they considered scientific inquiry to represent in classroom practice.
Declaration
I, Louise Lehane, hereby declare that this thesis is my own work. Where use has been made of the work of other people, it has been fully acknowledged and referenced.

Signature: _________________________

Louise Lehane
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Dedication

This thesis is dedicated to my mother Mary and my father Eddie (RIP). I hope I have made you proud.
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Introduction
The following chapter seeks to give the reader an overview of this current research study. A brief rationale is provided which will be developed further in the chapter following on from this with a description of the place of science education in Ireland. The background underpinning this study is presented and leads on to the main aim and the research questions. A description of the research participants, research phases and the research questions aligned with the different phases are outlined. Finally a summary of the content of the thesis chapters is provided.

### 1.1 Rationale for the Study

“I hear and I forget
I see and I remember
I do and I understand”

(Confucius 551-479 BC)

Interest in undertaking this research study arose from the concern with the teaching and learning of science in Irish post-primary schools evidenced from studies which position Irish education within a wider international context (Shiels et al. 2009; PISA Report 2006; Mathews 2007). Proficiency levels in science are below the OECD average (Perkins et al. 2012) with achievement levels in science generally regressing (State Examinations Commission 2013). It can be suggested that rote learning, with the focus on product over process, contributes to this failing in the Irish education system (Griffin 2014). Indeed the current focus in Ireland is on prescribed practices towards science teaching and learning where students are able to recall simple definitions only. In other words they lack the higher order cognitive skills which allow for the deep conceptual understanding of the content (Perkins et al. 2012; Chief Examiners Report 2013). These conditions may bookend the spectrum of cognitive attainment in science but the issues run deeper; the fundamentals of scientific practice i.e. inquiry seem to be lacking altogether.

Much of the literature recognises the need to change the teaching methodologies in the classroom to include more student-oriented learning processes which could lead to a higher level of conceptual understanding (Rocard et al. 2007). Pedagogical activities shown to enhance students’ comprehension of scientific concepts are those
focused on a degree of student inquiry. Scientific inquiry and its constituent practices are grounded in the same epistemological commitments as those of science practiced in the real world setting. Scientific inquiry therefore mirrors the actions of a scientist which ultimately leads to a greater understanding of scientific concepts as students construct their own knowledge through experience.

The movement towards inquiry-based science education (IBSE) has been most apparent when looking at the sheer volume of European funded projects focused on developing an inquiry habitus in teachers’ practices. The habitus is essentially the way in which a culture is embedded in an individual (Harker 1984) and how this internalisation is the basis for a person’s behaviour (Bidet 1979, cited in Harker 1984). It is the belief or orientation of the teacher towards how their subject should be learned and this ultimately influences their decision-making regarding particular pedagogical approaches. Projects such as the Fibonacci and ESTABLISH project (both of which included an Irish partner) were developed with the aim of promoting inquiry in schools through a variety of dissemination networks. Despite such attempts, international data presented in recent years has revealed that the practice of inquiry is currently the exception rather than the norm in classrooms (Campbell et al. 2010; Roth 1995; Capps and Crawford 2013). Data pertaining to the Irish context is not available however the OECD TALIS Report does suggest that Irish teachers practice student-led approaches, which would include student-focused inquiry, significantly less than their international counterparts (Shiels et al. 2009).

If the habitus of the teacher is dominated by a high-stakes assessment system and not with the induction (Stenhouse 1978, cited in Taylor and Richards 1985) of the student into the scientific process, then the avenue of rote learning, didactic, prescribed recipe-like approaches to science is likely the one most frequented. Indeed the reality of a high stakes summative examination, which ultimately determines the path that a student takes in life, leads to a system where teachers are teaching for and students are learning for the exam. This results in the ideological place of assessment within the curriculum as it is seen to be the tail that wags the curriculum dog (Hargreaves 1989). This in turn leads to routines in the classroom focused on product-driven learning. Indeed Nuthall (2005) refers to the “ritualised
routines” (p.895) of teaching where challenging learning is avoided as the collective (student and teacher) focus is to arrive at the answer in the most expedient manner possible.

The use of scientific inquiry activities focus on the process of learning science, rather than the product, by doing it in such a manner that it resembles the practice of science in the real world context. Its focus is on enhancing knowledge by engaging in diverse ways to make sense of phenomenon. If exams were to be reduced in significance would Irish science teachers have the capacity to develop learning in their classrooms that is more inquiry-oriented? Do Irish pre-service teachers (PSTs) have the opportunity, indeed the knowledge, to consider how science can be taught with the motivation on the process rather than the product? The latter question is particularly relevant at a time of curricular change in Ireland where the new science syllabus is acutely focused on learning as a process-driven activity (Erduran and Dagher 2014). If teacher education is to play a role in supporting the changes in professional knowledge required to engage fully with the new science syllabus then new routines are necessary to provide the depth of critical rational engagement with the syllabus and to make understandings visible.

1.2 Introduction to this Research Study
This current study, a two year longitudinal exploratory case study, centres on examining the potential of a pedagogical content knowledge (PCK) lens for the investigation and development of PSTs’ orientations towards scientific inquiry. This lens, consisting of two tools, is referred to as Content Representation (CoRe) and Pedagogical and Professional experiences Repertoires (PaP-eRs). It was originally developed by Loughran et al. (2006) to capture and portray the PCK of expert teachers. The PCK construct was considered by Shulman (1986) in response to his expressed need to blend content and pedagogical knowledge to allow for more meaningful learning. PCK involves a teacher’s knowledge and understanding of how to present material in ways which make it comprehensible to others (Shulman 1986). A PCK aware teacher moves beyond thinking an activity is a “good activity” to reasoning why they would do something in a particular way, for a particular reason in a particular content area, with a particular group of students (Bertram 2010). PCK
is therefore the unique knowledge a teacher possesses which marries the knowledge of content and pedagogy together in such a way that it enhances student learning (Loughran et al. 2006). Orientations towards scientific inquiry can be embedded within a teacher’s PCK if it is part of their knowledge base (Jordan-Spang 2008).

The CoRe and PaP-eR has served as a useful framework in PCK research for being able to capture and portray concrete examples of PCK (Loughran et al. 2006). Individually the CoRe has been used in a number of research contexts; indeed a small number of studies within Ireland have recognised the value of the CoRe in serving the agendas of the researcher involved. Donnelly (2011) utilised the CoRe as a lens to capture features of teachers’ practices as they engaged in professional development around the use of a virtual chemistry laboratory as a vehicle for educational change. Dunne (2013) used the CoRe to evaluate the impact of an inquiry-based intervention on primary teachers’ practices. Indeed internationally the CoRe has been adapted to serve the needs of the researcher involved and has gained significant appraisal for its contribution to the advancement of PCK research (Lehane and Bertram 2015).

PCK can be socially constructed (using CoRes) and the very act of capturing PCK and making explicit teachers’ knowledge can serve to develop this knowledge in the process (Loughran et al. 2006). This study will explore how scientific inquiry can be articulated and developed in PSTs’ practices through social interaction and construction of meaning using the CoRe within a professional learning community (PLC). Results from the OECD TALIS report suggested that Irish teachers are weakly positioned in terms of their use of professional collaboration (Shiels et al. 2009). Indeed historical literature is scarce on the use of such learning communities in studies pertaining to the Irish context. However, more recently, a Framework Seven project known as Chain Reaction (2013-2016) does emphasise the use of PLCs with the focus on a cascading model for knowledge generation and dissemination (Lehane et al. 2015). With recognition being given to how interaction within a PLC impacts knowledge generation and dissemination, how would the PSTs in this study react to their involvement in a PLC? Could it enhance their professional practice, specifically towards their understanding and practice of scientific inquiry?
Focus on PSTs

Why is the focus of this study on PSTs? The author’s decision to focus on PSTs lay in part with her epistemological belief that PSTs are more open to change having not yet encountered the often restrictive nature of the real classroom setting (Wilcox et al. 1991). They want to learn how to teach (Loughran et al. 2008) and develop pedagogies that are often dramatically different from what they experienced as students (Rozelle and Wilson 2012). It must be reflected on in this discussion that PSTs are influenced initially by their experiences as students, referred to as their apprenticeship of observation (Lortie 1975) which may prove difficult to tap into and alter during their initial teacher education (ITE).

Despite this is must be considered that PSTs can become “agents of change” (Price and Valli 2005, P.59) since one way to promote curriculum reform is to affect PSTs’ views and actions towards inquiry-based science approaches during their ITE (Fazio et al. 2010). Teaching is complex however and ITE in general is failing to prepare PSTs for the complexities of teaching and has a negligible impact on teacher behaviour and learning (Korthagen 2010). Such complexities can be appreciated when one looks at how a teacher’s decision-making influences student learning and can be represented through the Gestalt-Schema-Theory model (Korthagen 2010).

Korthagen (2010) suggested that the way a teacher acted was primarily influenced on the basis of their “gestalt” which essentially refers to how they made spontaneous automatic decisions. These gestalt formations are inherently linked to the teachers’ experiences. The experiences of PSTs very much stem from their experiences of being observers as students at the other side of the classroom desk, i.e. their apprenticeship of observation (Lortie 1975). Some researchers stress the difficulty in preparing these novices to teach through IBSE having come from an apprenticeship system where they were recipients of science through rote learning and not as an inquiry process (Inoue 2009; Gess-Newsome 1999; Crawford 1999). Their gestalt formations result in the teacher forming and developing schemas. A teacher’s schema refers to their understanding of how to act in a particular situation, aided through reflective practice. Appropriate schemas lead to the development of a theory around the suitability of their decision-making abilities (Korthagen 2010).
In all this model helps to conceptualise the complexities of teaching, that decision-making is not a random causation but an internalised habit of mind resulting from teachers’ experiences of how to act in a particular situation. It can be suggested that a teacher’s PCK is intimately linked with their decision-making (Ogletree 2007). Using scientific inquiry in the classroom is a function of decision-making and this is essentially automatic and mechanical in nature, informed by an inquiry-oriented schema. If scientific inquiry is a function of a teacher’s decision-making in the classroom, then it is embedded within their PCK. However studies have shown that PSTs enactment towards inquiry-based practices is seldom applied in the classroom (Northcutt and Schwartz 2013). This suggests that their experiences as students result in gestalt formations removed of inquiry orientations. For this reason PSTs are the focus of this current study.

Therefore, in conclusion, this study set out to explore the use of a PCK lens in capturing evidence of PSTs decision-making in regards their orientations towards scientific inquiry within a supportive environment as part of a PLC. This study also set out to determine whether the social construction of meaning through interactions within this PLC, using the CoRe as a scaffold, could facilitate PSTs developing understanding of inquiry. The main aim therefore of this research study was:

To investigate the use of a PCK lens to capture, make explicit, portray and develop the inquiry orientations of a cohort of PSTs.

The research questions which formed this study were as follows:

- What are the foundational scientific inquiry orientations of a cohort of PSTs before, during and after a six week teaching practicum?
- What are the affordances of a PCK lens as a professional development aid, specifically its use in describing and developing inquiry orientations in PSTs through the social construction of meaning?
- How do the perceived developing inquiry orientations successfully translate into actual classroom practice?
How does the scientific inquiry practice of these PSTs compare with other teachers (pre-service and in-service): What factors inhibit its enactment?

The research questions were addressed separately over three phases and will be described in section 1.4.

1.3 Participants within this Current Study

A cohort of PSTs from the University of Limerick was the focus of this current study. When the study began, these PSTs were entering the second year of their ITE programme. In phase one thirty-five PSTs began the study however with any longitudinal study, drop out is possible (Cohen et al. 2011), and to that end twelve PSTs remained on for phases two and three.

While PSTs were the primary focus, it was important to gain an understanding and comparison of in-service teachers’ (n=94) practice of scientific inquiry. This was necessary for three reasons:

(1) To compare the findings with the PSTs to determine whether the case study group, having been involved in a targeted learning community, used scientific inquiry practices more frequently in their classrooms.

(2) To determine whether scientific inquiry practices develop naturally with classroom experience and if not to emphasise the need to target novice teachers in ITE.

(3) To understand that PSTs may be entering ITE programmes having come from an apprenticeship of observation not focused on inquiry practices.

Another cohort of PSTs (n=29) also formed one of the participant groups towards the end of the study. Similar to the role of the in-service teachers, their involvement was for comparative purposes to understand the impact of the study on the case study cohort.
1.4 Structure of the Study- the Methodological Approach

This study employed a mixed methods approach and, as mentioned previously, took place over two years with a three phase design. A principally qualitative methodology was employed with a quantitative approach utilised at the latter stages of the study to gain insight into the actions of scientific inquiry with a larger population. It was at this stage that data pertaining to the in-service teachers and non-case study PSTs was collected. The paradigm underpinning this study was social constructionism which is grounded on the theoretical assumption that knowledge can be socially constructed through interactions within a PLC. Fullan (2007) proposed that teachers are convinced by what other teachers do and think and the CoRe structure can allow for the latter to be made visible.

1.4.1 Phase One- Setting the Scene

Phase one began with a comprehensive review of the literature in order to begin to develop the conceptual framework which guided this study. The literature provided a particular focus on the PCK of PSTs with some credence given to measuring and articulating PCK. The literature also showed a consistent reference to a specific tool which could successfully capture and portray the PCK of both in-service (Loughran et al. 2006) and pre-service (Hume and Berry 2011) teachers. As mentioned previously, the CoRe is part of this PCK lens and captures espoused PCK. Espoused PCK reflects the teachers’ knowledge in the teaching of science which may not necessarily be enacted in classroom practice but is essential as it guides teachers to consider instructional decisions (Aydeniz and Demet-Kirbulut 2011). The CoRe forces teachers to consider the “what” and the “why” of teaching a particular topic and consists of a number of pedagogical prompts that draw out a teacher’s PCK (Loughran et al. 2006). Figure 1.1 shows the CoRe scaffold.
Further discussion of the CoRe will follow in sections 3.2.5 and 4.4.4.

The literature suggested that enactment of PCK in the classroom can be captured through PaP-eRs. A PaP-eR provides a narrative on classroom practice and highlights a particular aspect of science content to be taught (Loughran et al. 2006). It was decided from this to represent enactment of inquiry orientations in the classroom through a series of PaP-eRs which could be in the form of observations, lesson plans etc.

A link between scientific inquiry with the PCK model was developed by Magnusson et al. (1999). This model revealed that inquiry can be found as a componential element of a teacher’s professional knowledge base. The literature also identified this PCK model being the conceptualisation applied by researchers focused on using the CoRe and PaP-eR. Therefore it was decided to use it as the theoretical perspective in the current study. Finally the idea of the social construction of PCK through the development of a CoRe prompted the author to review literature associated with the use of a PLC to facilitate professional development.
The CoRe was introduced to the PSTs prior to their initial teaching practicum experience. This phase served as an introductory phase for PSTs to become familiar with PCK and the CoRe as a PCK tool. More specifically it focused on creating a foundational understanding of PSTs’ scientific inquiry orientations. CoRes were constructed in group environments (groups of 12, 12 and 11) and were completed before and after a six week teaching practicum experience on two topics, the particle theory and genetics. This was done in order to answer the following research question:

- RQ1. What are the foundational scientific inquiry orientations of a cohort of PSTs before, during and after a six week teaching practicum?

PaP-eRs searching for enacted inquiry orientations were developed during the six week teaching practicum in the form of classroom observations.

1.4.2 Phase Two- Exploring the developing Inquiry Orientations through Social Interaction

Before this phase began, the PSTs were offered the opportunity to withdraw from the study, twelve remained on. Within this phase a slight adaptation to the original CoRe was made to include a greater inquiry focus. The reason for this is that evidence of inquiry orientations was limited in light of the findings from phase one. It was hypothesised that doing this could reveal inquiry orientations that PSTs may have but simply could not articulate. It was also considered that this adaption could aid the professional development of PSTs, who were lacking in inquiry orientations, through the discussion environment (social construction of meaning) that was a defined feature of the CoRe workshops. A further dimension within this phase was to understand the additional professional learning experiences of the PSTs and how these linked intimately with their developing inquiry orientations.

The adapted CoRes were constructed over the course of the PSTs third year in their ITE programme within smaller groups of 3, 4 and 5; the differences in size were for logistical reasons and primary subject disciplines. The CoRes were developed on
topics of the groups choosing. In all seven different topics were covered which were respiration (2 groups chose this topic), modern physics, mechanics, heat, chemical reactions, the immune system\textsuperscript{1} and the nervous system. The following research question was addressed within phase two:

- RQ2. What are the affordances of a PCK lens as a professional development aid, specifically its use in describing and developing inquiry orientations in pre-service science teachers through the social construction of meaning?

The interactions between the PSTs within the PLC were of particular interest in this phase and how the dialogue between the PSTs served to promote their inquiry orientations.

\textbf{1.4.3 Phase Three- Putting Theory into Practice}

While the social construction of meaning was central to phases one and two, it was necessary to understand whether individual orientations towards inquiry were visible in classroom practice. Gillham (2000) considers the discrepancy between what people say and what they actually do. Literature identifies the difficulty in translating theory into classroom practice (Loucks-Horsley and Matsumoto 1999). Therefore with the developing evidence of a growing habitus towards scientific inquiry (espoused orientations) a key question was whether this could translate into classroom practice (enacted orientations). To that end the remaining research questions focused on classroom action.

The first key question here was:

- RQ3. How do the perceived developing inquiry orientations successfully translate into actual classroom practice?

\textsuperscript{1} The immune system was not completed in full due to the cohorts’ study commitments so it will not be included in this thesis.
Data collected relevant to this research question included classroom observations, lesson plans, a survey focused on the action of scientific inquiry\(^2\) and interviews.

In order to promote rigour in the study it was necessary to get a comparison of the experiences of inquiry with other cohorts and therefore the following research question directed the final phase of data collection:

- **RQ.4 How does the scientific inquiry practice of these PSTs compare with other teachers (pre-service and in-service): What factors inhibit its enactment?**

The reasoning for this comparison was outlined in section 1.3.

The first three research questions would be considered qualitative questions which were more answerable with a “thick description” (Geertz 1973) of the findings. Thick description refers to the systemic reflection on the meanings associated with specific scenarios (Geertz 1973) and involves the researcher describing what they find in great detail (Gillham 2000). It gives the reader an experience of “being there” (Geertz 1973) and allows the reader to consider the nature of knowledge, values and reality which exists in the research context. For descriptions to be “thick” they must include detailed observational data as well as data on meanings, participants’ interpretations and factors which have not be directly observed in the study (Cohen *et al.* 2011).

**1.5 Structure of this Thesis**

**Chapter Two- Background of Science Education in Ireland**

Whilst within chapter one, a brief insight into the place of science education in Ireland was provided, the purpose of this chapter is to explore current science education policy issues in Ireland. This involves a discussion on the structure of post-primary science education in Ireland together with documentary evidence of the prevailing attitudes of and achievement levels in science. The chapter also provides

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\(^2\) The data from which was also used to compare with the action of in-service teachers and the non-case study PSTs in RQ4
the reader with a brief insight into the ITE programmes in Ireland. It details specifically the structure of the ITE programme in the University of Limerick with an exploration into past research focusing on the experiences of PSTs at the university.

Chapter Three- Literature Review
This chapter presents the literature which contributes to the overall conceptual framework on which this study was based. The review begins with a brief discussion on the different models of teacher knowledge and then gives a rationale for choosing to focus on PCK as the theoretical knowledge base. A description of PCK, its varying conceptualisations and ways of conceptualising PCK are presented.

Scientific inquiry is then explored further together with its reported advantages towards student learning and the possible barriers preventing the action of scientific inquiry practice in the classroom. Then, key to this study, a focus is given towards the association between PCK and scientific inquiry. From this, a discussion related to facilitating the professional development of teachers towards the use of scientific inquiry is presented. Symbolic interactionism as a vehicle to promote the social construction of meaning within a PLC is also outlined. Because PSTs are the focus of this study, reference to literature on PSTs will be presented throughout the chapter.

Chapter Four- Methodology
This chapter presents a discussion on social constructionism and how this guiding paradigm underpinned the current study. A section on reflexivity is provided and outlines the importance of considering this in the presentation of this thesis. This is done parallel to the discussion of the use of validity and reliability tests in promoting intellectual rigor.

The methodological approach, namely the use of mixed methods, is outlined and the methodological design of using a longitudinal case study is presented. The advantages and disadvantages of this approach are also discussed. Each phase is described in detail and the methods of data collection are documented. Approaches
to analysis of the data are also discussed. Suggested limitations of the study are also given.

**Chapter Five- Findings: Phase One**
This is the first of three chapters focused on presenting the key findings from this research study. The overarching focus of the chapter is to look at the PSTs use of scientific inquiry and whether this developed over their practicum experience. It accounts for a foundational understanding of scientific inquiry orientations which would direct the research within phase two.

**Chapter Six- Findings: Phase Two**
This chapter presents exemplars of the PSTs’ developing theory of inquiry and espoused approaches to inquiry in the classroom. This chapter also presents a critical analysis of the use of dialogue in promoting the social construction of their understanding of inquiry. In other words, their interactions within the PLC are captured and discussed.

**Chapter Seven- Findings: Phase Three**
This chapter explores whether the perceived developing inquiry orientations presented in the previous chapter have translated into classroom practice. This chapter also offers a comparison with teachers not involved in their PCK/inquiry exploration. This is done to determine whether the case study cohort had a higher degree of inquiry practice within their teaching repertoire. Finally, this chapter will present a section on the perceived barriers that influence the practice of scientific inquiry.

**Chapter Eight- Discussion**
In this chapter, each of the four research questions are addressed and discussed with reference to both the findings and existing relevant literature. Because of the thick description mentioned previously, some discussion takes place within the respective findings chapters. However, within this chapter a critical discussion is presented which examines the meaning behind the key findings.
Chapter Nine- Conclusion
This chapter highlights the unique contribution this study has made to the field of science education and suggests further areas of research interest in light of the findings. It also provides a final comment by the author on the overall interpretation of this study and how it relates to teachers’ professional practice.

1.6 Chapter Summary
This chapter set out with the intention of providing the reader with an overview of this research study. Within this overview, the key bases of the study were touched upon from the general aim of the study, to the research questions and the methodological approaches which were used to answer these questions. The chapter also presented the general structure of the thesis. A brief rationale for the study was given however this will be developed further in the chapter related to the background and policy context of science education in Ireland.
Background and Policy Context of Science Education in Ireland
2.1 Introduction

The following chapter will provide a background related to the place of science education in Ireland with an emphasis on the structure of science and the reported nature of students’ experiences in Irish post-primary schools. The latter refers to the students’ achievement levels in science, but also emphasises the motivation and interest levels of students in science. An additional focus lies with the structure of initial teacher education (ITE) in Ireland and speaks of two models, the consecutive and the concurrent model of teacher education. This section also looks more specifically at the structure of ITE within the University of Limerick. It presents the findings from a recent study (Coady 2010) into the experiences of PSTs towards their ITE training in the University of Limerick. To that end this chapter provides an insight into the policy context and background of science education in Ireland which in turn gives rationale to the purpose of this current study.

2.1.1 Science Education in Irish Post-Primary Schools

The curriculum in Irish post-primary schools is divided into two cycles, the junior cycle and the senior cycle. Successful completion at the end of each cycle leads to the awarding of a certificate, namely the Junior Certificate and the Leaving Certificate. There is also an optional year called transition year which students can take before entering the senior cycle. There is no set syllabus within this year therefore the experiences of students vary according to school context. Typically students in this year experience the three primary science subjects (biology, chemistry and physics) for a period of 6 weeks each.

Junior Cycle

The duration of the junior cycle is three years which culminates in the completion of the Junior Certificate. Whilst some subjects are mandatory, science is an optional subject in the junior cycle in the sense that it is not compulsory in all schools. It is often the case that timetabling arrangements with other subjects mean that students have no choice in whether they take science for the Junior Certificate. The science syllabus for the Junior Certificate covers foundational aspects of physics, biology and chemistry. There are over 180 predefined learning outcomes listed in the science syllabus with the majority of these using active verbs such as recall, list etc. There
are few learning outcomes focusing on higher order cognitive demands such as classify and investigate (Department of Education and Science Report 2008).

The assessment associated with science for the Junior Certificate is comprised of three components. It firstly involves the completion of a number of mandatory prescribed experiments (30 in total) with a laboratory notebook being assessed which is worth 10%. Marks for this component are allocated by the classroom teacher on a pro-rata basis, then signed off by the school and sent to the State Examinations Commission (Chief Examiners Report 2010). The next component worth 25% consists of two prescribed investigations with which students must complete and fill in a pro-forma booklet to be externally assessed. These prescribed investigations vary each year. Instead of completing these two prescribed investigations, students have the option to complete their own investigation. However the Chief Examiners Report (2010) suggests that only 0.6% and 0.7% of Lower and Higher Level students respectively choose this option. While this is a small cohort of seemingly adventurous students, most use investigations from previous years for their answers and the average mark received was 59.5% for Lower Level students (Chief Examiners Report 2010). This was significantly less than the marks received by students who completed the prescribed investigations (Chief Examiners Report 2010). Interestingly, the average mark at Higher Level was 86.6% which was greater than the average mark of students who chose to complete the prescribed investigations. The Chief Examiners Report did include issues of authenticity where it was stated that across a number of examination centres, coursework reports lacked authenticity and marks associated with the coursework were withheld pending further investigation (Chief Examiners Report 2010).

Having students engage in their own investigations allows for the creative environment associated with the scientific process and indeed the use of scientific inquiry. However, as the above figures highlight, the opportunity is rarely taken in the classroom setting. The most recent Chief Examiners Report on science from 2010 identified that students engaging in investigative processes performed poorly in the areas of identification of variables, data analysis, drawing conclusions and
providing scientific comments (Chief Examiners Report 2010). These areas would be viewed as key features of the scientific practice.

The final assessment component involves a terminal exam worth 65% and consists of students answering a number of short questions related to the content on the syllabus. Some focus is given to the mandatory experiments which they would have completed over the three years. The exam is divided into three different sections, one for each of the three science subjects and there is no choice within each section, students must answer all questions (Chief Examiners Report 2010).

In 2010, there was a participation rate of 90% for students taking science to the completion of the Junior Certificate, with 71.8% of these students choosing Higher Level and 28.2% choosing Lower Level (Chief Examiners Report 2010). The number of students choosing Higher Level is thought to be as a result of the coursework components introduced to the syllabus which, if students achieve high marks in, can result in them having at least a grade D at Higher Level despite a poor performance in the written examination (Chief Examiners Report 2010).

**New Junior Cycle Framework**

In is necessary to note that the Junior Certificate is currently being reviewed with a new Junior Cycle Framework for science being disseminated in September 2016. Within this new framework there are twenty four statements of learning which serve as the scaffold for schools to plan for, design and evaluate their junior cycle programmes. Also within this framework, a new school based model of assessment is to be introduced with students becoming active participants in their own learning (A Framework for the Junior Cycle Report 2012). A large focus of the new Junior Cycle Framework is to allow students to make greater connections with learning and to improve the quality of learning that takes place. Coupled with this, the new Junior Cycle Framework is based on the principles of creativity and innovation, engagement and enjoyment and lifelong learning. As a result, students potentially develop critical thinking skills, communication skills and cooperative skills as well as the ability to explore options and alternatives related to the content being learned (A Framework for the Junior Cycle Report 2012). While this study took place
against the backdrop of the existing science syllabus, it is important to note that the implications for this study are particularly relevant with the new syllabus as the learning outcomes are to be pursued by students constructing their knowledge of content through scientific inquiry (NCCA 2014a).

**Senior Cycle**
The senior cycle, in which students are typically between the ages of 15-18, lasts two years. In the senior cycle students can choose between taking any of the science subjects, (1) physics, (2) biology, (3) chemistry, (4) physics and chemistry (combined) and (5) agricultural science. These are all optional, meaning a student can complete the senior cycle without having to undertake any of these subjects. The assessment in the Leaving Certificate biology, chemistry and physics subjects consists of a terminal state exam with no record of experimental work being viewed as a requisite to the completion of the syllabus. However the mandatory experiments associated with each subject can be tested in the form of questions on the terminal examinations paper.

As mentioned, the science subjects in the senior cycle are not compulsory yet some third level institutions require students, looking to enrol in particular courses, to have successfully completed at least one of the science subjects in their Leaving Certificate. Within the current Leaving Certificate, there is little emphasis on student-led engagement. It is mainly stated in the aims and principles of the science syllabus rather than being part of the process of how the content is learned. However, the Leaving Certificate curriculum is currently being revised by the National Council for Curriculum and Assessment (NCCA), who are the national body responsible for improving the quality of education through curriculum and assessment reform.

**2.2 The Place of Science in Ireland**
The ROSE report developed by Mathews (2007) looked at the relevance of science education (ROSE) in Ireland. It identified some significant findings from an empirical study carried out with Irish post-primary students. The study, in survey format, was carried out with 688 transition year and fifth year students. The sample had a presentable gender balance consisting of 330 girls and 358 boys. It looked at
the students’ perceptions of how they were taught science in school, as well as the relevance of science in their everyday lives.

This study found that less than 30% of students believed that school science was interesting and helpful to their everyday life and 55% of students did not wish to become a scientist. The latter is of particular concern as the scarcity of a skilled scientific workforce would have a detrimental impact on the generation of the knowledge economy (Report of Task Force on Education of Mathematics and Science at Second Level 2010). Other reports and studies have documented concern about the declining number in the uptake of science in Irish post-primary schools (Regan and Childs 2003; Report and Recommendations of the Task Force on the Physical Sciences- DES 2002; Smyth and Hannan 2006). For example, there was an uptake of 90% for the Junior Certificate science syllabus in 2009 and an uptake of approximately 7000 students in both chemistry and physics in 2008 (Report of Task Force on Education of Mathematics and Science at Second Level 2010). The uptake of biology for the Leaving Certificate had initially a higher starting point since the syllabus was introduced; however the uptake of biology has also seen a decline in recent years (Smyth and Hannan 2006). Students who are interested in the science subjects are more likely to take these subjects at senior cycle however the perceived difficulty of the subjects also influences students’ decisions to choose them at senior cycle (Smyth and Hannan 2006). At third level also, the uptake of science related courses is significantly lower than that of humanities, business and the arts (Report of Task Force on Education of Mathematics and Science at Second Level 2010). The demand for qualified scientists and engineers in Ireland is high, yet there is a declining pool of skilled graduates to meet the demand (Forfás National Skills Bulletin 2008).

A summary of the ROSE report findings is as follows:

1. There was a slightly more positive response than a negative one associated with the Junior Certificate science syllabus.
2. Students were more interested in certain themes such as health, sex, genetics, natural disasters and the origins of life, space and the universe.
3. Students were least interested when the themes had a more technical aspect to them, e.g. how petrol engines function.

4. Some of the lowest ratings were for topics that formed a substantial part of the Junior Certificate e.g. atoms and molecules, how plants grow, reproduce and electricity.

5. Girls’ responses were often very different to boys’ responses. Girls had more interest in topics like eating disorders, babies and cosmetics while boys had more interest in topics like explosive chemicals and nuclear weapons.

6. Roughly 50% of the participants found Junior Certificate science to be a demanding and difficult subject.

7. Students strongly agreed that science/technology is important for society.

(Matthews 2007)

This summary shows a mixed reaction but does suggest that students do have contrasting attitudes towards science therefore implying the complex nature of teaching a subject with such diverse views.

**Attitudes towards the Domain-Specific Science Subjects**

Research into the attitudes of Irish students towards the independent science subjects is sparse. For biology topics, international research shows that genetics and the nervous system are viewed as being the most difficult (Baher et al. 1999). In physics, friction, force, work, nuclear energy and speed, velocity and acceleration are viewed as the most difficult subjects (Okpala and Onocha 1998).

Regan and Childs (2003) focused their study specifically on the attitudes of Irish students towards chemistry. They asked students why they would choose to do chemistry for the senior cycle. The most popular answers related to interest in the subject and the fact that doing the subject can open up a variety of career doors. Only a small fraction of students (3.4%) said that they would not choose chemistry. Another study carried out by Sheehan (2010) highlighted some of the difficulties which students had in relation to chemistry. They include:
(1) Chemistry being an abstract subject with a symbolic and representational nature to it.

(2) The lack of laboratory classwork and the lack of discussion that takes place in the science classroom.

(3) Misconceptions both on the part of the teacher and the student.

(4) Students level of cognitive development; the teachers are demanding understanding at a higher cognitive level than students are currently at.

(5) The three levels of learning which are the macroscopic, microscopic and symbolic.

Topics which students found difficult at Junior Certificate level included the particle theory, chemical equations, covalent compounds, ionic compounds, chemical changes and covalent bonding and at the Leaving Certificate level included organic reaction mechanisms, organic synthesis, electrochemistry, chemical equilibrium calculations and infrared spectroscopy (Childs and Sheehan 2009).

2.2.1 Achievement Levels in Science

The achievement levels of students in the Leaving Certificate are generally regressing with more students failing and less students achieving well in science (State Examinations Commissions 2013). The achievement levels of students in the Junior Certificate are fairly static in comparison but slightly better than those of the Leaving Certificate. It must be considered however that there is a large discrepancy between the difficulty levels in the junior and senior cycles (Childs and Sheehan 2009).

The following tables present the grading differentiation in Junior Certificate science and Leaving Certificate biology, chemistry and physics from 2011-2014. These tables have been taken from the State Examination Commission (SEC) website (2013/2014).

**Junior Certificate**
Table 2.1: Percentage of A grades in the Junior Certificate Science syllabus 2011-2014

<table>
<thead>
<tr>
<th>Junior Certificate Science</th>
<th>2011 Number receiving an A1 grade in %</th>
<th>2012 Number receiving an A1 grade in %</th>
<th>2013 Number receiving an A1 grade in %</th>
<th>2014 Number receiving an A1 grade in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Level</td>
<td>9.7</td>
<td>9.4</td>
<td>8.8</td>
<td>11.3</td>
</tr>
<tr>
<td>Lower Level</td>
<td>1.4</td>
<td>1.6</td>
<td>1.4</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Table 2.2 Percentage of E/F grades in the Junior Certificate Science syllabus 2011-2014

<table>
<thead>
<tr>
<th>Junior Certificate Science</th>
<th>2011 Number receiving an E or F grade in %</th>
<th>2012 Number receiving an E or F grade in %</th>
<th>2013 Number receiving an E or F grade in %</th>
<th>2014 Number receiving an E or F grade in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Level</td>
<td>1.5</td>
<td>1.4</td>
<td>1.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Lower Level</td>
<td>4.3</td>
<td>3.7</td>
<td>0.8</td>
<td>1.2</td>
</tr>
</tbody>
</table>

The above tables are relevant as the decision of students to continue on their study of the science subjects can be influenced by how well they do in their junior cycle assessment (Smyth and Hannan 2006).

**Leaving Certificate**

Table 2.3: Percentage of A grades in the Leaving Certificate Biology syllabus 2011-2014

<table>
<thead>
<tr>
<th>Leaving Certificate Biology</th>
<th>2011 Number receiving an A1 grade in %</th>
<th>2012 Number receiving an A1 grade in %</th>
<th>2013 Number receiving an A1 grade in %</th>
<th>2014 Number receiving an A1 grade in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Level</td>
<td>6.7</td>
<td>7.8</td>
<td>6.0</td>
<td>5.4</td>
</tr>
<tr>
<td>Lower Level</td>
<td>0.6</td>
<td>0.4</td>
<td>0.5</td>
<td>0.3</td>
</tr>
</tbody>
</table>
In 2012 and 2013, the highest percentage rate was associated with a B3 grade in Higher Level biology with 10.10% and 10.4% of students achieving this grade. Whilst with students who sat the Lower Level paper, the highest percentage rate in 2012 and 2013 was a C2 and a C3 respectively.

Table 2.4: Percentage of A grades in the Leaving Certificate Chemistry syllabus 2011-2014

<table>
<thead>
<tr>
<th>Leaving Certificate Chemistry</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Level</td>
<td>11.6</td>
<td>11.6</td>
<td>9.6</td>
<td>9.4</td>
</tr>
<tr>
<td>Lower Level</td>
<td>3.3</td>
<td>2</td>
<td>2.6</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Interestingly in 2012, the highest percentage rate was associated with an A2 grade in Higher Level chemistry with 11.60% of students achieving this grade. However when one compares this with the results of Lower Level students, the highest percentage rate was an E grade in 2013 with 10.3% of students achieving this grade. This indicates a regression from the previous year where the highest percentage rate was C1.

Table 2.5: Percentage of A grades in the Leaving Certificate Physics syllabus 2011-2014

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Level</td>
<td>9.1</td>
<td>9.8</td>
<td>10.1</td>
<td>9.6</td>
</tr>
<tr>
<td>Lower Level</td>
<td>6.1</td>
<td>5.3</td>
<td>6</td>
<td>6.1</td>
</tr>
</tbody>
</table>
In 2012 the highest percentage rate for Lower Level students was 12.8% and this was associated with a grade B3. In 2013 the highest percentage rate was 12.3% for Lower Level students who achieved a grade B3.

The following tables present the data associated with the failure or near failure rates of students from 2011 to 2014 in biology, chemistry and physics.

Table 2.6: Percentage of E/F grades in the Leaving Certificate Biology syllabus 2011-2014

<table>
<thead>
<tr>
<th></th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number receiving an E or F grade in %</td>
<td>Number receiving an E or F grade in %</td>
<td>Number receiving an E or F grade in %</td>
<td>Number receiving an E or F grade in %</td>
</tr>
<tr>
<td>Higher Level</td>
<td>8.1</td>
<td>8</td>
<td>8</td>
<td>6.8</td>
</tr>
<tr>
<td>Lower Level</td>
<td>12.8</td>
<td>12.9</td>
<td>12.8</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Table 2.7: Percentage of E/F grades in the Leaving Certificate Chemistry syllabus 2011-2014

<table>
<thead>
<tr>
<th></th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number receiving an E or F grade in %</td>
<td>Number receiving an E or F grade in %</td>
<td>Number receiving an E or F grade in %</td>
<td>Number receiving an E or F grade in %</td>
</tr>
<tr>
<td>Higher Level</td>
<td>8</td>
<td>8.3</td>
<td>7.5</td>
<td>8.6</td>
</tr>
<tr>
<td>Lower Level</td>
<td>11.6</td>
<td>14.7</td>
<td>16.3</td>
<td>14.6</td>
</tr>
</tbody>
</table>

Table 2.8: Percentage of E/F grades in the Leaving Certificate Physics syllabus 2011-2014

<table>
<thead>
<tr>
<th></th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number receiving an E or F grade in %</td>
<td>Number receiving an E or F grade in %</td>
<td>Number receiving an E or F grade in %</td>
<td>Number receiving an E or F grade in %</td>
</tr>
<tr>
<td>Higher Level</td>
<td>7.5</td>
<td>6.9</td>
<td>6.8</td>
<td>7.9</td>
</tr>
</tbody>
</table>
It is important to note for all subjects that the failure rates remain alarmingly high but particularly for the students completing the Lower Level examination papers (SEC 2013).

Interestingly these statistics contradict the findings from the PISA report (Perkins et al. 2012) which document Ireland’s overall performance as being significantly above the OECD average in science. 15 year old students from each of the OECD countries completed the PISA assessment in March 2012 with the majority of Irish students completing their Junior Certificate the following June. This assessment was directed on a specific framework which focused on scientific literacy (Perkins et al. 2012). This framework was reflective of different aspects of scientific literacy which included “scientific knowledge and use of this knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues” and “understanding of the characteristic features of science as a form of human knowledge and enquiry” (OECD 2013, p.100).

While the overall performance of Irish students was significantly above the OECD average, the students’ science proficiency was considerably lower than the OECD average with one in nine students scoring low on the assessment scale (Perkins et al. 2012). This proficiency is reflective of students’ ability to consistently identify, explain and apply scientific procedural knowledge and knowledge about science content in a variety of complex life situations. Also students’ proficiency in science relates to their ability to use evidence from different data sources to justify decisions and use advanced scientific thinking and reasoning to solve problems (Perkins et al. 2012). These proficiencies in science are directly related to the key features of scientific inquiry (NRC 2000). The conclusion that may be drawn from this report is that Irish students are significantly below the OECD average in terms of their proficiency in the use of authentic scientific inquiry.
2.3 Initial Teacher Education in Ireland

Teachers play a central role in the future strategies of our nation therefore this brings teachers and how they are educated to the core of sustainable economic growth and prosperity (Report of the International Review Panel on the Structure of Initial Teacher Education Provisions in Ireland- DES 2012). ITE represents the entry point into the teaching profession and therefore how it is organised plays a crucial role in determining both the quality and quantity of teachers entering the profession (Musset 2010). There are a number of institutions in Ireland offering ITE in science education. Indeed a concern has been raised previously about the large number of higher education institutions offering ITE in Ireland (Report of the International Review Panel on the Structure of Initial Teacher Education Provisions in Ireland- DES 2012). Teaching in Ireland is deemed to be a popular choice of career for young people. It carries much social prestige and therefore admission to teacher education programmes in Ireland is highly competitive and academically demanding (Report of the International Review Panel on the Structure of Initial Teacher Education Provisions in Ireland- DES 2012).

There are two models of ITE that prospective teachers can choose between, the concurrent and the consecutive models. Musset (2010) offers a comparison of the characteristics between the concurrent and the consecutive model of teacher education as outlined in Figure 2.1
Figure 2.1: Comparison between the concurrent and consecutive models of ITE (Musset 2010, p. 6)

To summarise this figure, both models have their distinctive advantages and disadvantages but pertinent to this current study, the suggestion is that the concurrent model provides opportunity for a more integrated learning experience between content and pedagogical knowledge. In Ireland, the concurrent and the consecutive models of ITE co-exist with approximately 30% of post-primary teachers educated on concurrent programmes (Heinz 2008).

The University of Limerick offers the concurrent model of ITE which is interdisciplinary in nature with the science content being taught by the relevant department, i.e. the Department of Life Sciences, the Department of Chemistry and Environmental studies and the Department of Physics. The education component of the programme is run by the Department of Education and Professional Studies. Students engage in one education module every semester and two subject pedagogics modules over the duration of the four year programme. The subject pedagogics is associated with the relevant science department as opposed to the Department of Education and Professional Studies. Students partake in two teaching practicum experiences in their 2nd and 4th years lasting 6 weeks and 10 weeks respectively.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Scope</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concurrent and consecutive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concurrent</td>
<td>Academic subjects are studied alongside educational and professional studies throughout the duration of the course. Shorter.</td>
<td>Common for primary school teachers (except France and Germany). Lower and upper secondary education teachers in Belgium, Canada, Greece, Hungary, Ireland, Italy, Japan, Korea, Turkey, the United States.</td>
<td>Allows a more integrated learning experience, since pedagogical and subject-matter (content knowledge) training take place at the same time.</td>
</tr>
<tr>
<td>Consecutive</td>
<td>The specialized courses in pedagogy and in teacher teaching are accessible after having completed another degree in a discipline taught in school. Longer entry more restrictive.</td>
<td>More common for secondary school teachers than for primary school teachers. Denmark, France, Norway, and Spain, Austria, Australia, the Czech Republic, England, Finland, Ireland, Israel, the Netherlands, Northern Ireland, Scotland, the Slovak Republic, Sweden, Wales.</td>
<td>Allows a more flexible entry into the teaching profession. Allow teachers to have a strong subject expertise in a precise academic discipline.</td>
</tr>
<tr>
<td></td>
<td>In an educational system, both concurrent and consecutive models can coexist. Changing teacher education models can be a way to help resolve the problem of teacher shortage or to boost the quality of the teachers.</td>
<td></td>
<td>Extra financial cost for the country, less efficiency.</td>
</tr>
</tbody>
</table>
They also engage in an alternative educational experience in their third year of study which focuses on teaching away from the typical classroom context. There are two degrees on offer, BSc Education in Physics and Chemistry and BSc Education in Biological Sciences with Physics or Chemistry. Also if students choose to do a BSc in Physical Education, one of the elective subjects on offer is chemistry (Undergraduate Prospectus Handbook University of Limerick 2012-2013). With these degrees, teachers are qualified to teach the respective subjects at Leaving Certificate but are also qualified to teach Junior Certificate science.

University College Cork (UCC) offers this concurrent model for students wishing to obtain a BSc Education in Physical Sciences (Undergraduate Prospectus Handbook, University College Cork 2012-2013). UCC also offers the consecutive model with a Professional Diploma or Masters on completion. Dublin City University runs an ITE programme with a BSc in Science Education specialising in two of the following subjects, chemistry, physics and mathematics (Undergraduate Prospectus, Dublin City University 2012-2013). Another institution, the National University of Ireland (NUI), Maynooth has adopted a five year model. For the first four years, students take a two subject science degree along with modules in education. After the four years, they can progress to the second year of a Professional Masters in Education which they must complete to gain a teaching qualification (Undergraduate Prospectus, National University of Ireland Maynooth, 2013-2014). The other institutions which are the providers of ITE for science teachers are University College Dublin, NUI Galway and Trinity College Dublin, where PSTs complete a Professional Diploma or Masters in Education. Prospective teachers who use this consecutive model will have obtained a relevant Bachelor of Science before enrolment.

The OECD report (2003) suggests that there were no major concerns in Ireland in relation to attracting competent people to enter into the teaching profession. The report also revealed that 90% of entrants into ITE hold an honours degree if they are entering through the consecutive model while entrants into the concurrent model have performed highly in their Leaving Certificate (OECD 2003). While this is a historic report it can be suggested that to be accepted into an ITE programme, a
candidate needs to have a background of high achievement. In fact a recent review panel identified Ireland as having one of the highest, if not the highest calibre of ITE entrants in the world (Report of the International Review Panel on the Structure of Initial Teacher Education Provisions in Ireland 2012). This high achievement does not necessarily mirror a pre-service teacher’s effectiveness which is inherently linked to their PCK. Indeed the EU has indicated that ITE needs to be upgraded in many countries and there is a need to follow the system adopted by the ITE institutions in Finland where emphasis is placed on research as PSTs transit through their respective ITE programme (Report of the International Review Panel on the Structure of Initial Teacher Education Provisions in Ireland 2012).

Experiences of PSTs in the University of Limerick

Coady (2010) focused her research study on the experiences of PSTs in their ITE programme at the University of Limerick. This, a longitudinal study, researched the experiences of PSTs in their second and fourth years of study. Previous to this, a large gap remained in terms of research focused on the experiences of post-primary PSTs in Ireland (Coady 2010). Coady (2010) looked at a diverse range of PSTs’ experiences however the following section provides a discussion on some of her key findings relevant to this current study. It is necessary to note that Coady (2010) focused her study on all the ITE programmes at the University of Limerick, not just science-related ITE programmes.

Only 13.9% of second year PSTs strongly agreed that the university tutor had an influence over the teaching procedures that they employed on their teaching practicum experience. The same cohort was asked the question in their fourth year of study and in this case 20.7% of PSTs strongly agreed that the university tutor influenced their enactment of specific teaching approaches. Only 4.6% of PSTs in second year believed that the lectures they received before their teaching practicum experience were helpful with this number decreasing to 3.3% when the same cohort were asked in their fourth year of study. 27.2% of a particular cohort strongly agreed that they felt prepared for their teaching practicum experience. The qualitative data from this study revealed that PSTs believed that more focus should be given to subject pedagogies within the ITE framework. The most widely cited
recommendation being the need to have a greater emphasis placed on learning how to teach the subject and not just on the relevant subject matter (Coady 2010). One of the key recommendations from this study was the need to have the ITE programmes in the University of Limerick reconceptualised from a learner-centred constructivist approach with a changing capacity for PSTs to become active agents in their own learning and development (Coady 2010).

The above exemplars of PSTs’ experiences are part of a larger study but demonstrate the opinions with regard to their level of preparedness to teach and lack of exposure to subject pedagogics and understanding of teaching methodologies from their ITE.

2.4 Summary of Chapter
This chapter has given an insight into the place of science in the Irish post-primary education system both from the perspective of the science student and the PST. Specifically this chapter has outlined students’ historical achievement levels in science and the need to develop an increased motivation towards the subject. The information provided in this chapter has shown there to be a decline in terms of students’ achievement and interest levels in science. The teacher plays a vital role in fostering an attitudinal shift in students. PSTs are the “agents of change” (Price and Villi 2005, P.59) because of their desire to learn how to teach. Ireland is purported to have one of the highest calibre of entrants into ITE, yet is ITE in the University of Limerick providing these novices with the tools to enhance students learning and motivation in science? Preliminary findings from the study carried out by Coady (2010) would suggest that PSTs do not believe the education training facilitates their orientation towards student-led pedagogical practices.

The quantitative data from PISA (Perkins et al. 2012) and the examination results over the last number of years would suggest that students do not have the knowledge of science or the awareness of the scientific process. Are PSTs being adequately trained to stop the decline? This background and policy context analysis has revealed the nature of science education in Ireland and the data provided in this chapter is justification for the need to alter the current trend through facilitating the professional development of PSTs.
Literature Review
3.1 Introduction
This chapter presents a literature review examining PSTs’ professional development in terms of their orientations toward scientific inquiry, through a pedagogical content knowledge (PCK) lens within a learning community (Shulman 1986; Loughran et al. 2006; Park and Oliver 2008a). The flowchart for the review is given in Figure 3.1 and signposts for the reader the flow of the chapter. First, the review begins by looking at the models of teacher knowledge and in particular, the model of teacher knowledge put forward by Shulman (1986). Within this description, one category of teacher knowledge is stressed, PCK. Ways of conceptualising PCK are outlined. Second, following this an extensive discussion on scientific inquiry is given. Literature on how scientific inquiry is linked with a teacher’s PCK is explored. Third, ways of facilitating the professional development of teachers towards the practice of scientific inquiry are addressed with a particular focus on a professional learning community (PLC). Literature relevant to pre-service teacher education will be presented throughout. Finally, and arising from the literature reviewed the chapter concludes with a conceptual framework which synthesises the relationships between the key themes explored in this study (Magnusson et al. 1999).

![Figure 3.1 Flowchart of the main themes in the review chapter](image)

3.2 Models of Teacher Knowledge
Effective teachers of science are those who can create a classroom environment whereby both students and teachers are allowed to work in unison as active learners (Demir and Abell 2010). To allow this to happen, the teacher needs to have the requisite knowledge to facilitate this active engagement. This was not always the view as “a century ago the defining characteristic of pedagogical accomplishment was knowledge of content” (Shulman 1986, p. 7). However this view has changed considerably in recent times as the knowledge of teachers has become an area of interest for all actors involved in education, including educators themselves and policy makers (Shulman 1986).
According to Darling-Hammond (2008), a sophisticated understanding of the content, the learner and the goals of instruction is imperative in the delivery of effective teaching. Teaching is a complex endeavour which involves drawing on a number of different knowledge bases (Nargund-Joshi and Liu 2013). It is important to acknowledge that many academics have presented significant and relevant forms of teacher knowledge beyond content and pedagogical knowledge (Lee et al. 2007). Research on teacher knowledge came to be more closely studied in the 1960s and 1970s (Abell 2007) and a number of models of teacher knowledge were developed.

For example, Banks et al. (1999) suggests that teacher knowledge is derived from their subject knowledge, pedagogical knowledge and school knowledge. The latter is related to the way subject knowledge is taught in schools and how this knowledge is translated for a student audience (Banks et al. 1999). Prestage and Perks (2000) suggest that classroom events, professional traditions, practical wisdom and learner knowledge are key components of a teacher’s knowledge. Prestage and Perks (2000) argue that learner knowledge would reflect how the teacher themselves experienced science as a student, in other words, their apprenticeship of observation (Lortie 1975). Nicholson (1996) suggests that pedagogical knowledge, content knowledge and curriculum knowledge make up their model of teacher knowledge and can formally be acquired in the social context in which educational practices occur. Barnett and Hodson (2001) consider that teachers utilize four kinds of knowledge (1) academic and research knowledge, (2) pedagogical content knowledge, (3) professional knowledge and (4) classroom knowledge (Barnett and Hodson 2001). Within this framework all four components constitute their model of pedagogical context knowledge for good practice.

3.2.1 Shulman's Model of Teacher Knowledge

In 1986 Lee Shulman identified seven categories in his model of teacher knowledge, as follows:

- “Content Knowledge
• General pedagogical knowledge, with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter
• Curriculum knowledge, with a particular grasp of the materials and programs that serve as “tools of the trade” for teachers
• Pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding
• Knowledge of learners and their characteristics
• Knowledge of educational contexts, ranging from the workings of the group or classroom, the governance and financing of school districts, to the character of the communities and cultures
• Knowledge of educational needs, purposes, and values, and their philosophical and historical grounds”.

(Shulman 1986, p.8)

Shulman’s exploration into what exactly a teacher’s knowledge base was came about because of the negative attention associated with teachers at the time. Some researchers would argue that Shulman (1986) was driven by political reasons, not altruistic reasons, because of his involvement in the development of new ways to test teachers (Settlage 2013) however this would be seen as a negated viewpoint. Shulman recognised that there was a demeaning image of teachers’ capacities present, which one can say originated from George Bernard Shaw’s infamous aphorism that “He who can, does. He who cannot, teaches” (Shaw 1903, cited in Shulman 1986). Shulman (1986) found that there was an absence of focus on subject matter knowledge and an emphasis on teaching practices in the historical research. Essential questions in relation to knowledge were being avoided; questions like “how do teachers decide what to teach, how to represent it, how to question students about it and how to deal with problems of misunderstanding?” (Shulman 1986, p. 8).

Shulman’s research led him to decipher a distinction between content knowledge and pedagogical method in the hope that the findings of his research would reverse the current negative associations with teaching, so that it could be viewed as the
complex activity that it is (Shulman 1986). As Shulman began to probe the complexities of a teacher’s understanding and transmission of knowledge, he became increasingly aware of the need to develop a theoretical framework to categorise the knowledge represented in the minds of the teacher. From this his conceptualisation of PCK developed.

PCK was originally defined by Shulman (1986) as:

“for the most regularly taught topics in one’s subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations- in a word, the ways of representing and formulating the subject that make it comprehensible to others”.

(Shulman 1986, p. 9)

PCK reflects the knowledge a teacher possesses to facilitate their teaching of new material in such a way that it is made comprehensible to others (Shulman 1986). PCK signifies not only the amount of knowledge a teacher has of the content but also the organisation of that knowledge (Shulman 1986). Therefore PCK is essentially an acknowledgment of the importance of transforming subject matter knowledge into subject matter knowledge for teaching (Park and Oliver 2008a). Shulman considered this to be the missing paradigm in educational research (Shulman 1986).

An expert teacher has well formed PCK for all topics taught, developed over time from reflections of past experiences, active processing and integration of the components of PCK (van Driel et al. 1998). A teacher with well-formed PCK has a general understanding of students including their ability, cognitive development, attitudes and motivations and also has understanding of the social, political, cultural and physical setting in which they are required to learn (Cochran et al. 1993). Seixas (2001) noted that Shulman’s research on PCK was significant in exploring the teaching of content because it gave a theoretical framework for understanding the relationship between content and pedagogy. In turn it captures some essential qualities of teacher knowledge (Mishra and Koehler 2006). If science teaching is to be better understood and valued, articulation of teachers’ ways of knowing and approaches to and practices of teaching are expected (Berry et al. 2009). Berry et al.
(2008) have described one effective way of doing this, by referring to PCK. PCK is not only important for the classroom but is imperative for teachers to develop their teaching attributes to a professional best, in other words their professional understanding of how their domain, in this respect science, should be taught for effective instruction (Nuangchalerm 2012).

In this study, the author recognises the complexities of teacher knowledge (Loughran et al. 2006). Shulman’s framework of teacher knowledge was selected as the focus of this research because of its explicit reference to PCK as a singular knowledge category. PCK has been seen to have the greatest impact on teachers’ action in the classroom (Gess-Newsome and Lederman 1999) as it is the specialised knowledge that teachers have which differentiates them from content experts (Nargund-Joshi and Liu 2013). Indeed PCK would distinguish the knowledge that a science teacher has from that of a scientist. A scientist would have considerable disciplinary knowledge of the subject but would not necessarily have the knowledge associated with the effective instructional strategies for teaching the subject (NRC 1996). This assumption was conferred by Pitjeng (2014) who reported from a study with graduate science students that while they had the appropriate content knowledge initially, this was seen to reduce in teaching and learning situations. A scientist’s knowledge is structured from a research perspective whilst a teacher’s knowledge is structured for the purpose of student learning (Cochran et al. 1993).

**Contestations around PCK**

Shulman’s categorisation of PCK within his model of teacher knowledge is not without contestation. Recently, Settlage (2013) described PCK as being an “unfulfilled notion” (p.1) and an antiquated concept that has been persistent over the years to the detriment of advancing science education research. He proposed the notion of PCK as offering little substance resulting in an “intellectual dead-end” (p.1). He argued that using PCK as a framework for teacher knowledge confuses the situation when one is trying to distinguish the knowledge necessary for teaching science compared with other forms of knowledge. Overall, Settlage’s main argument is that the field of PCK research to be too vague, descriptive, out-dated and
incoherent (2013). Yet it can be argued that others interested in advancing research in science education see PCK as a necessary addition to the discussion (Kind 2009).

### 3.2.2 Conceptualisations of PCK

Since the construct was originally devised by Shulman (1986) there has been extensive research into PCK in an attempt to expand on its origins. Conceptualisations of PCK vary greatly and this motivated Lee and Luft (2008) to engage in a review of the literature showing the varying conceptualisations of PCK:

**Table 3.1: Historical conceptualisations of PCK**

<table>
<thead>
<tr>
<th>Knowledge of</th>
<th>Subje ct Matte r</th>
<th>Representati ons and Instructiona l Strategies</th>
<th>Student Learning and Concepti ons</th>
<th>Genera l Pedago gy</th>
<th>Curricul um and Media</th>
<th>Conte xt</th>
<th>Purpo se</th>
<th>Assessm ent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shulman (1987)</td>
<td>a</td>
<td>PCK</td>
<td>PCK</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>b</td>
<td></td>
</tr>
<tr>
<td>Tamir (1988)</td>
<td>a</td>
<td>PCK</td>
<td>PCK</td>
<td>a</td>
<td>PCK</td>
<td>b</td>
<td>b</td>
<td>PCK</td>
</tr>
<tr>
<td>Grossma n (1990)</td>
<td>a</td>
<td>PCK</td>
<td>PCK</td>
<td>a</td>
<td>PCK</td>
<td>a</td>
<td>PCK</td>
<td>b</td>
</tr>
<tr>
<td>Marks (1990)</td>
<td>PCK</td>
<td>PCK</td>
<td>PCK</td>
<td>b</td>
<td>PCK</td>
<td>b</td>
<td>b</td>
<td>b</td>
</tr>
<tr>
<td>Cochran et al. (1993)</td>
<td>PCKg</td>
<td>b</td>
<td>PCKg</td>
<td>PCKg</td>
<td>b</td>
<td>PCKg</td>
<td>b</td>
<td>b</td>
</tr>
<tr>
<td>Fernand ez – Balboa and Stiehl (1995)</td>
<td>PCK</td>
<td>PCK</td>
<td>PCK</td>
<td>b</td>
<td>b</td>
<td>PCK</td>
<td>PCK</td>
<td>b</td>
</tr>
<tr>
<td>Magnuss on et al. (1999)</td>
<td>a</td>
<td>PCK</td>
<td>PCK</td>
<td>a</td>
<td>PCK</td>
<td>a</td>
<td>PCK</td>
<td>PCK</td>
</tr>
<tr>
<td>Carlsen (1999)</td>
<td>a</td>
<td>PCK</td>
<td>PCK</td>
<td>a</td>
<td>PCK</td>
<td>a</td>
<td>PCK</td>
<td>b</td>
</tr>
<tr>
<td>Loughraith r et al. (2001)</td>
<td>b</td>
<td>PCK</td>
<td>PCK</td>
<td>b</td>
<td>PCK</td>
<td>b</td>
<td>PCK</td>
<td>PCK</td>
</tr>
</tbody>
</table>

**a:** distinct category in the knowledge base for teaching. **b:** not discussed explicitly.

**PCK:** Pedagogical Content Knowledge. **PCKg:** Pedagogical Content Knowing

There have been many expansions and interpretations of the model of PCK so much so that Barrett and Green (2009) state that there are as many variations of the term
PCK as there are researchers interested in it. Indeed Loughran et al. (2006) consider that some examples of PCK bear little resemblance to the construct originally developed by Shulman (1986). The table above identifies historical conceptualisations that have been presented in the literature on PCK since its inception into the research realm. Table 3.2 provides a summary of some of the conceptualisations and types of PCK found within the relevant recent literature:

Table 3.2 Recent Conceptualisations of PCK

<table>
<thead>
<tr>
<th>Literature Source</th>
<th>PCK Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball et al. (2005)</td>
<td>Knowledge of: a) subject area, for example being able to write up a report for a laboratory experiment b) content and students which refers to knowing of knowing the students, for example their commonly held misconceptions as well as knowing the subject matter and c) content and teaching.</td>
</tr>
<tr>
<td>Henze et al. (2008)</td>
<td>Knowledge of: a) instructional strategies b) knowledge about students’ understanding c) knowledge about ways to assess students’ understanding and d) knowledge about goals and objectives of the topic in the curriculum.</td>
</tr>
</tbody>
</table>
| Park and Oliver (2008a) | • Orientations towards Science Teaching  
                           • Knowledge of a) students’ understanding of science b) science curriculum c) instructional strategies and representations and d) assessment of science learning.  
                           • Teacher efficacy  
                           Model reflects interactivity and coherence between components. This model is referred to as the hexagon model. |
| Hagevik et al. (2010)   | Knowledge of: a) context, curriculum and assessment b) instructional strategies and representations of teaching science c) student learning and d) knowledge of student understanding about science concepts. |
| Mavhunga (2014)         | Knowledge of: a) students’ prior knowledge including misconceptions b) curricular saliency c) what makes a topic easy or difficult to understand d) representations including |

41 | P a g e
Individuals within different interest groups are likely to interpret the nature of PCK differently therefore resulting in multiple meanings and contestations (Park and Oliver 2008a). Despite the varying conceptualisations, most academics agree on two components of Shulman’s original definition which are a) “knowledge of instructional strategies incorporating representations of subject matter and responses to specific learning difficulties” and b) “student conceptions with respect to that subject matter” (Park and Oliver 2008a, p.264).

The idea that PCK is made up of constituent parts helps a researcher to frame research questions and guide the appropriate research methods (Abell 2008). Regardless of the different conceptualisations of PCK reported here, the constituent components of PCK can be modified to support the researchers’ beliefs (Kind 2009). The conceptualisation of PCK followed in this current study is that which was developed by Magnusson et al. (1999) where they attempted to build on the original ideas of Shulman (1986) and Grossman (1990).

<table>
<thead>
<tr>
<th>Types of PCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Veal and McKinster (1999)</td>
</tr>
<tr>
<td>Lee and Luft (2008) drew on the work of Gess-Newsome (1999)</td>
</tr>
<tr>
<td>Dachler and Heller (2012)</td>
</tr>
</tbody>
</table>
The constituent parts of this conceptualisation are presented in Figure 3.2:

![Diagram of PCK conceptualisation](image)

Figure 3.2: Model of PCK developed by Magnusson et al. (1999)

Jing-Jing (2014) considers that this model further specifies the PCK components which make the framework clearer and more easily applied to studies on PCK. Indeed the main reason this conceptualisation of PCK is followed is due, in part, to its extensive use in PCK research but more specifically, the extent to which it has been used by researchers who conceptualise PCK using the CoRe and PaP-eR (Hume and Berry 2011; Williams and Lockley 2012).

**The role of Beliefs and Values within PCK and how these Shape Teachers’ Practices**

Figure 3.2 highlights a particular component of PCK that is commonly placed within PCK conceptualisations (e.g. Grossman 1990; Park and Oliver 2008a; Magnusson *et al.* 1999), that of a teacher’s orientations towards science teaching. A teacher’s orientation towards science teaching reflects their beliefs and values about how science should be taught (Magnusson *et al.* 1999). In other words, it is a belief system reflective of the purposes and goals for teaching science (Jing-Jing 2014) at a particular grade level. This belief system in turn shapes a teacher’s knowledge of science curricula, students’ understanding of science, instructional strategies and
assessment of scientific literacy (Magnusson et al. 1999). Grossman (1990) considers that while PSTs may have limited knowledge in terms of the managerial skills necessary to facilitate students learning, their beliefs about the goals for teaching their subject becomes a conceptual map for instructional strategies. This implies the importance of a teacher’s orientations towards science teaching in terms of its influence on classroom practice, regardless of classroom and training experience. PSTs’ orientations towards science teaching are often determined by how they experienced science as students (Abell et al. 2010), in other words, their apprenticeship of observation (Lortie 1975).

With a focus on scientific inquiry in this current study, it was evidenced that Magnusson et al. (1999) bore consideration for inquiry practices as they described their model. In all Magnusson et al. (1999) considered nine orientations towards science teaching which reflect both didactic and student-led orientations. A teacher’s orientation towards inquiry is one of these (Magnusson et al. 1999). If a teacher has beliefs/values reflective of scientific inquiry this will influence their knowledge of instructional strategies pertaining to such practices. This view is vindicated by Crawford (2007) who suggested that epistemological beliefs (orientations towards science teaching) influence the enactment of inquiry. Despite the association between scientific inquiry and PCK (see section 3.3.9), Nargund-Joshi and Liu (2013) consider that few empirical studies have identified a science teacher’s orientations with scientific inquiry. Nonetheless such studies do exist where other researchers (e.g. Friedrichsen et al. 2011) have used the construct of teaching orientations as the conceptual framework for their study.

It is necessary to add that the relationship between orientations and practice is complex (Nargund-Joshi and Liu 2013) and therefore a focus on a teacher’s overall PCK needs to be considered if their orientations towards science teaching (approaches towards scientific inquiry) are to be put into classroom practice (Nargund-Joshi and Liu 2013).

A discussion of a teacher’s belief system needs to include their beliefs about their capacities as a teacher to enact effective teaching methods with Park and Oliver
(2008a) describing a teacher’s self-efficacy as an affective affiliate of PCK. Bandura (1986) considers that an individual’s perception of themselves mediates their behaviour. Therefore Park and Oliver ascribe to the understanding that if a teacher has belief in their capacities to execute their PCK effectively, PCK will likely be enacted in classroom practice (enacted PCK). Indeed Appleton (2006) would consider a teacher’s self-efficacy as a belief cluster rather than a knowledge component per say. This implies a link between a teacher’s orientations towards science teaching and their own self-efficacy. A teacher with low self-efficacy may have negative orientations towards scientific inquiry (Ketelhut 2007). Therefore it is important to focus on a teacher’s self-efficacy in PCK and more specifically in scientific inquiry discussions. A teacher’s self-efficacy can be heightened through involvement in a professional learning community and this will be discussed in section 3.4.2.2.

Within this discussion it is important to consider the distinction between a teacher’s belief system and their attitudes towards teaching and learning. Munck (2007) describes attitude as the outward and observable actions related to beliefs. A teacher’s orientation towards science teaching (belief and value system) is separate but related to their attitudes towards science teaching. Interestingly an interrelationship also exists between a teacher’s self-efficacy and their attitude (Kazempour 2013). A teacher with high self-efficacy for teaching science through scientific inquiry will likely have positive attitudes towards inquiry as a classroom practice (Kazempour 2013). Overall, a teacher’s PCK is seen to influence their attitudes towards best practices but a teacher’s attitude would not be considered part of the PCK construct (Lombaard 2015). In other words a teacher’s PCK influences a teacher’s attitudes towards constructivist practices (Lombaard 2015) but would not be measureable through PCK conceptualisations.

**Limitations of PCK as a Theoretical Perspective**

While PCK offers a new perspective within the area of teacher education, it is not without its limitations. PCK is made up of numerous categories of knowledge, therefore differences in PCK constructs can exist (Bodner and Orgill 2007). Having a lens such as the CoRe and PaP-eR to articulate the blended nature of PCK can
remove such differences as can defining the conceptualisation of PCK most aligned to the author’s interpretation of PCK. The use of the CoRes and PaP-eRs as a vehicle for the articulation and development of PCK will be discussed further in section 3.2.3.1.

3.2.3 Conceptualising PCK
There are a number of challenges which inhibit the fair conceptualisation of a teacher’s PCK. Common methods of conceptualising PCK are often complicated, time and labour consuming (Rohann et al. 2009). It can be implied that the reason for this is that a teacher’s professional knowledge is difficult to categorize, articulate and record (Loughran et al. 2004). The following section will present the PCK tools used in this current study which were developed in response to the concerns around the implicit nature of PCK (Loughran et al. 2006). Following this, a review of alternative tools developed to conceptualise PCK will be offered for discussion.

3.2.3.1 CoRes and PaP-eRs- a way of Capturing and Portraying PCK
As mentioned previously, PCK can be conceptualised using two tools created by Loughran et al. (2006). These tools have been widely used in the literature for the description and portrayal of exemplar samples of PCK (Loughran et al. 2006; Nilsson 2008; Hume and Berry 2011; Bertram and Loughran 2012). They denote concrete representations of PCK and are known as content representations (CoRes) and Pedagogical and Professional-experiences Repertoires (PaP-eRs). CoRes provide group representations while PaP-eRs account for individual portrayals of PCK. The PaP-eRs connect the practice with the understanding of the particular content found within the developed CoRe. The PaP-eRs are about teaching the content within the classroom context and help to illustrate aspects of PCK in action (Loughran et al. 2006). A collection of PaP-eRs are attached to different areas of the CoRe to highlight the different elements of PCK in that content area (Loughran et al. 2004).

Loughran et al. (2006) recognised that much of what comprises teacher knowledge is implicit and teachers are rarely given the chance to reflect on their practice in a

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3 See section 1.4 which provides the CoRe scaffold
formalised setting. Loughran et al. (2006) considers that there is a need to maintain the complexity of teaching whilst still offering ways of seeing past this complexity in order to gain insight into teachers’ PCK. These pedagogical tools (CoRes and PaPeRs) not only help capture the teachers’ PCK but can also be seen as a way of portraying this knowledge to others (Loughran et al. 2006). Also the act of articulating one’s PCK in the design of a CoRe can lead to its development as PCK can be considered a socially constructed phenomenon (Loughran et al. 2006). Teachers need to problematize the teaching of the content and this can be facilitated by the process of teachers sharing with others their unique knowledge about how to teach particular content for enhanced student learning (Loughran et al. 2006). Indeed it provides the opportunity to socially construct meaning from prior experiences (Bertram 2010). Therefore the interactions within a group setting, as CoRes are designed, can allow for the social construction of meaning. These interactions are referred to as symbolic interactions and will be discussed in due course.

Features of PCK captured through the CoRe
In all, the CoRe helps to consider knowledge of alternative conceptions, insightful ways of testing for understanding, known points of confusion, effective sequencing and important pedagogical approaches (Loughran et al. 2004). Linking back to the PCK conceptualisation considered by Magnusson et al. (1999), the components of PCK can very much be articulated through the CoRe. For example, knowledge of alternative conceptions and known points of confusion would be related to knowledge of students’ understanding of science (Magnusson et al. 1999). Effective sequencing would be part of a teacher’s understanding of the science curriculum (Magnusson et al. 1999). Important pedagogical approaches would inherently reflect a teacher’s knowledge of instructional strategies while insightful ways of testing for understanding would form part of a teacher’s knowledge of assessment for scientific literacy (Magnusson et al. 1999). The overall discussions around the pedagogical prompts can provide insight into the teachers’ orientations towards

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4 Captured through the “difficulties/limitations connected with teaching this idea” and “knowledge of students thinking which influences your teaching of this idea” pedagogical prompts.
5 Captured through the Big Ideas and the first three pedagogical prompts.
6 Captured through the “other factors” and “teaching procedures” pedagogical prompts.
7 Captured through the “specific ways of ascertaining students understanding…” pedagogical prompt.
science teaching (Loughran et al. 2006). In all, the completion of a CoRe provides a generalised understanding of the teachers’ PCK as it links the what, why and how of the content to be taught with what they agree to be important in shaping students’ learning and in turn teachers’ teaching (Loughran et al. 2006). It must also be noted that the components of PCK influence each other, therefore knowledge of assessment of scientific literacy would influence knowledge of students’ understanding and vice versa (Magnusson et al. 1999). As a result, discussion of all of the pedagogical prompts is important in capturing teachers’ generalised PCK.

**Use of the CoRe in Existing Literature**

Exploration of the literature suggests that the CoRe tool alone has been used by more researchers than PaP-eRs combined with the CoRe. This is dependent on the researchers’ interests but largely the CoRes were used because of their explicit focus on group exploration to facilitate espoused PCK development. Lehane and Bertram (2015) set about synthesising the use of the CoRe tool in educational research and concluded from their review that it has served a variety of purposes and has shown to advance the research into a teacher’s professional knowledge.

**Use of the CoRe with PSTs**

CoRes were originally constructed to capture the PCK of expert science teachers and more recently to gain insight into the PCK of PSTs (Hume and Berry 2011). When PSTs were asked to construct CoRes, Hume and Berry (2011) noted that they found this task to be challenging and their lack of experimentation and classroom experience proved to be a limiting factor. In spite of this, with appropriate and timely scaffolding, the process of CoRe construction could potentially aid PSTs in their PCK development (Hume and Berry 2011). They also concluded that if PSTs continued to work together and practice developing additional CoRes, they not only improved but were aided in their preparation for classroom teaching and learning (Hume and Berry 2011). If the CoRe design process is carefully scaffolded and PSTs work from experienced teachers’ PCK, then it would allow them to begin accessing

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8 Studies that have combined CoRes and PaP-eRs include Loughran et al. (2006) and Bertram (2010)
9 PaP-eRs formed part of this current study because of the focus of capturing classroom action
and accumulating some of the knowledge of experienced science teachers. This would help bolster feelings of confidence and competence when they begin to arrange their own knowledge for their model of PCK (Hume and Berry 2011).

Hume and Berry (2013) used the CoRe as a professional development tool with collaboration between PSTs and their co-operating teachers on a teaching practicum experience. The PSTs reported the value in the CoRe as a framework for engaging in professional dialogue with co-operating teachers. Nilsson and Loughran (2012) found the CoRe to be a useful tool in planning for and assessing PSTs own learning related to teaching elementary school science. Bertram and Loughran (2014) explored how the PCK of pre-service physics teachers might begin to develop and in turn used the CoRe as a frame for “planting the seed” (p. 151). They recognised that PSTs would lack appropriate PCK since PCK is linked with classroom experience. Their research revealed that by using a CoRe, the PSTs “shifted from a mostly transmissive content-focused delivery to one that considered more pedagogically-reasoned approaches…thereby providing that some aspects of their PCK have begun to be developed” (p.151). Indeed PSTs, while lacking experience in the classroom as the facilitators of learning, have developed scripts for teaching based on their years as a student and Abell (2008) believes that these scripts limit their views on teaching and learning. The CoRe can provide a cognitive and reflective challenge for PSTs as they continue to confirm or remove some of their pre-existing notions of teaching as they transition through their ITE programme.

Nilsson (2013) also used the CoRe to facilitate PSTs’ PCK. She noted from her study that developing a CoRe together with self-assessment and formative interactions with teacher educators and peers can potentially lead to PCK development. Loughran et al. (2008) focused their studies on having a teacher educator introduce PSTs to ideas about PCK through the CoRe and the PaP-eR. They found that the use of PCK, through the medium of the CoRe and PaP-eR, can offer another way of thinking about teaching that goes beyond the traditional range of “tips and tricks” about how to teach (Loughran et al. 2008). It encourages PSTs to engage in dialogue which leads to deeper understandings and the creation of links for teaching and learning purposes (Loughran et al. 2008).
Williams and Lockley (2012) expanded their use of the CoRe by using it with technology students as well as science students. This suggests that the CoRe can be utilised in a variety of general subject contexts beyond its ubiquitous use in the sciences.

**Use of the CoRe with In-service Teachers**

Williams *et al.* (2012) used the CoRe as a lesson planning tool with early career teachers and results showed that involvement in the CoRe construction helped these novices develop confidence in what they were teaching and to try new pedagogical strategies. The use of the CoRe as a lesson planning tool has also been advocated by others (Hume and Berry 2013; Bertram and Loughran 2012). Williams *et al.* (2012) also found that the support of expert teachers contributed hugely to the successful design of the CoRe. Williams *et al.* (2012) use of the CoRe as a lesson planning tool developed from an initial study carried out by Eames *et al.* (2011). They brought together science and technology experts in both content and pedagogy with early career science teachers and researchers to design a CoRe to assist the development of teachers’ PCK. This developed CoRe was then used by early career teachers in the planning and delivery of a classroom activity. Eames *et al.* (2011) believed that CoRes had the potential to help early career teachers gain access to the content and pedagogical expertise of others. Also the process of developing the CoRe with experts was nearly as important as the product of the CoRe itself (Eames *et al.* 2011). This suggests that taking part in the construction of a CoRe can allow for experiential learning.

Moore and Woolnough (2012) used the CoRe to facilitate the development of a science curriculum by introducing aspects of PCK into curriculum documentation. This use is far removed from its original intention but it does again confirm the flexible nature of the CoRe for individual educational purposes. Chordnork and Yuenyong (2014) used the CoRe with elementary school teachers to facilitate them in developing a greater understanding of teaching global warming. Findings from their study suggested that teachers found that the CoRe offered a means to understand PCK and its influence on science teaching.
Use of the CoRe with University Educators

Padilla et al. (2008) used the CoRe to capture the PCK of four university professors on the topic of the “amount of substance”. Similarly Rollnick et al. (2008) employed the CoRe as a tool to facilitate the teaching and learning of the amount of substance but included the topic of chemical equilibrium in their research agenda. The focus of the latter study was to investigate the effect of a teacher’s subject matter knowledge on their PCK. The success of the CoRe designed in this context illustrates how it can be used to facilitate teaching specific topics. Davidowitz and Rollnick (2011) used the CoRe to portray the practice of a university lecturer as they considered that the strength of the CoRe was in its ability to focus the lecturer’s understanding of the aspects of teaching that represent and shape the content.

Adapted uses of the CoRe

Donnelly and Boniface (2013) made the accessibility of the CoRe more interactive by creating an on-line Wiki in response to the potential issues in having teachers meet face to face to design a CoRe. It was also in response to the proclaimed issue of CoRe construction being a labour and cost intensive affair (Donnelly and Boniface 2013). They consider the idea that CoRes can be developed individually and shared online (Donnelly and Boniface 2013). Even though the CoRe was originally constructed to represent group PCK, others have found use in the individual construction of CoRes (Lehane and Bertram 2013). While the group construction and the professional learning community created does have its own benefits, studies have shown that teachers can also gain professional learning from creating a CoRe individually (Bertram 2010).

While the majority of researchers have kept the original CoRe scaffold, Aydin et al. (2013) adapted the CoRe slightly to include reference to expected students’ understanding and curriculum objectives.

Only one other study has used the CoRe to facilitate the use of scientific inquiry. Espinosa-Bueno et al. (2011) used the CoRe to document teachers’ pedagogical inquiry/content knowledge (PICK) and were more focused on getting the participants
to consider the implications of including the features of scientific inquiry in their lesson. The CoRe scaffold, named I-CoRe, was so significantly adapted that its resemblance to the original CoRe designed by Loughran et al. (2006) was minute as Figure 3.3 suggests:

![Figure 3.3](image)

Figure 3.3. The I-CoRe

The purpose of the I-CoRe was to consider the complexities of including the features of inquiry within a classroom and does little to suggest how inquiry is embedded within a teacher’s PCK. The reason for this is that within its description it does not integrate the components of PCK within the I-CoRe scaffold. Therefore while Espinosa-Bueno et al. (2011) did see the association between using the CoRe with a scientific inquiry focus, the emphasis was not on capturing and developing inquiry orientations.

The above section identifies the variations in which researchers have used the CoRe in their own research and professional development endeavours. However its use to capture and develop scientific inquiry orientations is yet to be presented.

3.2.3.2 Alternative Ways of Conceptualising PCK
The author will now speak of alternative methods of conceptualising PCK. A recent PCK summit, which brought together experts in the area of PCK, found that there was a mix of approaches used to uncover PCK. These include qualitative, quantitative and mixed methods approaches with semi-structured interviews, CoRes and stimulated recall using video observations serving as the qualitative tools and surveys as the quantitative tool (Friedrichsen et al. 2012).

One method, which has a quantitative focus, was developed by Rohann et al. (2009). They used a multiple choice testing system which would prove feasible when using a large sample size. Rohann et al. (2009) found that measuring PCK in this fashion was complicated, not impossible however. They concluded that a larger sample size again would be needed in order to use more sophisticated statistical techniques (Rohann et al. 2009). Another important recommendation was to have a methodology which included interviews and observations or other qualitative methods along with the multiple choice testing. This would lead to the more profound measurement of one’s PCK (Rohann et al. 2009).

Van der Valk and Broekman (1999) used a lesson preparation method which focused on having PSTs prepare a lesson on a specific topic with a follow up interview. The lesson preparation task involved a number of requisites. For example PSTs were not allowed to use a textbook in their preparation and the lesson had to be a 40 minute introductory lesson to a specific topic (van der Valk and Broekman 1999). The interview reflected two parts where participants had to firstly discuss what they believed the potential lesson would look like in practice (espoused PCK) and then answer a number of interview questions which followed five aspects of PCK developed by Shulman (1986):

- **Pupils’ prior knowledge** (what prior knowledge on area do you suppose the pupils have?)
- **Pupils’ problems** (do you expect pupils to have certain difficulties with learning “area”?)
- **Relevant representations** (what material for expressing representations, e.g. on the blackboard or on transparencies, was supplied?)
- **Strategies** (describe the strategy to be used when teaching the area concept?)
- **Student activities, e.g. cutting paper figures** (what materials do you intend to use when teaching the lesson?).

  (van der Valk and Broekman 1999, p.14)

Seymour and Lehrer (2006) used video-stimulated structured interviews, field notes and teacher journals to capture PCK. Due to the complex nature of PCK, Fischer *et al.* (2012) suggests that some researchers used mixed methods to uncover PCK as opposed to sticking with one approach, therefore supporting Seymour and Lehrer (2006) in their mixed methods approach.

Park and Oliver (2008a) developed a PCK rubric which measured a teacher’s PCK through the triangulation of data from classroom observations and pre/post observation interviews. This rubric was grounded in the hexagon model discussed previously. Jüttner *et al.* (2013) developed a PCK instrument based around a pencil and paper test. The items included in this test reflected three knowledge dimensions of PCK- procedural, declarative and conditional knowledge (Jüttner *et al.* 2013). The instrument would have determined the teachers’ knowledge about student errors and instructional strategies (models and experiments).

### 3.2.3.3 Concluding Comments on Conceptualising PCK

Gess-Newsome (2013) argues that measuring PCK can lead to some forms of knowledge being more highly regarded than others. No method of conceptualising PCK is without its barriers, however for the purpose of utilising a tool for professional development opportunities, CoRes and PaP-eRs appear to have the dominant appeal over other methods.

Loughran *et al.* (2004) highlighted some potential barriers which they sought to address through the development of the CoRe and PaP-eR. The first is that a teacher’s PCK may not be evident to the researcher examining the PCK of the teacher in just one lesson or teaching experience. Observation can only have a limited influence on giving insight into teachers’ PCK because it is an internal
concept (Baxter and Lederman 1999). Due to the fact that it is an internal concept, teachers should be asked to “articulate their PCK” in order to capture their true PCK (Loughran et al. 2004). Teachers rarely communicate the reasons behind their teaching procedures and provide insights into their teaching and learning practices (Loughran et al. 2004). There is also a lack of common vocabulary among teachers in respect of teaching and learning (Kagan 1990). Using the CoRes and PaP-eRs in professional development endeavours can alleviate these potential barriers (Loughran et al. 2006).

Gess-Newsome (2013) acknowledges that there is a clear distinction between capturing and measuring PCK. Loughran et al. (2006) conceded that much of research on PCK concentrates on evaluating PCK (as shown from the studies mentioned in section 3.2.3.2) rather than finding ways of helping teachers improve their practice through explorations using concrete examples of how teachers teach particular topics in particular ways which in turn could enhance student learning. By describing PCK through the articulation and documentation of concrete examples, teachers can use these examples to help shape their own practice (Loughran et al. 2006). Previously van Driel et al. (1998) noted how there were few science topic specific examples to illuminate this important aspect of a teacher’s professional knowledge in the literature. The CoRe and PaP-eR can provide a place for such discussion of topic-specific PCK to take place (Loughran et al. 2006).

One other issue that has been identified from the studies on PCK relates to the theory-practice divide associated with documenting PCK in a theoretical situation and in a practical classroom situation. Teachers tend to hold the view that the idea of PCK is just another representation of educational jargon and due to this, the diversity of direction, innovations and challenges that exist when creating the theoretical construct that is PCK lead to a theory-practice divide between the literature and the real-life classroom situation (Berry et al. 2009). The work of Loughran and his associates towards documenting exemplar samples of PCK in recent years has made the concept of PCK less elusive as a theoretical and practical construct (Bertram and Loughran 2012).
From the above section, the need is strong to consider a PCK instrument which is clear, concise and offers a detailed insight into a teacher’s PCK and the CoRe together with PaP-eRs appears to appeal to the widest spectrum of academics interested in the professional development of teacher knowledge.

Conceptualising PCK offers insight into how teachers would present material to make new knowledge comprehensible to all students. Imitating the practice of a scientist, through the use of scientific inquiry, can allow for this knowledge development and is the focus of the next section.

3.3 Scientific Inquiry
This section will explore the varying conceptualisations of scientific inquiry, the challenges attached to using inquiry in the classroom and the strategies for making inquiry orientations visible within a teacher’s practice. It will then present literature which associates scientific inquiry with PCK.

3.3.1 Inquiry-based Learning
Within the literature there is mention of a “family” of inquiry approaches which include project-based learning, design-based learning and problem-based learning (Darling-Hammond 2008). Inquiry-based learning is a flexible, holistic adaption of problem based learning where there is increased student involvement in their learning (Darling-Hammond 2008).

Inquiry-based learning develops students’ critical thinking skills and gives them responsibility for their own learning (Magnusson et al. 1999). It is an instructional strategy that can be applied to all subjects and is based on the constructivist theory of learning which emphasises the active role of the student in their own learning (Kazempour 2009). With a constructivist approach, the students come into a given situation with their own understandings and beliefs and try to link this new experience with their existing prior knowledge (Hume and Berry 2011). It is considered that the essence of one person’s knowledge can never be totally transformed to another person because knowledge is a result of personal interpretation of experiences (Snowman and Biehler 2006). Therefore the creation of personal meaning can lead to a deeper understanding of the concepts being explored.
When it is utilised in the science subjects with the focus on the scientific process, it is known as scientific inquiry. Scientific inquiry therefore stems from inquiry-based learning (Blessinger and Carfora 2015).

### 3.3.2 Definitions of Scientific Inquiry

The importance of scientific inquiry is seen as “indisputable” within the literature largely because of the essence of an inquiry practice where the student is removed from “rote memorisation” and they “become independent thinkers and problem solvers” (Hadzigeorgiou et al. 2010, p.32). The student develops their own autonomy and does not hold the teacher responsible for their knowledge base (Damnjanovic 1999). According to Stoddart et al. (2000), educators acknowledge the importance of learning science by actually doing science, using what is considered to be genuine scientific methods where students can employ the reasoning tools that a scientist would possess (Hadzigeorgiou et al. 2010). Further to this, there is widespread agreement among scientists, policy-makers, researchers, science teacher educators, and teachers that students should experience inquiry in science classrooms during the learning process (Lunetta et al. 2007). Recent science education reform movements place scientific inquiry (along with the nature of science) as an influential factor in fostering the development of scientific literacy for all learners.

The idea of inquiry historically dates back to the time of Greek philosophers (Shields 2014) however more recent attempts to reflect science learning through inquiry originated with Dewey (1938). He noted that developing thinking and reasoning, articulating ideas, learning science and understanding the process of science were the goals of teaching science through inquiry. He also reflected on the social and interactive processes that should be part of the symbiosis of teaching and learning (Dewey 1938).

Inquiry has since been defined as an 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
• communicating the results.

(NRC 2000, p. 23)

By making observations, posing questions etc. students can gain a better understanding of the nature of science and the importance of collaboration and communication in science (NRC 2000). The NRC (2000) also describes classroom inquiry as consisting of five essential features:

(a) Learner engages in scientifically oriented questions
(b) Learner gives priority to evidence in responding to questions
(c) Learner formulates explanations from evidence
(d) Learner connects explanations to scientific knowledge
(e) Learner communicates and justifies explanations.

Scientific inquiry goes beyond the ability to observe, infer, classify, predict, measure, question, interpret and analyse data. Firstly, it stretches to including all these process skills with scientific knowledge, reasoning and the ability to engage in critical thinking (Fazio et al. 2010). Secondly, it is the content that students should understand (Fazio et al. 2010). Thirdly, it is the range of teaching strategies and processes to engage learning that should take place in the science classroom (NRC 1996; Bybee 2000; Damnjanovic 1999). However it must be stressed that the practice of scientific inquiry mirrors the actions of a scientist. To that end Harwood (2004), through interviewing scientists, developed a model of scientific inquiry. Harwood’s model consists of ten activities which a scientist engages in. They are represented in Figure 3.4 below
One model of scientific inquiry that has gained attention in the literature is the 5E model developed by Bybee (2006a) which shows inquiry to be made up of five stages: engagement, exploration, explanation, elaboration and evaluation. Park et al. (2009) developed five models of inquiry, they include: linear, non-linear, cyclical, multi-cyclical and mixed process.

As well as the varying definitions of inquiry, there are also four levels of inquiry which differ according to the extent of teacher/student-led instruction (Herron 1971). They are 1) Confirmation, 2) Structured Inquiry, 3) Guided Inquiry and 4) Open Inquiry and are teased out in Table 3.3:

Table 3.3: Outline of the four levels of inquiry as proposed by Herron (1971)

<table>
<thead>
<tr>
<th>LOW LEVEL INQUIRY Very Teacher Focused</th>
<th>Becoming Less Teacher Focused</th>
<th>Becoming Learner Focused</th>
<th>HIGH LEVEL INQUIRY Very Learner Focused</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Confirmation</strong></td>
<td><strong>Structured Inquiry</strong></td>
<td><strong>Guided Inquiry</strong></td>
<td><strong>Open Inquiry</strong></td>
</tr>
<tr>
<td>Question given by teacher</td>
<td>Question given by Teacher</td>
<td>Question given by Teacher</td>
<td>Question derived by Learner</td>
</tr>
<tr>
<td>Procedure given by teacher</td>
<td>Procedure given by Teacher</td>
<td>Procedure developed by Learner</td>
<td>Procedure derived by Learner</td>
</tr>
<tr>
<td>Outcome known in Advance</td>
<td>Outcome not known in Advance</td>
<td>Outcome derived by Learner</td>
<td>Outcome derived by Learner</td>
</tr>
</tbody>
</table>
The table shows a relative shift from a teacher-centred approach to a more learner-centred approach. A summary of each of the four levels of inquiry are described below.

**Level 1 Confirmation/Verification** - This level of inquiry is suitable for those who are beginners in learning science (Exline 2004). Students confirm an existing concept through questions and procedures that the teacher has given them. The results are known in advance. This view is contradictory to the description offered by Settlage and Southerland (2007) where they say that in level 1 of inquiry, the conclusions are not immediately obvious to the students during the activities but the teacher guides them to an expected outcome. Some researchers would argue that it is still inquiry in nature but is quite limited (Blanchard *et al.* 2010). Others consider that it resembles the cookbook approach to learning science and therefore should not be considered authentic scientific inquiry (Abrahams and Miller 2008).

**Level 2 Structured Inquiry** - Students investigate a question that has been given to them by the teacher through a known procedure prescribed to them. The results are not known in advance and the student is able to interpret the relationship between the results of the activity and the concept being investigated (Exline 2004).

**Level 3 Guided Inquiry** - Students investigate a question that the teacher has presented to them using their own procedure. With this level of inquiry, the student has the chance to be able to design and defend a procedure that will result in data which will validly resolve the question (Exline 2004).

**Level 4 Open Inquiry** - Students investigate questions that they have devised themselves based around the topic they are studying. They have the responsibility of defining a doable question, designing a procedure which allows one to collect, record and evaluate data and draw conclusions (Exline 2004). Open inquiry would most closely resemble the actions of “real” scientists (Colburn 2000a).

It is important to note that the optimal level of inquiry will vary with the type of classroom and the material to be taught (Blanchard *et al.* 2010). However the use of
inquiry should begin in the classroom on a more teacher-led basis, i.e. at a level of confirmation. There would be no educational advantage of going straight into high level inquiry (Bell et al. 2005).

3.3.3 Difficulties in Defining Scientific Inquiry

McDonald and Songer (2008) express the view that a certain ambiguity exists as to what defines classroom science inquiry. Teachers and researchers have historically referred to several teaching methods as being inquiry-based instruction, e.g. guided inquiry, open inquiry and structured inquiry (Coburn 2000a). In fact it is the assumption amongst researchers that different aspects of inquiry are understood by different people, ideas about inquiry are partly embedded in classroom practice and are partly collated by various community-wide dialogues (Windschitl 2004).

The difficulties in defining inquiry have been highlighted in a plethora of literature so much so that Anderson (2002) sought to identify the commonly identified usages of inquiry. He hoped that by doing so may lead to a defined agreement as to what inquiry is. Through a systematic review he concluded that there were three usages of the term inquiry; scientific inquiry, inquiry learning and inquiry teaching (Anderson 2002). Inquiry teaching would reflect instructional approaches which mirror aspects of scientific inquiry (Bybee 2004). Confusingly the first term, scientific inquiry, was devoid of educational processes and just referred to how scientists study the natural world while the latter two had educational orientations in their descriptions. Burgh and Nichols (2012) verified this perceived confusion by referring to the ambiguity over the differentiation between classroom science inquiry and the inquiry that takes place in the natural laboratory setting by scientists. Both allow for the social construction of understanding but the classroom setting is often devoid of complex reasoning and discussion of meaning (Chinn and Malhorta 2002). The difference between inquiry in a professional setting and classroom setting is conferred by Kirschner et al. (2006) when they make the distinction between teaching of a discipline as inquiry and teaching of a discipline by inquiry. The former refers to a “curricular emphasis on the research processes within a science”, while the latter refers to “using the research process of the discipline as a pedagogy for learning” (Kirschner et al. 2006, p. 78). It can be considered that the theory of inquiry is very
much related to the orientations of the teacher who believes in the curricular or pedagogical approaches to inquiry (Kirschner et al. 2010).

To decide if a process is inquiry-oriented, regardless of whether there is a curricular or pedagogical emphasis, the first question that needs to be asked is whether a research question has been developed (Bell et al. 2005). Having students simply read library or internet resources is not inquiry practice (Bell et al. 2005). However it is deemed to be inquiry practice if the student analyses data collected by the teacher or data available on the internet, so long as they have analysed the data themselves and in turn have answered the research question (Bell et al. 2005).

3.3.3.1 Definition of Scientific Inquiry referred to in this Research Study
The fundamental and common themes running through the definitions of inquiry relate to inquiry being a vehicle for learning science content and designing experiences and activities that result in developed knowledge and understanding of scientific ideas and concepts (Asay and Orgill 2010). This research study will be steered initially by the definition of inquiry invoked by the NRC (1996) which includes the following student-led features:

- Framing research questions
- Designing investigations
- Conducting investigations
- Collecting data and
- Drawing conclusions.

The reason why the author refers to this definition is for two reasons:

(1) Her epistemological belief that this presentation of inquiry is simplistic yet covers all the features of the inquiry process that mirror the action of a scientist.

(2) This definition has been referred to in many other studies on scientific inquiry (Campbell et al. 2010; Dudu and Vhurumuku 2012; Luft 2001).
Many researchers including DeBoer (2000) recognise that there is considerable agreement in the education community that science education should provide understanding, skills and values for young people to incorporate science in their everyday lives. However there is much debate on how to achieve this. In fact the transition from theory to practice has up to now proven unsuccessful (Wilson et al. 2010). The reason for this lies in the contestations around what inquiry looks like in actual classroom practice (Anderson 2002). Therefore while the propositional forms of theory about inquiry are importance, the author would agree with Whitehead’s living educational theory (1989). This theory invokes that the social actor, in this case the pre-service teacher, develops their own understanding of inquiry through their lived experiences.

3.3.4 Stages in Achieving Inquiry
The teacher is central to the implementation of authentic inquiry in the classroom with their practice serving as a necessary support to student learning as they engage in the inquiry process (Dudu and Vhurumuku 2012). One factor that Ruebush et al. (2009) deemed to be of particular importance when engaging students in any degree of scientific inquiry is the need for a pre-test prior to the inquiry-based activity in order to judge students’ prior knowledge and possible misconceptions. Ruebush et al. (2009) propose that the best way to learn about teaching authentic inquiry is to have the teachers themselves engage in inquiry exercises during their professional development. This is done to evaluate what possible errors, advantages and disadvantages they can envisage when teaching through inquiry.

Uno (1990) developed a number of steps that a teacher can take towards the teaching of inquiry in the classroom. They are as follows:

- Begin teaching a concept by showing students some natural phenomenon.
- Ask students to observe it and then speculate why the phenomenon happened or suggest its significance.
- Choose one question and develop a hypothesis based on the observations. Design an investigation to test the hypothesis.
• Allow students to conduct the investigation testing their hypothesis, or provide them with information about such a test.
• Analyse and discuss the data.
• Allow students to draw conclusions about the hypothesis and the nature of the phenomenon. Apply newly gained knowledge to new situations.

(Uno 1990, p.842)

The first step highlighted above, where it is recommended to show students some natural phenomenon, would, according to Hadzigeorgiou et al. (2010), foster students’ curiosity and their sense of wonder. This could be done through using something as culturally normal as watching a feature film which relates to the topic under consideration to promote interest and engage students in posing questions (Hadzigeorgiou et al. 2010).

Van Rens et al. (2010) focused their study on developing a framework for the teaching of authentic scientific inquiry by involving the teachers in the design of this framework. By involving the teachers, they are then challenged to think of inquiry-based approaches that aid student learning in the context of their own classroom environments (van Rens et al. 2010). The teachers in this study were required to design an inquiry framework on the particle theory and then enact it in the classroom. They were then asked to evaluate the framework. This in turn could create a theoretically and practically founded framework (van Rens et al. 2010) which could allow them to develop a living educational theory (Whitehead 1989) of inquiry. This particular study served as a professional development opportunity. The professional development of teachers towards the practice of scientific inquiry will be discussed further in section 3.5.2.

3.3.5 Initiatives to Promote Inquiry Practice

In 1999, there was an initiative put in place to include scientific inquiry as part of the chemistry examination program in the Netherlands (van Rens et al. 2010). The effect of this change to the examination program led to a number of teachers having to get advice from teacher educators as to how to teach through scientific inquiry (van Rens et al. 2010). In more recent times, the Fibonacci Project, which ended in 2013,
was a European wide project looking at the design, implementation, testing and formalising of a process to disseminate inquiry-based teaching and learning methods in both primary and post-primary schools. This project focused on the tutoring of teacher education institutions by expert institutions in science education to allow for the successful dissemination of inquiry-based techniques (Fibonacci Project Presentation Booklet 2010-2013). The Irish centre involved in this project was the Centre for the Advancement of Science and Mathematics Teaching and Learning (CASTeL). The broad aims of this project related to students developing awareness of the scientific aspects of the world around them through their use of critical thinking under the direction of the teacher (Fibonacci Project Presentation Booklet 2010-2013).

Ireland was also involved in the ESTABLISH project. ESTABLISH stands for European Science and Technology in Action: Building Links with Industry, Schools and Home. This FP7 funded EU project involved eleven countries working together on a four year project to encourage and promote an increased use of inquiry-based science education (IBSE) in second level schools. The uniqueness of this project lay in its rationale for creating authentic learning environments by bringing together and involving all relevant stake holders, i.e. industry, parents, policy makers, teachers and science education researchers (ESTABLISH presentation booklet 2013).

A project called TEMI (Teaching Enquiry with Mysteries Incorporated) is currently being run across several European partner institutions. This project focuses on the “engage” feature of Bybee’s five E model (Childs 2015). Another recent project which has been given funding under the FP7 framework is called the Chain Reactions project which is unique in the sense that role models (existing scientists) play an integral part in sharing their experiences with students in participating schools. This project works with teachers to design and disseminate inquiry-focused research briefs in the classroom and these teachers in turn aid the training of teachers in subsequent years (Chain Reaction Project Handbook 2013).

Despite these initiatives, Campbell et al. (2010) suggests inquiry is currently the exception rather than the norm and that there is a struggle to implement inquiry in
the classroom in America due to top down influence from the policy makers, whose emphasis is on measurement driven performance. Demir and Abell (2010) suggests that there is a need to move away from a deregulation agenda, where subject matter knowledge and teachers’ verbal abilities are the dominant factors in determining teaching ability, to a professionalization agenda, where reform-minded teaching is focused on science subject matter knowledge and pedagogical knowledge (Demir and Abell 2010).

Smolleck and Yoder (2008) identify a possible reason for the lack of implementation of inquiry in the classroom as being the low self-efficacy levels of teachers in relation to how well they would be able to integrate inquiry into the learning process of the students. Smolleck and Yoder (2008) suggest that the reason why teachers have low self-efficacy levels when teaching through inquiry is due to the fact that they have little prior experience with teaching and learning through inquiry. This is intimately linked with their PCK and was discussed in section 3.2.2.

Additionally, Chinn and Malhorta (2002) found from their studies that there was little resemblance in classroom practice to the authentic inquiry process practiced by scientists. Therefore while the students may have experienced some degree of inquiry, the features of inquiry which encapsulate the work of a scientist are not being observed (Chinn and Malhorts 2002). The challenges towards implementing inquiry will be discussed in section 3.3.7.

3.3.6 Research Vindicating the Use of Scientific Inquiry
As Campbell et al. (2010) highlight, research is now active into the impact of inquiry increasing students’ understanding, interest and attitudes of science. Anderson (2002) summarises the findings in the literature to suggest that, generally speaking, inquiry teaching produces positive learning outcomes. Relevant studies will now be presented.

**Improving Student Attitudes**
Crawford (2000) undertook a yearlong observational activity whereby she reviewed the teaching of a particular teacher who claimed to teach through inquiry. During this
time Crawford (2000) attempted to understand students’ attitudes towards learning science in this manner. She found that the authentic nature of the inquiry projects which they engaged in throughout the year motivated the students and made them consider the importance of doing science in this way for future college studies. Students revealed the respect they had for their teacher because he viewed them as necessary contributors to the classroom “research team” (Crawford 2000). Some students felt however that the teacher’s high expectations of them had a negative impact but the majority of the students valued the rigor expected of them (Crawford 2000). Another study by Rees et al. (2013) found that when using a supportive framework during an open inquiry activity, students were highly engaged in the task.

**Increasing Achievement Levels**

On the back of the contrasting results in the literature, Mao and Chang (1998) investigated the effect of inquiry-oriented instruction on the achievement of students towards Earth science using a comparative studies method. The results showed that students who were taught by inquiry scored significantly higher than those taught by the traditional method. Wilson et al. (2010) undertook a more recent study which looked at two groups of students both of whom had the same learning outcomes to achieve. One group were taught through inquiry-based instruction and the other group through the traditional, common, didactic styles of teaching. The results of this study showed that there were significantly higher achievement levels for students who were subject to the inquiry-based approach both straight after instruction and four weeks post-instruction (Wilson et al. 2010). Smolleck and Yoder (2008) suggest that better learning outcomes result because inquiry leads to higher order thinking.

Blanchard et al. (2010) also engaged in research where they not only determined the effectiveness of inquiry-based instruction over traditional didactic instruction but they also revealed in their study that participants who engaged in inquiry-based learning activities had higher retention rates than the other students. They do acknowledge however that it is dependent on the level of inquiry. They found that when taught through a guided inquiry approach, there was shown to be stronger understanding by students than if taught by the confirmation/verification level of inquiry (Blanchard et al. 2010).
Perhaps one study that epitomises research into the effectiveness of inquiry instruction lies with Colburn (2000b). He undertook a comprehensive literature review of the studies which demonstrated increased student learning from an inquiry-based approach from the 1960’s to the 1990’s. Colburn found that inquiry instruction is equal to or superior to traditional instructional strategies in aiding students’ achievement levels. Brickman et al. (2009) found that confidence levels of students in terms of their use of scientific literacy increased when they were taught through inquiry over the traditional approach. Their process skills also improved during investigations reflective of the scientific inquiry approach (Brickman et al. 2009).

**Increasing Student Interest**
Palmer (2009) undertook a study with the objective of uncovering whether or not student interest levels increased during an inquiry skills lesson. His primary objective was to understand teaching strategies which could enhance student motivation. Palmer (2009) focused on short term interest, situational interest, which is defined as interest present as a result of a specific situation. Research has concentrated on this type of interest as it centres on classroom events and their immediate impact on students, as opposed to personal interest (Palmer 2009). The latter type of interest is difficult in lesson planning as it is near impossible to consider all students personal interests when planning a lesson (Palmer 2009). Palmer (2009) found that their situational interest was apparent during inquiry-based activities but that it did fluctuate with the type of activity students were engaged in. He found that one of the main sources of interest was the novelty factor of doing something different. He also found that giving students a choice in terms of how they approached solving a problem increased interest levels. Other factors which influenced their interest levels were (1) that they were learning and (2) they were engaged in social interactions as they learned (Palmer 2009).

**3.3.6.1 Justification for Using Inquiry as a Pedagogical Focus**
The previous section has outlined the considered benefits of engaging students in the scientific inquiry process from personal benefits (increased situational learning) to
academic benefits (enhanced understanding and increased achievement levels). Recognition needs to be given to additional teaching strategies that can be part of a teacher’s pedagogical repertoire. Inquiry does not have to take place in every lesson as not every worthwhile activity is inquiry-based (Bell et al. 2005). It is more successful when combined with the necessary instruction that is typical in a classroom setting (Barron and Darling-Hammond 2008).

There are many other approaches that have a high effect size in regards to student learning, for example the use of jigsaw, reciprocal reading, snowballing etc. (Petty 2009). Similar to inquiry, all of these strategies involve co-operative learning between students and they all relate to students uncovering new knowledge themselves (Petty 2009). The reason why scientific inquiry has been the focus of this study is that the approach mirrors the scientific process in the real-world setting and facilitates in the students developing a more philosophical understanding of the nature of the scientific process in the real-world (Abd-el-Kalick et al. 2004). Hence at a time where policy-makers are trying to reflect science in society, how students learn science needs to mirror how science operates in society (Driver et al. 1994).

3.3.7 Challenges to and Contestations for using Scientific Inquiry in Practice

The embedding of scientific inquiry into classroom practice continues to be a source of concern for all parties involved, be it practitioners, researchers etc. Despite the attention given to creating a greater awareness of inquiry-based practice, the traditional didactic approaches with the occasional verification style laboratory experiment is still very much the norm internationally (Abd-el-Kalick et al. 2004). It can be suggested that this is due to certain challenges and contestations around using scientific inquiry.

Contestations towards using Scientific Inquiry

Research does exist which revokes the practice of scientific inquiry. For example, Mao and Chang (1998) state that comparative data on the efficiency of inquiry instruction versus the traditional instruction are conflicting. Their research led them to conclude that students who engaged in inquiry had more positive attitudes towards Earth science at a participatory and confidence level. However they found that there
were no significant differences in interest levels between students who learned via the inquiry method and those who learned through the traditional method (Mao and Chang 1998).

Kirschner et al. (2006) argue that instructional strategies that have minimal guidance from the teacher and therefore ignore the limits of the working memory are unlikely to be effective. They also suggest that there is no evidence to suggest that presenting learners with partial information enhances their ability to learn more than if they have been given full information (Kirschner et al. 2006). As well as that Johnston (2008) emphasises that there may not be enough evidence currently to support the usefulness of inquiry solely for the purpose of refining student achievement on standardized measures. Other studies such as that carried out by Brickman et al. (2009) reveal that students actually resented activities that were inquiry-oriented because of the increased workload which they had to do in terms of engaging in critical thinking. This enhanced experience in critical thinking is not something that they necessary engage in when experiencing traditional didactic methods. Klahr and Nigam (2004) also show opposition to the use of discovery learning, which similar to scientific inquiry, models the constructivist approach to learning.

It is important to note that Blanchard et al. (2010) examined the studies undertaken by Klahr and Nigam (2004) and Kirschner et al. (2006) and concluded that the discovery approach of Klahr and Nigam (2004) and the inquiry approach used by Kirschner et al. (2006) resembled open inquiry. Students need to have prior experiences of learning through inquiry to engage in open inquiry (Abrams et al. 2007).

**Challenges towards using Scientific Inquiry**

Table 3.4 summarises some of the key challenges identified in the literature which may help to illuminate possible reasons for its limited practice in the classroom.
Table 3.4 Challenges to implementing inquiry

<table>
<thead>
<tr>
<th>Literature Source</th>
<th>Challenge</th>
</tr>
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<tbody>
<tr>
<td>Darling-Hammond (2008)</td>
<td>Controversy whether the practice can be effective in developing students’ basic knowledge.</td>
</tr>
<tr>
<td>Asay and Orgill (2010)</td>
<td>• Fear of loss of control in the classroom</td>
</tr>
<tr>
<td></td>
<td>• Ability of students</td>
</tr>
<tr>
<td></td>
<td>• Time constraints</td>
</tr>
<tr>
<td></td>
<td>• Missing features of scientific inquiry in practice</td>
</tr>
<tr>
<td>Fazio et al. (2010)</td>
<td>Time constraints (identified by PSTs).</td>
</tr>
<tr>
<td>Ruebush et al. (2009)</td>
<td>Teaching students of mixed ability-increasing diversity of the student population.</td>
</tr>
<tr>
<td>Crawford (1997); Kazempour (2009); Ruebush et al. (2009); Bell et al. (2005)</td>
<td>Lack of operational models/mentors to refer to.</td>
</tr>
<tr>
<td>Crawford (2000)</td>
<td>PSTs’ apprenticeship of observation.</td>
</tr>
<tr>
<td>Zion et al. (2004)</td>
<td>Students misunderstanding in regards to the essence of inquiry.</td>
</tr>
<tr>
<td>Blanchard et al. (2010); Darling-Hammond (2008)</td>
<td>Teachers’ attitudes: perception that inquiry does not lead to higher test scores. There is a perception of doing for the sake of doing rather than for the sake of deeper learning outcomes.</td>
</tr>
<tr>
<td></td>
<td>Teacher certification.</td>
</tr>
<tr>
<td>Hofstein (1986)</td>
<td>Students’ attitudes: does not increase motivation.</td>
</tr>
</tbody>
</table>

The above challenges are varied and reflect concerns affecting both teachers and students. It can be argued that these challenges are exacerbated when concerned with PSTs practice due in part to their low level PCK (Faikhamta et al. 2009) and limited
classroom teaching experience (Gess-Newsome and Lederman 1999). The expectations of PSTs to teach through scientific inquiry will be discussed next.

3.3.8 Expectations of PSTs to Teach through Scientific Inquiry

Much of the literature argues the difficulties experienced by PSTs in trying to develop an inquiry dimension to their teaching. This is in part due to the varied teaching and learning experiences which PSTs had prior to entering their ITE (Crawford 1999). As well as this, some ITE centres may not have a coherent focus on the development of inquiry orientations. An example comes from universities in the USA and Turkey where Cakiroglu et al. (2005) identify scientific inquiry as having three credit hours in the USA but no credit hours in Turkey.

Many PSTs have difficulty with improvisation (Crawford 1999) therefore they struggle to think “on the spot” and during inquiry-based activities, such thinking is necessary. Crawford (1999) identified a number of supports and constraints which can determine a PST’s ability to design and carry out inquiry-driven instruction. The supports identified included a) prior research experience b) volunteering in project-oriented classrooms c) having a clear vision of learning goals d) developing a trusting relationship with their co-operating teacher e) collaborating with experts outside the classroom and f) consistent and thought evoking reflection on their practice. The constraints identified by Crawford (1999) included a) limited experience in dealing with group-work b) difficulty in giving clarity to unfamiliar vocabulary c) inexperience of supporting students whose thought processes are going off in different directions and d) misjudging students’ prior skills.

All of these supports and constraints, it is argued, would be related to PSTs’ PCK level. Indeed research has suggested that if PSTs are taught through inquiry-based methods in their ITE, this can enhance their PCK (Nuanghalerm 2012). Teachers need to be given the skills and knowledge to challenge traditional pedagogy (Nuanghalerm 2011, cited in Nuanghalerm 2012). Therefore the induction into the necessary skills and knowledge should be considered in ITE (Shulman 1986), teacher education programmes need to support PCK and in turn support the practice of scientific inquiry.
3.3.8.1 Attitudes of PSTs to Scientific Inquiry

Because of the potential that practical work has on student learning, science teacher educators should encourage PSTs to understand the nature of practical work and ways of developing strategies to include it in their classroom teaching (Kim and Tan 2011). According to Crawford (2007) however, PSTs start out with attitudes that act as a barrier towards them developing and enacting inquiry orientations. Such attitudes can be linked to their orientations towards science teaching (Boesdorfer and Lorsbach 2014). Indeed Crawford (2007) sees the personal beliefs about teaching (orientations) as the “most critical factor influencing a prospective teacher’s intentions and abilities to teach science as inquiry”, (Crawford 2007, p.636). With this in mind Crawford (2007) found from her study that some PSTs viewed inquiry-based instruction as being inappropriate in the classroom and not possible in the school culture they were a part of. Lotter et al. (2007) suggests there to be four core components to a teacher’s belief system which indicate dispositions of a teacher towards the practice of scientific inquiry. If a teacher has a positive disposition towards scientific inquiry they will

a) See science as a process where students find out more about the world.
b) Believe that the goal of education is to help develop problem solving skills in students.
c) Believe that effective teaching is in itself a chance to provide students with the opportunity to engage in independent thinking.
d) Recognise that students have the ability to think and solve problems for themselves.

(Lotter et al. 2007)

Hubbard and Abell (2005) looked at the attitudes of two groups of PSTs, with one group involved in an inquiry preparation module. PSTs who did not experience the inquiry preparation module maintained their belief that science should be fun and the teacher is the teller and the fun-maker while PSTs who did undertake the inquiry preparation course began to revise their pre-existing beliefs towards inquiry. A study conducted by Rees et al. (2013) found that PSTs did see the value in using inquiry if they had an adequate support framework in place to approach inquiry in the classroom. This support framework involved the assistance of co-operating teachers.
who taught using an inquiry approach. PSTs revealed that such a framework helped them feel more organised and it gave them more guidance (Rees et al. 2013).

Co-operating teachers can also have an inhibiting effect on PSTs’ practice of scientific inquiry. In the study conducted by Crawford (2007) she found that when co-operating teachers conducted a class with structured, lecture style approaches to teaching, the PSTs rarely attempted an inquiry-led lesson. One of the possible reasons for this was the lack of PSTs’ understandings of how to enact inquiry in the classroom. The attitude of co-operating teachers towards inquiry could also influence the PSTs’ enactment of inquiry in the classroom (Crawford 2007).

3.3.9 The Association between Scientific Inquiry and PCK

In order to help students develop a deeper understanding of specific scientific concepts, it is necessary for teachers to move from traditional didactic instructional strategies, towards a more student-centred instructional orientation (Inoue 2009). Central to this is the process of students making sense of the concept and for this to happen students need to be guided by the teacher (Inoue 2009). What is necessary for effective explanations of scientific concepts is not only the degree of content knowledge but also how teachers present this content knowledge in a pedagogically meaningful way (Inoue 2009), in other words their PCK. Reflecting on the defining feature of a teacher’s PCK is their ability to make the material comprehensible to students (Shulman 1986) through an amalgamated knowledge of content and how to teach that particular content (Loughran et al. 2006). Therefore the author argues that scientific inquiry as a process which influences the students understanding of material is closely aligned with the theoretical construct of PCK.

There is some association in the literature between inquiry and PCK. Jordan-Spang (2008) focused her theoretical framework on novice teachers’ understandings and use of scientific inquiry around the PCK model developed by Magnusson et al. (1999). Indeed David and Krajcik (2005) coined the term pedagogical content knowledge for scientific inquiry and expanded the conceptualisation of PCK brought forward by Magnusson et al. (1999) to include (1) knowledge of the orientations of scientific inquiry (2) understanding of the instructional strategies and tools for
supporting inquiry (3) knowledge of children’s understandings and misunderstandings associated with inquiry (4) knowledge of appropriate curriculum for inquiry and (5) knowledge of assessment techniques for inquiry.

Other researchers have also placed association between scientific inquiry and PCK for their own research endeavours (Espinosa-Bueno et al. 2011; Davis and Krajcik, 2005; Park et al. 2011; de Jong and van Der Valk, 2007). It is also suggested that low levels of PCK are attributed to low confidence levels which therefore lead to more restricted and controlled forms of teaching (Varley et al. 2008a). In that regard, a PCK tool which captures and develops PCK is an appropriate research lens to explore inquiry orientations.

Schuster et al. (2007) focused their studies on developing an assessment instrument to support the training of elementary PSTs to teach science as inquiry using PCK as their theoretical framework. Scarlett (2008) focused his study on how an inquiry-based professional development programme influenced teachers’ perceptions of their PCK. Wongsopawiro (2012) embraced scientific inquiry within PCK as part of the theoretical framework guiding his study focused on creating a professional development programme. He particularly targeted a teacher’s orientations towards science teaching and how this related to their level of inquiry-based instructional knowledge. The notion of a teacher’s orientation towards science teaching is central to understanding one’s PCK and the relationship between their knowledge, beliefs and practice (Abell 2007). If a teacher’s orientations towards science teaching are grounded in constructivism then emphasis will be given to approaches such as scientific inquiry in the classroom. In other words they will use approaches like inquiry to support their beliefs (Jones and Carter 2007). How receptive a teacher is towards using inquiry-based instruction can be heavily influenced by the teacher’s core teaching conceptions which include their views of science, the purpose of education and effective teaching strategies (Lotter et al. 2007; Roehrig and Luft 2004). However the relationship between knowledge, beliefs and practices is often viewed as a messy construct (Pajares 1992). With this in mind, Nargund-Joshi and Liu (2013) focused their study on the association between a teacher’s orientations
towards science teaching and their practice of scientific inquiry and held the belief that a teacher’s orientation was a central component of their PCK.

It must be noted that a constructivist approach to teaching is not without its limitations. It is more time consuming and requires a higher demand of learners (Snowman and Biehler 2006). It should be mixed with other orientations to learning which extend into the teacher’s knowledge of presenting the material to make it comprehensible to others, which is the essence of PCK. It is necessary to add however that PCK is not the only knowledge type needed to implement inquiry practices. Both content knowledge and pedagogical knowledge individually (Englehart 2008) are required however a teacher’s decision to implement inquiry practices in the classroom is ultimately decided upon by their PCK (Englehart 2008; Vail Lowery 2002). Indeed Li and Xiong (2012) consider that PCK is the face of scientific inquiry. The reason for this relates to the fact that PCK is the knowledge of effective instructional strategies pertinent to specific content areas (Schuster et al. 2007). This includes an understanding of inquiry as an approach to the teaching and learning of science (Vail Lowery 2002).

In order to facilitate PSTs in developing orientations towards scientific inquiry within their PCK, there is a need to focus on their professional growth within ITE. The next section will discuss the professional development of PSTs towards the practice of scientific inquiry.

3.4 The Professional Development of PSTs

The preparation of science teachers is necessary for the future of science education (van Driel et al. 2001). Therefore, as Nilsson (2008) expresses, teacher education programmes need to be targeted at meeting student teachers desired needs in order to translate their required knowledge into successful classroom practice. Loughran et al. (2008) concede however that those who are responsible for educating our future teachers face a difficult task. According to Shulman (1986), a central question around teacher education lies with the concern of the transition from expert students to novice teachers.
The key issue that needs to be addressed in pre-service teacher education, according to Inoue (2009), is how to free PSTs from past learning experiences, many of which would create beliefs about learning that are problematic. These past learning experiences can be summarised as their apprenticeship of observation (Lortie 1975) where they have spent much time in the classroom, soaking up the pedagogical approaches that their own teachers have used. Freeing them from past learning experiences could help develop pedagogically meaningful explanations that result from a profound content knowledge (Korthagen 2010). It could allow them to construct theories (Korthagen 2010) focused on developing students’ conceptual understanding. As a reminder Korthagen developed a model reflective of how a teacher’s decision-making was based on an intricate system whereby teachers’ experiences could lead to their formation of a theory related to teaching and learning. This system can best be described in the below level reduction model (Figure 3.5) which helps to frame the relationship between theory and practice (Korthagen 2010).

![Figure 3.5 Gestalt-Schema-Theory model](image)

This model signals the process of learning which lead to a teacher making decisions within the classroom (Korthagen 2010). PSTs’ experiences are based initially on their apprenticeship of observation and the focus of ITE should be on freeing them from past learning experiences (Inoue 2009) centred on prescribed, didactic approaches to teaching and learning. However Korthagen (2010) recognises that there is a gap between the theory and practice in teacher education, which can invariable affect the PSTs’ professional formation. The above model is considered to be a realistic approach to teacher education if the focus within the learning process is on
developing pedagogies grounded in theory related to best practices for student outcomes (Korthagen 2010). This model aims to support a bottom-up process starting from past experiences, leading to fruitful knowledge about teaching (Korthagen 2010).

However many PSTs have preconceived notions about teaching and about what they need to learn about teaching (Pajares 1992) and often tend to underestimate the cognitive aspects of teaching (Loughran et al. 2008). This is verified by Hume and Berry (2011) who argue that PSTs come into teaching with wide and varied experiences and opinions about what the profession is and what teaching involves. Then upon entering teacher education programmes, they are concerned with trying to learn how to teach in an expedited manner (Loughran et al. 2008) without developing a deep conceptual awareness (theory) of what real learning involves. Furthermore, many PSTs are unaware of the fact that pedagogical reasoning and action are supported by a multifaceted knowledge base that experienced teachers utilise (Hume and Berry 2011). This view is supported by Roychoudhury and Rice (2013) who see teacher education programmes largely focusing on the learning of content knowledge as opposed to the multiple facets that need to make up teachers’ knowledge. This is seen to be more problematic in the concurrent model of teacher education where content knowledge is central to the teacher training (Musset 2010). In contrast within the consecutive model the association between learning the content and the pedagogical approaches is fragmented (Musset 2010).

Regardless of which model of teacher education, research indicates that many PSTs lack a deep conceptual understanding of science and their particular science concepts are often fragmented and disorganised or confused (Loughran et al. 2008). This results in PSTs focusing on delivering facts and not addressing key ideas that their students need for understanding science (Gess-Newsome 1999). Coupled with all these barriers, Loughran et al. (2008) identify the issue of PSTs adapting the practice of in-service teachers who inadvertently may “reinforce preconceptions of teaching as routines to learn and perform”, (p.1303). As well as this, the lack of critical reflection in which in-service science teachers engage in may result in them being unable to reinforce to PSTs the “what and why” in their teaching (Loughran et al. 2008).
This idea of understanding the “what and why” of teaching is crucial in gaining an appreciation for the complexities of teaching and is the essence of a teacher’s PCK.

There have been a number of studies which have looked at PSTs’ professional development from varying focal points. For example, Isikoglu (2007) focused on three professional development themes (1) evaluation (2) problem-solving and (3) consciousness, all made visible through the use of reflection. Arnold et al. (2009) focused on professional development in relation to ICT. Beck et al. (2005) looked at the effect of self-assessment on PSTs’ professional development. Others have studied the effect of classroom culture on PSTs’ professional development (Altun 2013). Mavhunga (2014) suggests that developing PCK and in turn a teacher’s professional development is a journey whereby the PST needs to seek development and display endurance in the early years of their teaching experience.

These studies all emphasise the importance of developing a culture of professional development and this should start with PSTs. Showalter suggests that “for a teacher to grow professionally and become a better teacher of science, a special, continuous effort is required” (Showalter 1984, p. 21). What is being proposed here is that the learning does not stop once a teacher has received their initial education and training; it is a continuous process throughout their careers (NRC 1996).

3.4.1 Scientific Inquiry and Professional Development (PD)

There can be a significant increase in students’ learning gains once teachers are given strong professional development (Darling-Hammond 2008). This section therefore focuses on professional development towards the practice of scientific inquiry in the classroom.

Many professional development experiences are not successful, according to Kazempour (2009), due in part to the approach taken which is often in the form of lecture style delivery of information as opposed to actively involving the participating teachers in the process. Kazempour (2009) encourages the use of a learning cycle when engaging in professional development where teachers provide
critical reflections on their developing awareness and practices. Professional development towards the use of inquiry should model the inquiry process in an active, collaborative setting (Kazempour 2009). By engaging in appropriate inquiry-based professional development, a teacher can experience changes in their conceptions of teaching and learning (Kazempour 2009). He considers that a teacher’s conception of students, effective teaching, the purpose of learning and science can all change to some degree over a professional development experience.

Johnson (2006) focused her study on profession development of teachers towards the use of inquiry-oriented practices in two middle schools in America. Johnson (2006) specifically looked at the barriers that science teachers encountered when implementing these practices. The findings of her study showed that even if effective professional development does occur, science teachers still encounter barriers be it technical, political or cultural (Johnson 2006). Technical barriers would refer to content knowledge, pedagogical knowledge and a teacher’s own ability to teach constructively and implement reform (Johnson 2006). The results of the study showed the political barriers were the ones that teachers found to be most difficult to control (Johnson 2006). Johnson (2006) also found that it tended to be veteran teachers who did not buy into the use of inquiry-based instruction. She concluded that more support is required for professional development efforts to succeed (Johnson 2006). However the best intended professional development efforts do not address existing beliefs of teachers (Johnson 2006).

Bell and Gilbert (1996) developed a model around science teacher development and emphasised there being three components within this model. The first component is personal development which aligns to the fact that teachers must recognise their need for professional development and must have the desire to want to gain new understandings in terms of new ideas and strategies (Bell and Gilbert 1996). The next component is referred to as the social component which relates to the teachers having the opportunity to discuss ideas with other teachers and to engage in discourse around what it means to teach science and be a teacher of science, in a sense the holistic nature of science teaching (Bell and Gilbert 1996). This gives attention to the use of professional learning communities which will be discussed in
due course. The third and final component is professional development in which teachers are supported in implementing the new ideas and strategies in their class. These components, according to Akerson and Hanuscin (2007), would be key to effective change by teachers in their classrooms.

3.4.1.1 PSTs’ Professional Development towards Scientific Inquiry

Windschitl (2004) assumed that one way to influence PSTs’ eventual enactment of inquiry was to first of all understand how educational and cultural experiences moulded their thinking about scientific inquiry. They also need to have authentic inquiry experiences in their undergraduate experience (Windschitl 2004). In order to educate PSTs towards the use of inquiry, it is necessary to have a research-based approach in ITE (Byman et al. 2009).

Putting Theory into Practice

Some literature suggests the importance of teaching practicum to PSTs’ emerging views and practices of inquiry-based science approaches (Fazio et al. 2010). They found that having an explicit and reflective approach to doing inquiry-based science during teaching practicum can help strengthen teachers’ perceptions of it (Fazio et al. 2010).

The practice of scientific inquiry in the classroom after theoretical-based professional development is also critical. Indeed the issue of bridging the gap between what is learned in a professional development course and what is enacted in the classroom is identified by Smithenry (2010). He found that teachers modify their enactment of inquiry when in real classroom situations to such an extent that researchers did not recognise the practice as authentic inquiry (Smithenry 2010). The reason for this was due to the nature of the courses which did not provide teachers with the knowledge of how to go back into the classroom and integrate inquiry into their current curriculum framework (Smithenry 2010). Kanter and Konstantenopolis (2010) stipulate that teachers are often left alone to apply what they have learned in the professional development course to their own practice, away from the support of the professional development setting.
3.4.2 Factors influencing Professional Development (PD)

Two factors that can lead to professional development have been highlighted in the literature. The first is the importance of reflection in promoting deep change. The second factor is the community of practice element where Fullan (2001) argues that if teachers are going to listen to anyone else, it will be other teachers.

3.4.2.1 Reflective Practice in facilitating Professional Development

There has been strong support recently for the mechanism of reflective practice in the accomplishment of effective teachers (Barrett and Green 2009). Indeed the reason for this could stem from the fact that “it rings true for most people as something useful and informing” (Loughran 2002 p. 33). Reflection is at the centre of being a professional (Hargreaves and Goodson 1996) and is key to the generation of a theory around teaching and learning (Korthagen 2010).

The importance of reflection is also considered in developing a teacher’s PCK with Cochran et al. (1993) suggesting that:

“The construction of pedagogical content knowledge results from multiple opportunities to teach, and to observe and to reflect on one’s own teaching and that of others in a content area”

(Cochran et al. 1993 p. 16)

In fact, Koh et al. (2010) propose that knowledge from critical reflection was one of the constructs of PCK. Park and Oliver (2008a) from their studies concluded that PCK can be developed through two types of reflection, reflection in action and reflection of action and that the most powerful changes can occur through experiences in practice. Through the process of reflection, teachers will be able to transform their knowledge from inert learners into active classroom practitioners that continually evolve as they encounter new situations and reconsider past practices in light of more recent practices (Barrett and Green 2009). Every teacher is part of the context in which learning takes place, therefore in order for teachers to create a better understanding and develop their PCK, they must reflect on their own practice (Barrett and Green 2009).
Reflection is a necessary practice that needs to be experienced by both pre-service and in-service teachers during professional development endeavours. So much so that Nilsson (2008) focused her studies on how PSTs could build on different knowledge bases through the use of reflection in their work and in doing so develop PCK. Sutherland et al. (2010) suggests that the importance of reflection to the continued professional development of PSTs is well recognised within the education community. However prevailing systems for preparing and accrediting teachers remain (Barrett and Green 2009).

For PSTs the process of reflection allows them to create their own self-image (Sunderland et al. 2010). Through development of their own self-image, PSTs are closer to creating their own professional identity (Sutherland et al. 2010). Whitehead (1989) argues for the concept of the living educational theory of professional practice where individuals asked themselves “how can I improve my practice?” and this essentially is a reflective process where the individual is inquiring into their practice. Indeed reflection is also viewed within Korthagen’s three level model (see section 3.5.1) as being the key to teachers developing a theory around teaching and learning. Therefore it can be argued that PSTs through engaging in active learning processes focused on level reduction from the development of their gestalt, through to their development of a schema (both with the focus on reflection) can lead to a living educational theory of inquiry.

In this current study this theorisation will be achieved using the CoRe as a scaffold within a professional learning community, the latter of which will now be described.

3.4.2.2 Professional Learning Communities in Facilitating Professional Development

Van Driel and Berry (2012) argue with the need to focus on collaborative interactions within professional development, in other words the use of a professional learning community (PLC). A PLC constitutes a group of people sharing and critically interrogating their practice in an ongoing, reflective, collaborative, inclusive, learning-oriented and growth-promoting way (McRel 2003). Others argue that such a community of practice is a way of doing, way of talking, the
beliefs, values and power relations that come from a mutual endeavour (Eckert and McConnell-Ginet 1992).

Bausmith and Barry (2011) and the NRC (1996) suggest that recognition needs to be given to the importance of PCK as a focus of PLCs. Indeed Dogan et al. (2015) suggests that PLCs can help increase teachers’ PCK by collaboratively focusing on student learning within the learning communities. The opposite tends to be the norm where teacher communities can ignore the importance of teaching and learning (van Driel and Berry 2012) and therefore ignore the importance of PCK in facilitating teaching and learning. Using a PCK lens to facilitate the professional development of teachers within a PLC is justified as both the construct of PCK and the goal of professional development reflect ways of enhancing student learning.

A number of studies have highlighted the use of PLCs in facilitating a discourse around the development of scientific inquiry orientations. Lewis et al. (2014) found that through active discourse within a PLC, teachers affected change in their classroom towards inquiry-based practices. They also found that the longer teachers engaged in these learning communities, the more diverse inquiry-oriented practices filtered into the classroom (Lewis et al. 2014). Kim et al. (2012) used an online PLC to promote early career teachers understanding and practice of scientific inquiry by having practising scientists recruited with the PLC. Having a scientist involved can allow for the developing understanding of authentic scientific inquiry (Kim et al. 2012). Dohan et al. (2015) reviewed the empirical literature regarding PLCs and found that as a result of their involvement in PLCs, teachers shift towards more student-centred approaches, such as scientific inquiry. A teacher’s knowledge base needs to be at the centre of a PLC with Crawford (2000) suggesting that a focus on a teacher’s knowledge base is fundamental in implementing inquiry in the classroom. Therefore it can be argued that if PCK is part of the focus within a PLC, then authentic changes in teacher practice towards inquiry can be achieved (Kim et al. 2012).

However, as mentioned previously, a factor which influences the enactment of inquiry in the classroom is the self-efficacy of a teacher to teach through inquiry.
According to Klassen and Chiu (2011), self-efficacy refers to the beliefs that teachers hold about their capabilities to influence the learning of students. A person’s self-efficacy is thought to be an important influence on human achievement in a variety of settings, from the sports field to the classroom (Bandura 1977). Bandura (1977) defined self-efficacy as consisting of two parts, an individual’s belief about action and outcome and an individual’s belief about how well they would be able to carry out a task.

From their studies, Cakiroglu et al. (2005) found that the self-efficacy of teachers can differ substantially between PSTs in different cultural contexts. While there is no literature on the self-efficacy of Irish PSTs, the TALIS Report developed by Shiel et al. (2009) highlighted the fact that the majority of in-service teachers in Ireland, compared to other countries researched, had a particularly low self-efficacy level. A study by Klassen and Chiu (2011) noted that pre-service and in-service teachers had the same level of self-efficacy. Can this be generalised across different cultural contexts? Cakiroglu et al. (2005) suggest that teachers who have higher self-efficacy levels will be more inclined to use inquiry-based student-led teaching strategies with the opposite (using didactic approaches) being the more likely case if teachers have low self-efficacy. Engaging in a PLC can facilitate a teacher’s changing self-efficacy (Mintzes et al. 2013).

A learning community is by its very nature concerned with and committed to the learning of each student (duFour et al. 2010) and is a powerful vehicle for synergy and the creation of an environment in which change is possible (Crawford 2007). Despite this assertion, there is limited reference to the use of PLCs in facilitating PSTs’ professional development (Sim 2006). The importance given to collaboration cannot be ignored when one focuses on the past experiences of those involved in PLCs (Sugrue 1996). To that end, a PLC allows the conglomeration between people of varying experiences, whether they are pre-service or in-service teachers. It can be considered that CoRes can be created through the use of an organic PLC (Lehane et al. 2013) and experiences, values and understanding can be articulated through the construction of the CoRe (Loughran et al. 2006) within the learning community. Key to a successful PLC are the interactions which take place within it (Spradley 2008) and to that end symbolic interactionism will now be discussed.
3.4.2.3 Symbolic Interactionism within a Professional Learning Community

The interactions with the PLC and how PSTs make sense of meaning is aligned with the theory of symbolic interactionism. Symbolic interactionism was coined by Herbert Blumer in 1937 as a theoretical and methodological approach to the study of social phenomenon (Blumer 2004). It is grounded on the principles of human behaviour within an interacting environment, the construction of “self” and the perception of reality (Bodner and Orgill 2007). Garvin (2011) conceptualises symbolic interactionism as a theoretical lens used to examine the interactions between people within a specific social situation. In all, it is concerned with the construction of shared meaning through social interaction (Bodner and Orgill 2007), in this study within a PLC.

The term symbolic reflects the idea that we communicate through language that is symbolic of our understanding and knowledge of the world (Bodner and Orgill 2007). Interactionism, both visually or orally, places emphasis on the role of social interactions in the construction of knowledge (Bodner and Orgill 2007) and therefore is intimately linked with social constructionism (see section 4.2).

There have been a number of studies reported in the literature which focus on investigating the symbolic interactions of participants within a PLC. Garvin (2011) explored the dialogue within a PLC and determined that the symbolic interactionism between the teachers involved in the PLC facilitated their professional development. Ford and Vaughn (2011) used symbolic interactionism to analyse how students’ self-perceptions evolved in the context of a PLC. Gohn (2004) studied how teachers interact with each other within a PLC, specifically looking at their behaviour within the PLC.

Studies in pre-service teacher education that used symbolic interactionism have historically examined either the PSTs’ teaching experience or events within the methods course (Bodner and Orgill 2007). PSTs’ beliefs and how these beliefs shape their actions have also been studied (Bodner and Orgill 2007). Looking back on Magnusson’s et al. conceptualisation of PCK, the teachers’ orientations towards
science teaching (their beliefs) shape their actions so it can be suggested that symbolic interactionism is appropriately placed to look at teachers’ PCK.

A limitation lies in the fact that symbolic interactionism ignores socioeconomic categories and class/social structure (Archibald 2014). However some concepts associated with interactionism, i.e. social constructionism, connect individual behaviour with micro level societal structures (LaRossa and Reitzes 1993) as was the case with the PLC in the current study. Another limitation is that symbolic interactionism can often exclude developing a holistic account of human behaviour as it focuses on the nature of social interaction (Benzies and Allen). However using the CoRes which capture a holistic understanding of teacher knowledge (Loughran et al. 2006) can help alleviate such weakness in the research.

3.4.3 Challenges to Effective Professional Development (PD)

Professional development can be complicated at times due to the beliefs and values of the teacher and they might display negative emotions towards reform (Schmidt and Datnow 2005), resist reform (Kelchtermans 2005) and their professional identities might feel threatened (van Veen and Sleegers 2006). Also according to Hargreaves and Goodson (1996) teachers, on both an individual and collective level, are often uncertain whether they are deemed professionals or just cultural workers.

Coenders et al. (2010) found that one stop workshops given to teachers are seldom put into practice by the teacher in the classroom. Follow up support mechanisms for teachers in the classroom may be the more feasible contributory factor in knowledge retention (Goldschmidt and Phelps 2010). A study undertaken by Guzey and Roehrig (2009) found that contextual factors, like the classroom environment and the teachers’ own pedagogical thinking had an effect on their ability to carry out what they learned in professional development courses. Garet et al. (2001) argue for the sustained and intensive approach to professional development which they see as having a greater impact over shorter term professional development. This can be created by removing the situated learning where teachers are “passive consumers of pre-packaged knowledge” (Lieberman and Woods 2002, p.316) instead of being active agents in the development of their own knowledge base for teaching.
3.4.4 Concluding Remarks on Teacher Professional Development

Professional development of teachers is currently seen as the most promising procedure for improving teacher quality (Goldschmidt and Phelps 2010). Changing instructional strategies is not something that can be accomplished easily or without conflict (Johnson 2006). Added to this, little intellectual and resource support is offered to teachers engaged in educational change endeavours (Nakedi 2014). Change is not just about putting in place the most updated policy; it is about changing the cultures in the classroom, school, university etc. (Fullan 2007). Successful change also depends on tapping into the ritualised routines of teachers which are central to the structure of classroom teaching (Nuthall 2005). These ritualised routines become part of a teacher’s culture where they become so embedded within the teacher that awareness of their own perceptions are lost (Nuthall 2005) in other words their awareness of their habitus (beliefs) around how science should be learned is lost.

Nuthall (2005) warns however that even innovative teachers who want to move away from the standard routines in the classroom can be misled by dominant myths that permeate the common classroom setting. If the dominant myth in the classroom is that rote learning can achieve authentic learning, measured by standardised tests, then even teachers, who want an alternative classroom setting where innovation is saturated in the practice, can be misled down the frequented path. All parties involved in the education system be it the stakeholders, teachers, teacher educators, students and parents have an opportunity to influence the current system. PSTs, as future teachers, can be viewed as “agents of change” (Price and Villi 2005, P.59) that can influence changing educational practice.

3.5 Chapter Synopsis

Having presented a variety of studies related to the key concepts pertinent to this study, the association between these concepts will be presented below:
PCK forms part of the theoretical perspective on which this study is grounded. PCK is the professional knowledge base unique to the province of teaching and constitutes an amalgamation of content and pedagogical knowledge which leads to the presentation of material in such a way that it is made comprehensible to the learner. Scientific inquiry is viewed as one approach that can make material comprehensible to learners. A teacher’s PCK can be captured through the use of the content representation (CoRe) tool on either a collective (Loughran et al. 2006) or individual level (Bertram 2012). Within a teacher’s PCK lie their orientations (beliefs and values) to science teaching which influence their knowledge of instructional strategies. Teachers with a constructivist view of learning use strategies like inquiry which support their beliefs (Jones and Carter 2007). Therefore if teachers have orientations towards scientific inquiry within their PCK, these can be captured and
developed through their exposure to the CoRe scaffold. The CoRe serves two purposes:

1. It makes visible teachers’ PCK on either an individual or collective level (linked through RQ.1)

2. It serves to facilitate teachers’ professional development through interactions in a bid to make sense of meaning (linked through RQ 2)

Because the contents of the CoRe are reflective of a teacher’s knowledge at either the collective or individual level, the CoRe can be used to describe the teachers’ living educational theory (Whitehead 1989) which is constructed from the teachers’ exploration into how they can improve their practice. More specific to this study, the construction of the CoRe can be used to capture teachers’ living educational theory of what they believe scientific inquiry to be in practice. The CoRe represents espoused PCK; indeed it represents espoused professional development opportunities. Caution needs to be maintained however as to whether or not this development in theory has been enacted in actual classroom practice. Indeed studies have identified the contestations with putting into practice the learning that teachers engage in from professional development opportunities (Goldschmidt and Phelps 2010). The CoRe is propositional in nature meaning that it does not give account of actual classroom practice. PaP-eRs provide real-life windows into actual classroom practice. Hence teachers developing orientations to scientific inquiry can only truly be captured in classroom accounts of practice, meaning authentic professional development can only be confirmed by translating theory into practice (linked through RQ.3 and 4). Key to development is the teachers’ ability to reflect on their classroom action and give credence to the spontaneous decisions they have made in the classroom as well as the pedagogical reasoning they have considered in their planning of the lesson.

The end goal of professional development is to facilitate educational change. The importance of freeing PSTs from past learning experiences (their apprenticeship of observation) is considered one target in professional development opportunities. As
Fullan (2007) suggests, if teachers are to listen to anyone in the change process, it will be fellow teachers. This gives weight to the importance of engaging teachers in professional development opportunities which involve teachers supporting each other in a scaffolded manner (through the use of PLCs) as they make explicit their knowledge about teaching and learning. The interactions within the PLC can allow for meaning to be socially constructed with the author choosing symbolic interactionism as a key theoretical perspective because it is concerned with how these interactions form new meanings within a community.

A teacher’s self-efficacy, meaning their belief in themselves as classroom practitioners, is a dependent variable affecting each of the key concepts described above. A teacher’s self-efficacy is an affective affiliate of a teacher’s PCK (Park and Oliver 2008a) but more specific to instructional strategies, it can influence whether a teacher initiates activities which are inquiry-oriented (Cakiroglu et al. 2005). The self-efficacy of a teacher can be strengthened through collaborative professional development (Rostan 2009).

To that end, this study focuses on using a PCK lens to facilitate the professional development of a cohort of PSTs towards the enactment of scientific inquiry practices within the classroom using a model of collaborative interactions to encourage this development. While studies on characterising examples of PCK are numerous, studies using PCK as a theoretical framework are less common but Bodner and Orgill (2007) consider its value in organizing important research on teacher education. Therefore PCK (specifically the conceptualisation by Magnusson et al. 1999) and how scientific inquiry is embedded within it, serves as part of the theoretical framework guiding this research. The reason why PSTs are the focus of this study is in keeping with the author’s epistemological view that as future practitioners, they can be “agents of change” (Price and Villi 2005, p.59) to enable the opportunity for sustained educational change.
Methodology
4.1 Introduction

The previous chapter finished by presenting a visual synopsis of the key theories which informed the research questions, research design and the methodological direction which this study took (e.g. Magnusson et al. 1999; Loughran et al. 2006, Bodner and Orgill 2007). The conceptual framework is now continued in this chapter together with a description of what the author intends to investigate, her critical reflexive positioning – epistemological, theoretical and ontological perspectives- and how the research methodology, data collection, data analysis and ethical consideration were achieved (Leshem and Trafford 2007).

The research literature reminds us that qualitative researchers need to pay attention to their worldview – epistemology and ontology – and to share with the reader their reflexive positioning so that the rigor of the study is fully assured through validity testing (Yin 2009; 2012). In this chapter I will be exploring my own reflexive positioning, advocacy for teachers and teaching, and possible biases and data threats and I will justify my selections in relation to this (Finlay, 2002). Key to this discussion on the intentions of this research is acknowledging the influence of the Hawthorn effect (Shuttleworth 2013) on the possible responses of the PSTs and the importance of being a critically reflexive researcher throughout the research process.

This chapter will explore in greater detail the setting and the various phases for this research study. The principle setting for the study was a university setting where PSTs were undergraduate students taking part in their ITE. This was supplemented with a school setting for the practicum placement. Other actors involved in the study were in-service teachers within the national context of rapidly changing policy times for post-primary teachers and schools (NCCA 2012).

After the context for the study, participants and settings, and the reflexive positioning of the researcher is explained and justified then the remainder of this chapter speaks to the selections and justifications for the data collection, analysis and ethical considerations. For example, CoRes and PaP-eRs were used to capture the PCK of PSTs as the data collection approach and a coding scheme based on an extended version of Magnusson et al. ’s model was used for thematic analysis (Cohen
et al. 2011; Kothari 2004.). Table 4.1 provides a summary organiser of the key issues/concepts that need to be considered when conducting doctoral research and outlines where within this chapter and the previous, each are covered in detail.

<table>
<thead>
<tr>
<th>Key Issue/Construct</th>
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<td>Creswell and Plano-Clark (2011)</td>
<td>4.2.1.1 and 4.3.1</td>
</tr>
<tr>
<td><strong>Epistemology</strong></td>
<td>Social Constructionism</td>
<td>Bodner and Orgill (2007)</td>
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<td><strong>Research Questions/ Research Design/ Sampling/</strong></td>
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<td><strong>Research Methods</strong></td>
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<td><strong>Ethical Considerations</strong></td>
<td>ULEHSREC</td>
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<tr>
<td><strong>Data Collection</strong></td>
<td>Focus Groups, Survey, Interviews, CoRes and PaP-eRs</td>
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<td>4.4.3, 4.4.4, 4.4.5</td>
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<tr>
<td><strong>Data Analysis</strong></td>
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<td>Braun and Clarke (2006)</td>
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<td><strong>Theoretical Framework</strong></td>
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<td>Magnussen et al. (1999), Loughran et al. (2006), Bodner and Orgill (2007)</td>
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Table 4.1: Key issues/constructs to be considered when conducting doctoral research
The main purpose of engaging in research is to answer particular questions. As a reminder, the research questions which underpin this study are as follows:

- What are the foundational scientific inquiry orientations of a cohort of pre-service science teachers before, during and after a six week teaching practicum?
- What are the affordances of a PCK lens as a professional development aid, specifically its use in describing and developing inquiry orientations in pre-service science teachers through the social construction of meaning?
- How do the perceived developing inquiry orientations successfully translate into actual classroom practice?
- How does the scientific inquiry practice of these PSTs compare with other teachers (pre-service and in-service): What factors inhibit its enactment?

These questions were unpacked in chapter one and serve as a reminder here.

4.2 Ontological and Epistemological Considerations

4.2.1 An Epistemological Consideration: A Social Constructionist Positioning

Reference was made in the previous chapter to the social construction of meaning (developing scientific inquiry within PSTs’ PCK) through symbolic interactionism as part of a PLC. The author will now speak of her epistemological and ontological positions which underpinned the methodological design of her study.

In all, an ethnomethodology approach to this study was taken which reflects the assumption that the realisation of facts is socially constructed and in turn defines the constructionist model (Silverman 2010). Given the emphasis placed in this study on the construction of new knowledge through social interactions, it was decided that a social constructionist paradigm accurately described the worldview held by the author. While the definitions of social constructionism vary in the literature, Burr (2003) provides a description of the key assumptions which underpin a social constructionist position. Firstly, that we take a critical stance towards our taken for
granted ways of understanding the world where we challenge the view that conventional knowledge is based upon objective, unbiased observation of the world (Burr 2003). Secondly, knowledge is sustained by social processes and knowledge and social action go together (Burr 2003). In other words, social actors construct knowledge, their own versions of reality, between them through their daily interactions, namely through language (Burr 2003). Ultimately our way of understanding the world does not come from an objective reality but from other people (Burr 2003). Creswell (2007) suggests that individuals seek to gain understanding of the world in which they live and therefore develop subjective meanings of their personal experiences. This assertion supports the view that people generate knowledge and meanings from their own experiences, which is critical in a study focused on constructing new knowledge from prior experiences.

Social constructionism is a form of constructivism which is a theory of learning that originated in the cognitive sciences but has since been applied to science education research (Bodner and Orgill 2007). Constructivism has a long history, indeed Socrates should receive credit as the first to articulate the idea of the learner as the builder of knowledge (Bodner and Orgill 2007). He argued that the process of learning within a learning community was more important than the assimilation and accommodation of new knowledge. Social constructionism finds its origins in John Dewey’s premise that the “psychological and social sides of education are organically related and that education cannot be regarded as a compromise between the two or a superimposition of one upon the other” (Dewey 1963, p.20). Therefore the psychology of learning is intimately linked with the context in which it takes place and inherently the context within the social constructionist paradigm is a consortium of different experiences and prior knowledge bases. The idea of social constructionism was further explored by Berger and Luckmann (1966) who built on the work of Mead, Marx, Mannheim, Wilhelm and Hegel and originated as an attempt to come to terms with the nature of reality (Andrews 2012).

In the previous chapter the literature suggested that teacher knowledge (specifically PCK) can be a socially constructed phenomenon (Loughran et al. 2006) therefore this author asserts that new knowledge can be generated from prior experiences
within a socially constructed setting. Indeed Bodner and Orgill (2003) consider PCK as being a theoretical framework tied to the constructivist theory of knowledge. It can also be argued that the model of constructionism gives way to the idea that reality in general can be socially constructed (Silverman 2010). This idea purports that a person’s reality can be constructed and for research purposes deconstructed through social interactions. This gives realism to such research as a person’s reality is made visible. This can be articulated when looking at the experiences/reality of the PSTs involved in this current study as they engage in capturing and developing their PCK while concurrently engaging in the realities of becoming a teacher, defined by the constraints and possibilities of their ITE experience.

There are some methodological limitations to having PCK as part of the theoretical underpinning of a study. The ever changing nature of PCK makes it a challenge for the researcher to determine the impact of experience on PCK (Bodner and Orgill 2007). Therefore engaging in longitudinal research is a requisite (Bodner and Orgill 2007) and it is for this reason that the author chose to engage in longitudinal research. Also PCK is a personal transformation of knowledge so generalisations will not be valid (Bodner and Orgill 2007). The case study nature of this research meant that the author did not intend to promote generalisations but sought to extend an existing theory.

**Characteristics of a Constructivist Environment**

Jonassen (1994) proposed a number of characteristics which govern a constructivist learning environment. He considered such a learning environment to encourage thoughtful reflection on experience. The PSTs in this study were asked to engage in reflection throughout their involvement in the study as PCK develops also through the active reflection of experiences. For example, having the PSTs construct another CoRe after school placement was a reflective process where they were able to capture their learning from their classroom experience.

Jonassen (1994) also stressed the importance of dialogue in a constructivist learning environment. Indeed Pierre Hirtle (1996) considers that the actual words spoken in a social context leads to the construction of knowledge. The idea of constructing
learning experiences through language is also proposed by Dewey (1963) where he argues that language is a mediating tool for learning where learners come to collaborate with their own and others’ thoughts and feelings. Indeed this argument can be upheld when one considers that speech is the first tool that culture provides for a child to engage in collaborative thinking with others (Pierre Hirtle 1996). For these reasons the author chose to have the PSTs complete the CoRes verbally rather than filling in a CoRe template as has been done in previous studies (e.g. Hume and Berry 2013). In doing so the PSTs speech is, according to Vygotsky’s Theory, gradually internalised to become a semiotic resource which they can use for problem solving and thinking (Pierre Hirtle 1996). Therefore a theoretical construct aligned to the social constructionist theory and indeed the use of PLCs is that of symbolic interactionism. In truth, it is considered foundational to contemporary social constructionism (Burr 2003). Symbolic interactionism is concerned with the meanings, processes and interactions in people’s lives and therefore is an appropriate tool for approaching aspects of social life as they emerge and transform (Plummer 2003a). Observing and documenting the PSTs conversations within the PLC allowed the author to study the “processes of interaction among individuals” (Creswell 2007, p.21) where individuals are active agents rather than passive beings shaped by external forces (Appelrouth and Edles 2011). There are a number of variants of interactions, with this current study centred on face to face communication where there is a single focus of attention (McGall 2003).

The main limitation of symbolic interactionism relates to the exclusion of outside influence of social structures (Archibald 2014). Thereby the researcher needs to consider comparison to allow for the understanding of whether knowledge construction is related to the research situation. This was achieved through the use of mixed methods which was the focus of the final research question.

Another feature of constructionist-based research focuses on the context in which the participants live and work as society exists in action and must be viewed in terms of action (Appelrouth and Edles 2011). Indeed, the social context is at the centre of meaning-making and our culture shapes the way in which we see things (Crotty 1998). So while the CoRe has been constructed in various different contexts it is yet
to become part of the learning experience for PSTs in Ireland. In addition the use of a PLC in an Irish ITE context, to facilitate the developing inquiry orientations, is yet to be reported in the literature.

Finally the social constructionist paradigm is intimately linked with the idea of individuals opening boundaries through inquiry and not by unquestioned acceptance of what is the prevailing knowledge on a concept (Pierre Hirtle 1996). A goal of constructionism is that individuals can understand that the ways in which knowledge is mediated and created are as dynamic and important as the learning itself (Pierre Hirtle 1996). It can be suggested that this goal is intrinsically linked with scientific inquiry in the classroom as the focus is on the process of learning as well as the knowledge generated (Wyllys 2003). Therefore the author would suggest that a study grounded in developing an inquiry habitus in PSTs should be underpinned by social constructionism. In other words a proponent of the constructivist theory of learning advocates that constructivism should guide research focused on meaning-making (Bodner and Orgill 2007). This idea is also put forward by Watson (2001) who considers that teachers can also be constructivists in the classroom when they lend themselves to teaching science through inquiry. Therefore having a study grounded in constructivist orientations both from the perspective of the research paradigm and the goal of educational change can provide validity in terms of the purpose and realism of the study.

**Critics of the Constructivist Theory**

The author acknowledges critics of constructivist theory who consider that upholders of this epistemological position deny the existence of “reality” (von Glasersfeld 2000; Stam 2001). The author also recognises the position that social constructionists are accused of being “anti-realist” in denying that knowledge is a direct perception of reality (Andrews 2012). However the author agrees with Bodner and Orgill (2007) who assert that this is not an accurate reflection of constructivist theory and that there is little evidence to support this claim (Andrews 2012). As considered by Tobin (1990), most constructivists do not question the existence of reality rather they only question our ability to judge or know reality and in turn judge whether something is “true” or “false”. This lends back to the notion of the
subjective or objective reality and social construction of knowledge as a subjective reality based on the socially defined experiences of everyday life (Andrews 2012).

### 4.2.1.1 Ontological Positioning

Ontologically this author would hold the position of a relativist. While realists and relativists agree that our knowledge of the world is based on our experiences of our senses, they differ in terms of their beliefs about the extent to which the world is knowable (Bodner et al. 2001). From the constructivist perspective, truth is based on coherence with our knowledge rather than correspondence between knowledge and objective reality (Staver 1998). Constructivists believe that knowledge only exists within us, the cognizant beings (Bodner and Orgill 2007).

It must be considered however that a certain tension exists in science education research as a subject grounded in objective fact is studied from a subjective perspective. The author acknowledges this tension. However she agrees with Cohen et al. (2011) who suggest that human research is part of an ongoing action being investigated and that the model of a human is ever changing, not a plastic version favoured by positivist researchers. Therefore the complex nature of human participants (within science education research) should divert away from the position that fact is fact and focus on the position that human is human (Cohen et al. 2011).

### 4.2.2 Reflexivity in Educational Research

Reflexivity is viewed as a defined feature of qualitative research (Banister et al. 1994) with a long history in social inquiry (May and Perry 2014). Reflexivity denotes a position where a researcher tries to make explicit how inter-subjective elements impact on the trustworthiness, transparency and accountability of the data and in doing so make themselves aware of their own role and how this affects the integrity of the data (Finlay 2002). In a sense it is the act of reflecting on the knowledge we produce and our role in producing that knowledge (Braun and Clarke 2013), that is the biases that the researcher brings into the research process. It must be considered that reflexivity is not a “method” per say but a way of thinking that aids interpretation and representation of data (May and Perry 2014). Reflexivity is a contested term in educational research yet it can be argued that having a reflexive
positioning plays an important role in the evolution of qualitative research (Finlay 2003).

Bryman (2008) would argue that what is key to defining reflexivity is the acknowledgement given by social researchers in relation to how bias, decisions, methods and values can have implications for knowledge generated. The researcher at all times, particular in qualitative research, needs to be aware of their positionality within the context of the study. Due to the close proximity with the participants in the current study, it is necessary to explore the nature of the relationship between the author and the participants and in doing so, contemplate the idea of the author’s positionality within the context of the study. Ultimately reflexivity identifies the researcher’s biases as potentially leading to threats within the presentation of the data. Because of this the author needed to engage in critical internal dialogue to make explicit the hidden assumptions of her practice (Cohen et al. 2011; Finlay 2002) to understand what is known and how it is known (Patton 2002).

Etherington (2004) further describes reflexivity as the researcher’s awareness of their own personal responses and how they choose to use these responses. However Clandinin and Connelly (1994) warn against the researcher’s “signature” being written too strongly which can result in over-subjectivity. A balance between the researcher’s voice and the researched voice is therefore key to a critical piece of research. A researcher needs to consider the implications and significance of their own choices as both an observer and a writer (Bryman 2009). A reflexive stance is crucial in augmenting the integrity, credibility and trustworthiness of qualitative research and encourages the notion of researcher “coming clean” (Gilgun 2006).

One way of “coming clean”, according to Valandra (2012), is to attend to the power relations within a study and how these power relations influence the recruitment of participants and the interviewing processes in research. This includes showing an awareness of whose voices are heard, how these voices are constructed and what knowledge is produced as a result (Daley 2010). The researcher’s professional and personal experiences influence their reflexive positioning (Valandra 2012) where the researcher brings their own biography to a research situation and the participants can
in turn behave in particular ways when engaging in the research process (Cohen et al. 2011). Indeed the researcher may be viewed as a powerful figure and it can be argued that our (social) constructions of the world are bound by power relations existing within a social context (Burr 2003).

Warin (2011) speaks of the research relationship and how to manage this within a longitudinal study. Bryman (2008) refers to the idea of methodological self-consciousness in research where one needs to take account of their relationship with those who they study. Warin (2011) suggests that reflexivity is interwoven with the concept of ethical mindfulness. Holland et al. (2006) refers to the growth of familiarity and trust over the duration of a qualitative longitudinal study and how this can be a source of exploitation. This is acknowledged. However it can be argued that building familiarity and trust is key to uncovering participants’ true feelings (Zaltman and Moorman 1998) but ethical behaviour is of paramount importance to avoid exploitation.

4.2.2.1 *The Hawthorne Effect*

Also within any research study it is imperative that the researcher can determine whether or not the Hawthorne effect influences the participants’ contributions to the data. The Hawthorne effect refers to the altered behaviour of a participant because of their awareness that they are being observed as part of a research study (de Amici et al. 2000). The Hawthorne effect can be particularly influential when engaging in any type of intervention-based research regardless of the context of the investigation (Wickstrom and Bendix 2000). The Hawthorne effect is seen as an unavoidable bias that the researcher must try to take into account during the stages of data analysis (Shuttleworth 2009). Wickstrom and Bendix (2000) disagree with this assumption and consider that it is only within certain contexts that the Hawthorne effect can be made presentational in research.

Regardless of the varying contributions, the author needs to be aware of the Hawthorne effect throughout the research study. While there is some belief that the Hawthorne effect is a negative affiliate of social science research, this view is not echoed by all educational researchers. Raywid (1979) asserts that successful teacher
education may be obtainable through having a positive approach to the Hawthorne effect. Regardless, it is always necessary to present findings in a tentative manner and bear in mind the validity and reliability testing (see section 4.2.4) which can help overcome the Hawthorn effect in research (Cohen et al. 2011).

4.2.3 Adopting a Reflexive Position within this Research Study

The motivation of the researcher to engage in particular research endeavours can suggest that a certain agenda is being advocated by the researcher. Etherington (2004) speaks of the idea that the topic we choose to enact research in will often have some personal significance to us as researchers, whether consciously or unconsciously. This view is echoed and extended upon by Braun and Clarke (2013) who consider that the topics we find interesting, the ways we ask questions about them and the pieces of data that excite us all reflect on who we are, in other words our subjectivity. Braun and Clarke (2013) go further to say that like the participants who bring their own experiences, they are not robots and the researcher is not a robot, we are all subjective human beings, partial in our knowledge and flawed.

Engaging in reflexive practice means that the researcher needs to position themselves in the research to acknowledge how their interpretations of the data could be influenced by personal and historical experiences. It is about acknowledging who we are as researchers (Braun and Clarke 2013) and this can be considered both from the perspective of our worldview, our theoretical perspectives and our data collection/analysis method. The author has already spoken of her worldview and will now consider how her advocacies towards PCK and scientific inquiry (theoretical perspectives) form part of who she is as a researcher. The latter (data collection/analysis) will be discussed with the view to addressing validity and reliability in this research study.

**Personal Biography**

I am a graduate of the same ITE programme which is the focus of this current study and from my experiences I always wished to understand what made a teacher’s knowledge different to say that of a scientist. In other words, I was curious about what a teacher’s knowledge should look like and how it could influence students
learning. I was always a person who sought answers to questions, a natural inquirer in some respects, and having completed my ITE, I felt I needed to learn more. I was struck when I came across the construct of PCK as it is something that was not explicitly discussed during my studies. Further research invoked a sense of confusion in me that such an important model, which made explicit the knowledge needed to be an effective teacher, was not presented during my ITE. This is where my initial thoughts about engaging in research came about. I then considered whether or not my study would focus on pre-service or in-service teachers. I reviewed similar studies and noted that the PCK of PSTs was the focus of several research studies, particularly ones related to the CoRe tool. I am a particular advocate of research on PSTs as I consider the importance of tapping into their understandings before they are consumed by the constraints of the classroom.

While engaging in the literature research I came across the model of PCK by Magnusson et al. (1999) which positioned knowledge of instructional strategies as being a key component of a teacher’s knowledge base. Having orientations towards the constructivist model of learning I found that my actions in the classroom most resembled the practice of scientific inquiry. Though somewhat unpolished, I did consider my approaches to mirror such an orientation. This came about not from my training but from an experience I had when in primary school where we embarked on a science project which I would now consider to be guided inquiry in nature. To this day I can still recall the enjoyment, understanding and motivation that I had when completing the project and it was something which became embedded within me that was untapped until I got the opportunity to teach.

I do acknowledge that my positioning and interpretation of the data could serve as a threat to the data, however I have attempted throughout the study to present the data as accurately as possible while still showing awareness as to how my bias could pose as a potential data threat.

Cohen et al. (2011) considers the four potential roles of a researcher in a study and these are outlined in Figure 4.1:
The author would see herself as an observer within the study but could not consider herself detached as it must be noted that within a PLC the moderator needs to have a professional relationship with the participants in order for them to begin to explore their beliefs and values about teaching.

The researcher is a central figure who influences the collection, selection and interpretation of data as our behaviour will always affect the participants’ responses (Finlay 2002). It was critical therefore during the phases of this research study that I considered my own reflexive positioning about the place of PCK and scientific inquiry within the study. This was done in order to reduce the likelihood of the PSTs presenting false positives in a bid to impress me as I would be seen to be in a position of power due to my role as a tutor within the University of Limerick. I was at no time a tutor of these particular PSTs therefore the willingness to please me was not considered to be as much of a risk. Also I became a tutor one year after the study began therefore the initial recruitment of the PSTs was not in line with me having a position of power within the university. Indeed phase one had been completed before I took up my role as a tutor in the university. Also while I am an advocate of the practice of scientific inquiry, I did support an environment during CoRe construction where the PSTs could offer alternative practices. This was evident in the CoRes presented in the appendix section which show a selection of teaching approaches.

Research is regarded as a joint product of the participant, the researcher and their relationship (Finlay 2002). I was conscious throughout the study that true responses would be captured and was aware of the potential for PSTs to give a response that they perhaps believed I wished to hear in order to facilitate the objectives of the study. A long term approach to data collection can help reduce the chances of the
Hawthorne effect (Gaskell 2012). If the researcher monitors closely their own interactions with participants, their reactions, biases and other roles they may have, then the potential reactivity that can lead to threats in the data can be avoided (Cohen et al. 2011).

Finally key to being a reflexive researcher is to achieve validity and reliability (Darawsheh 2014) through multiple perspectives and methods and will be explored in the next section.

4.2.4 Validity and Reliability

As mentioned previously, the author considered the need to adopt a reflexive position where she outlined her biases, role and advocacy towards PCK and scientific inquiry in a bid to show how she is external to the situation and was an objective observer throughout the data collection, analysis and presentation of the findings. As this study was qualitatively dominant, the objectivity reality of the situation can often be sacrificed by the subjective nature that is commonly associated with qualitative research (Bodner and Orgill 2007). In a sense, reliability and validity are conceptualised as trustworthiness, rigor and quality in qualitative research (Golafshani 2003). Therefore throughout the study there was a need to consider validity and reliability testing which would seek to create an objective understanding of the data.

Validity is concerned with the integrity of the conclusions (Bryman 2008) and whether or not the research questions have been answered based on the findings. Reliability can be defined as a determinant of whether a research instrument is stable, predictable, dependable, accurate and free from error (Burns 2000). It is concerned with whether the measures used for specific concepts are consistent (Bryman 2008). This study follows a case study design (more later) and Yin (2009) considers the validity and reliability tests that should be immersed within the design. There is a certain bias attributed to case study research and can at times lack rigour (Kyburz-Graber 2004) therefore consideration of such tests is crucial. Table 4.2 highlights the validity and reliability tests to be considered in case study research:
<table>
<thead>
<tr>
<th>(A) Test</th>
<th>(B) Case Study Tactic</th>
<th>(C) Application in Current Study</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construct Validity</strong> (Operational methods)</td>
<td>Use multiple sources of evidence</td>
<td>Mixed methods design.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Triangulation of data and participants (RQ.4).</td>
</tr>
<tr>
<td></td>
<td>Have key informants review draft case study report</td>
<td>Supervisors reviewed and provided feedback on thesis. PSTs reviewed the CoRes once constructed from review of the audio data.</td>
</tr>
<tr>
<td><strong>Internal Validity</strong> (Results due to approach being tested, not from an external situation)</td>
<td>Do pattern matching</td>
<td>Critical friend coded data for comparison with author’s interpretations.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comparisons with existing empirical data from the literature.</td>
</tr>
<tr>
<td></td>
<td>Do explanations building</td>
<td>Making initial theoretical statement and comparing them with findings from the study- e.g. can scientific inquiry be embedded within a teacher’s PCK.</td>
</tr>
<tr>
<td></td>
<td>Address rival explanations</td>
<td>Review of contentious literature (Settlage 2012; Mao and Chang 1998).</td>
</tr>
<tr>
<td></td>
<td>Use logic models</td>
<td>Coding scheme an expanded version of Magnusson et al. (1999) model of PCK with reference to the model of inquiry-based on Campbell et al. (2010).</td>
</tr>
<tr>
<td><strong>External Validity</strong> (Generalizability)</td>
<td>Use theory in single-case studies</td>
<td>Review of existing literature on PCK, scientific inquiry, PLCs and the social constructionist paradigm.</td>
</tr>
<tr>
<td><strong>Reliability</strong> (Repeatability of study with same findings and conclusions)</td>
<td>Use case study protocol</td>
<td>Reviewed literature attached to case study research design and field procedures. Considered the research questions based on the conceptual framework and collected appropriate data.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Communicated the design of the thesis and considered the reflexive position of the author throughout to allow for subjective reporting of the data</td>
</tr>
<tr>
<td></td>
<td>Develop case study database</td>
<td>Generation of author’s own case study notes (reflective pieces).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Storing of quantitative information for later retrieval (within SPSS).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Storing of qualitative information including the</td>
</tr>
</tbody>
</table>
Table 4.2 has summarised the validity and reliability testing considered during the phases of data collection and in the presentation of the findings in the write-up stage. As well as those considered by Yin (2009) the use of thick description to convey the data is considered by Creswell (2009) where a detailed description of the themes is presented. The descriptions are rich in presenting the PSTs’ orientations towards scientific inquiry as well as their interactions within the PLC, the latter of which is in line with the social construction of reality. The detailed descriptions allow the reader to interpret the findings in a naturalistic, rich and objective manner.

Creswell (2009) also suggests the researcher presents a description of their background and how this may shape the interpretation of the findings. The author’s consideration of their reflexive position and the presentation of their advocacy towards PCK and scientific inquiry in the previous section sought to clarify the potential bias (Creswell 2009) that could come from a qualitatively dominant research design. Finally Creswell (2009) suggests the need to present negative or discrepant information which contradicts the general themes of the study in order to present a more realistic and valid account of the findings. The author ensured such data was presented. This can be viewed particularly with reference to RQ2., RQ3. and RQ4 where the focus was on exploring how the interactions within the PLC accounted for the developing espoused and enacted orientations towards scientific inquiry.

4.3 Research Design
The following section explores the research design of this study which inherently reflects a longitudinal case study mixed methods design.

4.3.1 Mixed Methods Research
A relativist position was previously described as the ontological position held by the author. However it is recognised that at times there is a need to align with realist orientations when the direction of the study requires this. To that end a mixed methods approach, though qualitatively dominant, was followed in the current study. A mixed method approach is aligned with pragmatism which is not committed to any one system of reality (Creswell 2007). A mixed methods approach can be defined as research in which the researcher collects and analyses data, integrates the findings and draws conclusions from both quantitative and qualitative avenues within a single study (Tashakkori and Creswell 2007).

Indeed from a constructivist perspective, knowledge should be approached in the sense of a lock and key metaphor; there can be many keys with slightly different shapes to open the same lock (Bodner and Orgill 2007). Knowledge in social science research can be viewed under the same lens. A pragmatist would argue that there may be both singular and multiple representations of the truth and reality, sometimes subjective, sometimes objective, sometimes scientific and sometimes humanistic (Cohen et al. 2011). Despite past debate as to whether a quantitative or qualitative approach best serves the social research agenda, scholars now agree that both approaches are needed since no one methodology can answer all questions and provide insights into all issues (Burns 2000). The choice of using a qualitative or quantitative approach is considered relevant to which approach best answers the research question as opposed to the researcher having a preference or allegiance towards a particular educational paradigm (Johnson et al. 2007).

There are a number of reasons why mixing methods are favoured amongst researchers, they include: being able to provide a stronger base for drawing conclusions and being able to explore the macro and micro dimensions of the problem being explored (Tormey 2010). Whilst the arguments for using mixed methods research are prolific, there still lies a paradigmatic argument in the research community. This argument reflects the position that qualitative and quantitative research and the epistemological values, assumptions and methods which reflect these individual paradigms are intricately intertwined and are therefore incompatible.
between paradigms (Bryman 2008). However this author believes in the argument that a mixed methods approach provides a stronger base for drawing conclusions.

The need for mixed methods can arise in a study where the initial results may provide an incomplete understanding of the data and there is a need for further explanation (Creswell and Plano Clark 2011). Qualitative research alone may be viewed as deficient because of the potential bias that the researcher can hold which may lead to personal interpretations of the data. Quantitative research does not have these weaknesses as the objective nature of reality is a key characteristic of quantitative research therefore a combination of strengths from one approach alleviates the potential weaknesses from another approach (Creswell and Plano Clark 2011). Mixed methods would also be seen as a more “practical” approach as the researcher is free to use all the methods necessary to address a research problem (Creswell and Plano Clark 2011). Also the notoriously complex nature of research problems requires answers beyond simple numbers in quantitative data or words in qualitative data (Creswell and Plano Clark 2011).

A number of considerations need to be taken into account when organising a researcher’s particular view of mixed methods research (Teddlie and Tashakkoir 2006). These include the number of methodologies used and the stage at which integration is applied, the number of phases, whether priority is given to one or more methodological approaches and if they are qualitative or quantitative (Teddlie and Tashakkoir 2006). Indeed there are a number of mixed method design structures according to Teddlie and Tashakkoir (2009). The one which this study inherently reflects is that of a quasi-mixed design where both qualitative and quantitative data are collected but are not used together to answer a particular research question, quantitative data would answer one research question and qualitative data another (Teddlie and Tashakkoir 2009). This mixed methods design would support the complementary strengths (Greene 2007) philosophical stance which is “strongly attuned to the philosophical assumptions of each approach, considering the methodologies as different and requiring appropriate implementation” (de Lisle 2011, p. 91). Qualitative research mainly looks at processes that are happening within smaller groups in focus groups for example, while quantitative research looks
to measure the extent of the issue within a population, i.e. using surveys (Tormey 2010).

Qualitative dominant is viewed as one of the three subtypes of mixed methods research along with pure mixed and quantitative dominant (Johnson et al. 2007). This study takes the form of a qualitative dominant approach as the interpretivism orientations attached to a qualitative approach are much in line with the social constructionism epistemology (Andrews 2012).

4.3.1.1 Limitations of Pragmatism
There are a number of challenges attached with using mixed methods in research. Creswell and Plano Clark (2011) recommend the need for a researcher to have experience with both qualitative and quantitative research before undertaking a mixed methods study. With this in mind, a mixed method researcher would need to have experience with statistical software packages and would need basic skills in analysing qualitative data including coding text and developing themes based on these texts (Creswell and Plano Clark 2011). Another challenge that has been recognised in the literature relates to the inexperience of novice researchers. Their inexperience means that when they are planning and implementing mixed methods research they need to adopt a clear philosophical stance and a design framework (de Lisle 2011) to meet the requisites associated with the pragmatic approach.

4.3.2 Longitudinal Research
This research study resulted from the collection and analysis of data over a two year period. It would therefore be regarded as a longitudinal study. By definition, a longitudinal study would be described as a variety of studies that is carried out over a period of time (Cohen et al. 2003). According to Bergman and Magnusson (1990), longitudinal research is deemed to be the essential component in the study of individual development. An important consideration which a researcher carrying out a longitudinal study needs to be aware of is that the research design distinguishes change as a result of experiences from being involved in the research study from those that can occur as a result of normal human development (Tuckman and Harper 2012). The use of comparative analysis can allow for this distinction to be made as can the use of triangulation of data.
This study would further be described as a cohort study, where a certain group is tracked over a specific period of time but selective sampling does occur within the sample (Borg and Gall 1979 cited in Cohen et al. 2003). Some members of the group may not be included each time. Therefore while the PSTs would have been involved in the development of specific CoRes, when it came to observation in the classroom etc., only some participants were involved.10

4.3.3 Disadvantages of Longitudinal Studies

Literature reveals that there are a number of disadvantages to engaging in a longitudinal study. The disadvantages include the following:

- Longitudinal studies are time exhaustive and expensive
- It can be difficult to keep all participants involved fully in the study- there will more than likely be dropouts over the course of the study.

(Cohen et al. 2003)

Bryman (2012) has suggested that it is a little used design in social research attributed mainly to the time and the cost involved. Despite these disadvantages, the author would argue that the advantages of using a longitudinal approach to answer a research question far outweigh these disadvantages. Longitudinal research allows the researcher to explore emergent patterns over time, allowing them to observe similarities and differences both on an individual and collective level in respect of certain exploratory variables (Cohen et al. 2011). Longitudinal research can also allow for causal inferences to be made (Bryman 2012) meaning that the researcher can gain rich insight into the study of individual development.

The suggested disadvantages of longitudinal research being time consuming and expensive were not an issue as the research was always intended to be a two year study within a specific institution, therefore cost was not seen as a disabling factor. Also the decision to use the CoRe as a research lens meant that acknowledgement was given as to the time constraints associated with using this lens (Rohann et al. 10

10 The reason for this selective sampling will be discussed towards the end of this chapter.
2009). However the author believes that the rich data the CoRe would provide from a research point of view and for the PSTs, the potential professional development opportunities, meant that the CoRe was a necessary addition to facilitate the articulation and development of PCK and in turn their inquiry orientations.

In relation to dropouts in longitudinal research, this indeed was the case in the current study. Despite this, it was the assertion that commitment would result in a more reliable insight into the PSTs’ experiences.

4.3.4 Case Study Research

Yin (2009) considers there to be a two-fold definition of a case study which includes a case study being an empirical inquiry which investigates a contemporary phenomenon within a real-life context and relies on multiple sources of evidence which benefits from the prior development of theoretical propositions. Central to a case study is research into particular cases. A case can be individual (e.g. a person, family) or it can be institutional (e.g. college, hospital ward) or finally it can be a large scale community study (town, professional) (Gillham 2000). All of these would be regarded as single cases even though they may contain a number of participants; they are all part of a similar context.

One of the key features of case study research is that the researcher examines the context and the other conditions related to the cases (the participants involved in the study) in order to gain a better understanding of the cases (Yin 2012). The real-life context associated with this study is related to the experiences of pre-service science teachers as they transition through their ITE programme and takes place within both a university and school context (teaching practicum), depending on the stage within the programme. It must be mentioned however that a case study can also be used to conduct evaluations (Yin 2012) of interventions. Part of this case study involved an adaptation of a PCK lens to facilitate the development of inquiry orientations and therefore serves as a potential intervention.

The features of case study research not only resemble a real-life situation but also focus on exploring the real-life phenomenon as close to the people in question as is
possible by describing the situation in detail and presenting the findings in a clear and comprehensive manner (Kyburz-Graber 2004). To facilitate an understanding of participants’ actions, the framework and subjective theories which underpin their actions must be drawn from their life experiences (Kyburz-Graber 2004). Case study research allows the researcher to describe the processes (social construction of meaning) leading to a result rather than the significance of the results themselves (Gillham 2000). It is therefore strongly aligned with symbolic interactionism within a PLC.

Case study research is a dominant approach used with the longitudinal research design (Bryman 2012) where the aim is to understand the meaning behind the knowledge and the actions of the participants (Kyburz-Graber 2004). Indeed other studies involving the CoRe tool have been conducted using a case study approach (Hume and Berry 2011). It allows the researcher to “get under the skin” of the group to ascertain true representations of experiences (Gillham 2000).

Qualitative methods are more commonly associated with case study research as they provide an intensive detailed examination of a particular case (Bryman 2008). However key to a successful case study is the use of multiple data sources each with their own strengths and weaknesses (Gillham 2000). Deciding whether a study should take the form of a case study design over other methods depends firstly on the type of research question that the researcher is trying to address. If questions are either descriptive (what is happening) or explanatory (how and why something happens) then a case study approach is pertinent to answering these types of questions (Yin 2012). Other research methods, like the use of experiments, are not likely to offer the rich descriptions that might arise from doing a case study (Yin 2012). Case study research is not intended to answer “who” or “how many” questions and is not intended to answer questions in a controlled and even artificial environment (Kyburz-Graber 2004).

This current study took the form of an educational case study (Bassey 1999) and more specifically a longitudinal case study where a particular case is investigated at two or more junctures (Bryman 2008). This study is also considered to be an
exploratory case study rather than a descriptive case study where the experiences of a single case within a particular context are explored (Yin 2009). The latter merely describes a case while an exploratory case study seeks to go beyond description and tries to provide an understanding of the case against the background of its context (Kyburz-Graber 2004). Exploratory case studies would be strongly aligned with intervention-based research (Yin 2009). Furthermore this research would be considered limited exploration where a researcher is looking systematically for something in particular (Stebbins 2001).

The author is aware of other qualitative designs such as action research however the premise of action research is to engage the participant in the diagnosis of a problem and the development of a solution based on the diagnosis (Bryman 2008). The PSTs in the current study were asked at certain stages as to whether they had suggestions to make (i.e. in how the workshops were conducted) and if they approved the changes that were made (i.e. the adaptation of the CoRe to include a greater inquiry focus). They were not actively involved in the diagnosis of the problem and the development of a solution. More specifically, they did not suggest their lack of inquiry orientations was a problem or offer a suggestion on how this problem could be alleviated. Furthermore, action research would also be viewed as a form of self-evaluation (McNiff 2010) and is carried out by practitioners who see a need to improve their own practice (Bell 2010). The action research design inherently reflects a professional development opportunity for the researcher however this was not the focus of the current study.

**Contestations around Case Study Research**

There has been a traditional viewpoint in the research community that case study research serves as a prelude for using other social science methods in the exploratory phase of data collection, however this traditional view is entirely outdated (Yin 2012). Yin (2009) suggests that case study research is now considered as a separate research method with its own associated research design. This view is vindicated by Gillham (2000) who suggests that case study research has only recently come into its own as a valid research design. However there exists a viewpoint amongst some researchers that case study findings cannot be generalised to a broader level (Yin
Indeed Flyvbjerg (2006) considers such a viewpoint to be a misunderstanding about case study research. In response to this, Yin (2012) negotiates that when case study research is done poorly, these and other challenges combine in a negative way. Others hold the view that case study research lacks a certain rigour in its design. Kyburz-Graber (2004) examined this assumption and concluded that if certain quality criteria, achieved through validity and reliability testing, are met rigour is not an issue in case study research.

Another criticism lies with the analysis of the data provided from case study research as case studies tend to yield a vast amount of information which to coherently interpret can be difficult and time consuming (Cohen et al. 2011; McLeod 2008). Also Creswell (1994) argues that the data collected can be selective and personal due to the researcher providing their naturalistic interpretations and summaries of the data. The use of more than one method of data collection can, according to (Bell 2010), alleviate potential bias within the collection, analysis and reporting of the data.

The literature tends to include issues of case selection bias, subjective conclusions and unpredictability of the findings (George and Bennett 2004) as well as the difficulty in replicating results (McLeod 2008). These issues require the researcher to present a reflexive positioning in the presentation and the discussion of the findings. This was discussed in section 4.2.2, 4.2.2.1 and 4.2.3.

4.4 Overview of Research Methods
An overview of the research methods and the timeline for implementation is presented in Table 4.3. The number of participants involved during each phase is also given. The research question addressed through each research approach is presented.

4.4.1 Advance Organiser of the Study Process
Table 4.3 provides an advance organiser of the design process in the current study:
Table 4.3: Advance organiser of this research study

<table>
<thead>
<tr>
<th>Approach carried out</th>
<th>Participants</th>
<th>When</th>
<th>Research Question Addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>• CoRe introduced before and after teaching practicum</td>
<td>N=35 PSTs divided into groups of 11, 12 and 12</td>
<td>Feb 2011 (before teaching practicum) April 2011 (after teaching practicum)</td>
<td>What are the foundational scientific inquiry orientations of a cohort of pre-service science teachers before, during and after a six week teaching practicum?</td>
</tr>
<tr>
<td>• Classroom observations</td>
<td>N=5</td>
<td>Feb 2011</td>
<td></td>
</tr>
<tr>
<td>• Semi-structured individual interview</td>
<td>N=1</td>
<td>Feb 2011 to April 2011</td>
<td></td>
</tr>
<tr>
<td>• Continued CoRe development</td>
<td>N=12</td>
<td>Sept 2011 to April 2012</td>
<td>What are the affordances of a PCK lens as a professional development aid, specifically its use in describing and developing inquiry orientations in pre-service science teachers through the social construction of meaning?</td>
</tr>
<tr>
<td>• Focus group semi-structured interview (to review existing CoRes and PaP-eRs)</td>
<td>N=12</td>
<td>Feb 2012</td>
<td></td>
</tr>
<tr>
<td>• Focus group semi-structured interview (to understand how this study has facilitated their professional development)</td>
<td>N=12</td>
<td>May 2012</td>
<td></td>
</tr>
<tr>
<td>• Personal definitions (living educational theory) of inquiry</td>
<td>N=11</td>
<td>Sept 2011 and May 2012</td>
<td></td>
</tr>
<tr>
<td>• Classroom observations</td>
<td>N=4</td>
<td>Sept 2012 to Dec 2012</td>
<td>How do the perceived developing inquiry orientations successfully translate into actual classroom practice?</td>
</tr>
<tr>
<td>• Action of inquiry survey</td>
<td>N=12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Lesson plans</td>
<td>N=5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Semi-structured individual interviews</td>
<td>N=3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action of inquiry survey</td>
<td>N=135</td>
<td>Dec 2012</td>
<td>How does the scientific inquiry practice of these PSTs compare with other teachers (pre-service and in-service) - What factors inhibit its enactment?</td>
</tr>
</tbody>
</table>
4.4.2 Site, Setting and Participants- PSTs

The initial step in selecting a sample is defining the population of interest (Fraenkel and Wallen 2003). This study namely took the direction of an embedded single case study (Yin 2012) where a cohort of people has been selected where the research is embedded within their organisation. Critical-case sampling was used as it was important to select based on a certain set of characteristics (Cohen et al. 2011), i.e. that the participants were pre-service science teachers within their second year of training (to allow for the longitudinal collection of data). For convenience, pre-service teachers from the University of Limerick were selected as this was the institution in which the author was registered.

PSTs in year 2 of the science ITE programme were selected. The reason for this choice of population was because of the subject specificity of the cohort and the fact that they were in second year which allowed for the natural progression of this longitudinal study. The accessibility of the cohort was also a deciding factor in the selection as the author was registered in this university. They volunteered to be part of this research study following a brief presentation given by the author. Within the presentation the author discussed the key concepts which informed the theoretical underpinnings of this study together with an insight into the contributions asked of them throughout the two years of the study.

As the PCK of all teachers is important, the author made the conscious choice not to select PSTs based on factors like gender, age or achievement levels to date. Also the research questions which drove this study did not focus on any of these factors. In all there were thirty five PSTs involved initially (25 females and 10 males). By the end of the study, this number was down to twelve participants (11 females and 1 male) due to dropout that, as mentioned, is often considered to be a possible limiting factor in longitudinal research. After the first phase of data collection, the participants were given the option of withdrawing from the study as it was felt that full commitment would be needed from participants.

The CoRe workshops and focus group semi-structured interviews with the PSTs all took place in the University of Limerick. On average a topic took four hours of
which 2 x2hrs a week was allotted to facilitate the completion of each CoRe. It is important to note here that as the participants became more familiar with the process, the CoRe sessions went on for longer. It can be hypothesised that the reason for this was related to the increased discussion within the PLC and their developing familiarity with the process. All classroom observations took place in the schools to which the participants were allocated to as part of their teaching practicum. The schools were relatively well distributed across the country and involved all types of schools ranging from community to vocational schools. The participants were observed when they were teaching one of the topics from which a CoRe was developed on. The reason for the limited number of observations was due in part to the unpredictability of lessons each week in terms of topic, visits for teaching practicum tutors coinciding with planned visits and contextual factors in the school like cancellation of classes due to school concerts, fairs and exams. Also permission had to be sought from the principal in order to enter the school to observe and on a small number of occasions the principal was unavailable to give their permission.

4.4.3 Research Methods-Use of Interviews

While involvement in the CoRe workshops was the primary source of data collection, interviews did take place to answer particular research questions. Interviews afford the participants the opportunity to discuss their interpretations of the world in which they live and in turn present their own view of a given situation (Cohen et al. 2011). In other words they help to capture participants’ (social) construction of meaning (Burr 2003).

The interviews, both individual and group, would have been semi-structured in nature (Cohen et al. 2011). The individual interviews served as PaP-eRs and will be discussed in section 4.4.5. Within an interview setting, there is a certain control over the proceedings but there is still flexibility for the interviewee to be given a certain amount of space for spontaneous contributions (Cohen et al. 2011). The interviews in this study would have been typed as an interview guide approach where the participants are aware of the topics or issues for discussion and the interviewer decides the sequence of the conversation and asks the questions within the interview setting (Patton 2002). The strengths of such an approach relate to an increase in the
comprehensive nature of the data collected together with the reduction in perceived
gaps in the data with the interview remaining conversational in nature (Patton 2002).
The major weakness of this approach would be the possibility of important topics
being omitted from the discussion. That was not the case in the current study as the
order of questions were developed around the research questions meaning that all
important issues/topics related to the research questions were under discussion.

The interviews were carried out on both an individual (after classroom observations)
and collective level (using focus groups) at varying points in the study (see
appendix F and G for the list of questions asked). Focus groups are
methodological tools that have been used since the 1940s and have been an integral
part of social science ever since (Stewart and Shamdasani 1990). A focus group is an
interview with several people on a specific topic/issue, usually with at least four
people in the group. This method is conducted under the pretence that all persons
involved possess views and attitudes that are socially constructed and are not formed
within a vacuum, devoid of any social experiences (Marshall and Rossman 2011). It
is a method intimately linked with the social construction of reality as those involved
in the group provide their own experiences, knowledge and values related to the
topic under investigation. Often the persons involved share certain common features
or characteristics, which allow the participants to be involved in a particular
discussion of a common topic (Wellington 2000). It focuses on how individuals
discuss a certain issue as members of a group instead of as individuals.

**Benefits of using Focus Groups**

There are a number of benefits to using focus groups aside from those mentioned
previously. Focus groups would be seen as a dynamic and synergistic means of
encouraging participants to speak and react to comments made by other participants
(Stewart and Shamdasani 1990). This results in the more likely scenario where the
researcher ends up with realistic accounts of what people think (Wellington 2000).
Members of a focus group can also feed off one another’s contributions and can
stimulate each other into new thinking, therefore creating a conductive environment
(Wellington 2000). The use of focus groups allows the researcher to develop an
understanding of why people feel the way they do and it allows participants to probe each other’s reasons for holding a certain view. Participants can bring issues in relation to the topic to the fore which they deem to be important or significant (Wellington 2000). As the members of the group have common characteristics, e.g. they may all be teachers, a synergic situation is created between the members of the group in their interactions and this can create a better insight into an interview (Wellington 2000). The results of a focus group are often easy to understand which is critical for easy analysis of the data (Stewart and Shamdasani 1990).

A focus group is seen to be less artificial than other methods as the setting is more natural when compared to an artificial experimental situation (Marshall and Rossman 2011). They are also seen to be less intimidating than a one to one, researcher to participant interview (Marshall and Rossman 2011). Also the cost compared to using other methodological tools is relatively low as these group interviews take place in the one location (Marshall and Rossman 2011) and can foster a huge amount of information from one session. Focus groups are also very flexible as they can be used to discuss a wide range of topics from participants with similar fields of interest (Stewart and Shamdasani 1990).

**4.4.3.1 Conducting a Focus Group**

Smaller groups are more suitable when it is anticipated that participants are likely to have contribute substantially to the subject, most likely when they have an emotional attachment to the topic. However groups should not be too small as it is necessary to capture as much diversity as possible. Also, experience has proven that if smaller groups are utilised, they may be dominated by one or two members of the group. While if larger groups are chosen, they are difficult to manage and may inhibit the participation of all members of the group (Stewart and Shamdasani 1990).

**Moderator’s Role**

Understandings of the group dynamics may help the researcher/ moderator to anticipate the potential problems that can arise during the focus group meeting and they may be able the design ways of controlling and reducing the disruptive
behaviour of group members who are becoming emergent leaders and prominent speakers in the group (Stewart and Shamdasani 1990).

The researcher/moderator has an essential role in ensuring that the discussion of the focus group runs smoothly (Stewart and Shamdasani 1990). The researcher/moderator also needs to be able to pick up on points that have not already been highlighted by the other participants.

4.4.3.2 Limitations of Focus groups

As mentioned previously, there are a large number of advantages to using focus groups but some of these advantages may also have associated dangers and limitations (Stewart and Shamdasani 1990):

- The generally small number of participants in focus groups limits generalization of the larger population.
- Less control of the researcher over proceedings. Time can be lost if irrelevant issues are discussed. There is a delicate balance between over control and lack of control during the session.
- Recordings are very time consuming to transcribe.
- Tendency for two/ more participants to speak at the same time- needs careful management or the problem of an over-prominent speaker.
- Participants for whatever reason may feel that they have to conform to the general views of the group so as not to be challenged by their views.
- The researcher/moderator may consciously or subconsciously bias results by providing prompts to the participants about what types of responses are desirable.
- The “live” nature of the engagement between the members of the focus group and researcher may lead the researcher to have greater faith in the findings that is actually merited.

(Stewart and Shamdasani 1990)

The author was fully aware of these disadvantages both when conducting the focus groups and during the analysis of the data. Again these disadvantages require the
Some disadvantages required more practical action to be taken during the focus group discussions. For example in regards to having an over-prominent speaker, individual PSTs were asked their views if it was felt that they were not contributing to the discussion.

### 4.4.4 Research Methods- Use of CoRes

The CoRe and the PaP-eR were identified in the previous chapter as providing a lens into the PCK of individuals both from an espoused (CoRe) and enacted (PaP-eR) orientation. The CoRe template is provided again in Figure 4.2.

![Figure 4.2 CoRe Scaffold](image)

Teachers construct a CoRe by answering a number of framed questions. A CoRe is a research tool for accessing and representing science teachers’ understanding of the content (Loughran et al. 2006). As well as its methodological role, the CoRe can serve as a professional development tool for teachers since the act of articulating PCK can help develop a teacher’s PCK (Loughran et al. 2006). More recent attempts to have pre-service science teachers construct CoRes individually have proven to be fruitful experiences for those involved (Bertram and Loughran 2012).
The main purpose of a CoRe is to codify the teachers’ knowledge across the content area that is being examined, which allows one to see what level of understanding each teacher has (Loughran et al. 2006). CoRes are mainly developed in groups and PaP-eRs are individual representations (Loughran et al. 2004). The reason for this difference is due to the fact that complementary aspects of PCK can be examined through group exploration as well as individual exploration; therefore, as suggested previously, PCK can be a socially constructed phenomenon (Loughran et al. 2004).

4.4.5 Research Methods- Use of PaP-eRs

While knowledge can be socially constructed, it is important to conceptualise individual knowledge based on individual practices. As mentioned in the previous chapter, a PaP-eR relates to teaching the content within the classroom context and illustrates individual aspects of PCK in action. PaP-eRs are developed from detailed descriptions offered by individual teachers, and/or as a result of discussions about situations/ideas/issues relating to the CoRe, as well as classroom observations, interviews (Loughran et al. 2006) and lesson plans. A PaP-eR is further developed through the interaction between “prompts, questions, issues and difficulties that influence the particular approach to teaching that content to which the PaP-eR is tied and reflects the richness of the teacher’s understanding of science teaching and learning in that field” (Loughran et al. 2004, P.377). Therefore the classroom observations, interviews and lesson plans will serve as a window into the PSTs’ experience of teaching the content in the classroom context and will help determine whether the PSTs socially constructed meaning of scientific inquiry does translate into classroom practice.

Lesson plans served as a form of artefact collection. Artefacts can be used to convey even implicit messages and have been shown to be useful in educational research (Cohen et al. 2011). Using artefacts, such as lesson plans, is strongly aligned with the promotion of reflexivity in the study as the presence of the participant, as opposed to the researcher, is evident through their work (Savin-Baden and Howell-Major 2013). In saying that interpretations of artefacts can vary widely between researchers (Cohen et al. 2011) and therefore thematic analysis (more later) was used to analyse the lesson plans.
Classroom observations were carried out during two key stages of this research study, when the PSTs were completing their teaching practicum in their 2nd and 4th year of training. These observations were non-structured (Cohen et al. 2011) where the author audio recorded the conversations and took notes throughout the observation. Three observational variables were dominant in this study. They were descriptive, inferential and evaluative (Cohen et al. 2011). Descriptive observation is where the researcher sees something and writes down what is happening, there is no inference making done on the part of the researcher. With inferential observation the researcher makes inferences about what is observed and the underlying emotion. In some cases the researcher makes an inference and a judgement on the behaviour, this is called evaluative observation (Cohen et al. 2011). The observation variable depended on the situation and the instructional strategies employed by the teacher.

**Strengths of Using Observations**

Observations are a way of gathering data by looking at behaviour, events, or noting physical characteristics in a participant’s natural setting (Cohen et al. 2011). They are a way of gathering “live” data so that the researcher can see the reaction of the participant in a naturally occurring social experience (Cohen et al. 2011). The type of observation that was central to this study was direct observation, where the participant(s) knew they were being observed.

According to Simpson and Tuson (2003), many experienced researchers use observations as a data gathering tool as it brings with it the “sweetest” of data. The reason for this is that observations can give direct access to social interactions in a realistic setting (Simpson and Tuson 2003). In a sense the researcher can get more detailed information from watching the participant in their natural environment than by simply asking a participant how they would do something. This, according to Simpson and Tuson (2003), is because there may be times when people do not tell the researcher all that is relevant in a given situation for a variety of reasons like deliberately withholding information or forgetting to mention something. An additional strength of using observations is that it can enrich and add substance to data collated by alternative means (Simpson and Tuson 2003).
Weaknesses of Using Observations

Simpson and Tuson (2003) propose there to be two main weaknesses associated with using observations. They include the time, resources and effort needed to undertake observations and also the potential observer bias of the researcher. The first perceived weakness was not an issue in this study as the lessons observed were selected based on whether a CoRe was developed on the topic. The PST had to be teaching one of these topics, assigned by their co-operating teacher, and in fact it was the case that only a small number of classes could be observed. Also other factors such as difficulty in getting permission from the principal and lack of communication from the PST led to a limited number in the classes observed. Observer bias was avoided as the author literally wrote down point by point everything that happened in the class and also had audio recordings to help with later analysis. Simpson and Tuson (2003) noted that observe bias happens when the researcher records what he or she actually thought as opposed to recording what actually happens, therefore the technique the author used helped reduce the likelihood of observer bias.

Another disadvantage is the participant may be reacting to your presence (Cohen et al. 2011) and may be teaching according to how they think you want them to teach (Hawthorne effect). However the triangulation with lesson plans and interviews could help alleviate the potential for this effect.

4.4.6 Quantitative Data Collection- Self Administered Survey

Case study research can use a combination of data collection tools including surveys (Gray 2004). Surveys can be used on a “one shot basis” to represent a wide target population (Morrison 1993). Most surveys are conducted using questionnaires and in education a researcher often uses a survey to gather data in order to get a large representational sample size to give some degree of statistical certainty that observed characteristics occur with an element of certainty (Cohen et al. 2011). Surveys can be exploratory or confirmatory with an exploratory survey developed with no assumptions or hypotheses considered beforehand (Cohen et al. 2011). A confirmatory survey however seeks to test a specific hypothesis that the researcher has generated before developing the survey (Cohen et al. 2011). They can also be
descriptive or analytical with the former simply describing data on the variables of interest while the latter examines relationships between variables (Cohen et al. 2011). This study employed a confirmatory, analytical survey.

When planning a survey, it is important to consider a number of factors which influence the design of it. Factors include deciding what the purpose of the survey is, the population that is being tested in the survey, the resources available and the mode of collection (Cohen et al. 2011). Cohen et al. (2011) proposes there to be several stages that a researcher goes through when using a survey as the chosen research method:

Stage 1: Define the objectives
Stage 2: Decide the kind of survey- cohort survey
Stage 3: Formulate the research questions and the null and alternative hypotheses
Stage 4: Decide the issues on which to focus
Stage 5: Decide the information that is needed to address these issues
Stage 6: Decide the sampling requirements
Stage 7: Decide the instrumentation for data collection
Stage 8: Develop the instrumentation
Stage 9: Decide how the data will be collected- through mail or internet
Stage 10: Pilot the instrument and refine if needed
Stage 11: Collect the data
Stage 12: Analyse the data
Stage 13: Report the results

There are a number of advantages to using surveys in research. Surveys are seen to be low cost in terms of money and time. Closed questions can be readily analysed as the answers to the questions can be coded quickly (Gray 2004). They are also seen to be more convenient for respondents because often they can complete the survey when they want and at the speed they want to go (Bryman 2008).
Challenges of using Surveys

Like any research tool, there are a number of challenges to using surveys including poor question design/wording and incorrect or biased responses (Cohen et al. 2011). Often they are carried out in the absence of the administrator of the survey so there may not be a person present to help participants if they are having difficulty answering a question and also there is no opportunity to probe respondents to elaborate on an answer (Bryman 2008). There is also a greater risk of missing data as only partial answering of questions is more likely. Thirdly, the response rate may be lower and with this there is a risk that bias in the findings will be greater (Bryman 2008). A classification band for response rates with postal surveys was provided by Mangione (1995) who suggest the following bands:

- Over 85% excellent
- 70-85% very good
- 60-69% acceptable
- 50-59% barely acceptable
- Below 50% not acceptable

Response rates can be improved by including a stamped addressed return envelope if the survey is disseminated by post, following up with potential participants, having as short a survey as possible and having clear instructions and an attractive layout (Bryman 2008). Whilst having open questions is important, Bryman (2008) stresses the point of having only a small number of open-ended questions as people are often deterred from completing a survey if asked to write a large amount. Cohen et al. (2011) also considers that the time in the week in which a survey is sent out can have an impact on the response rate. They suggest that if sending out a survey to an organisation, then posting the surveys on a Monday or Tuesday is recommended.

4.4.7 Site, Setting and Participants- In-service teachers

This part of the study was carried out in collaboration with the National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL), now referred to as EPI•STEM, the National Centre for STEM Education. Collaboration was sought because of the large database of schools which the centre would have
access to and because of the centre’s interest in establishing a baseline for inquiry practice in Irish schools. It must be acknowledged that Dr. Jennifer Johnston and Dr. Joanne Broggy, project officers within the NCE-MSTL, facilitated in adapting the survey to the Irish context while Dr. Joanne Broggy facilitated in the piloting and disseminating the survey. In all 94 teachers completed the survey of which 21 were disseminated and collected by Dr. Joanne Broggy, the remainder (N=73) were disseminated and collected by the author.

The participating schools were chosen by random stratified sampling. The intent of random sampling is to select a representative sample from a population (Fraenkel and Wallen 2003). Random stratified sampling involves the population being divided into homogenous groups with each group containing subjects with similar characteristics (Cohen et al. 2011). In this study there were three homogenous groups based on school type, i.e. secondary schools, vocational schools and community and comprehensive schools. In all 85 schools were selected through a national database and were initially contacted through cold calling. 60 schools were contacted by the author and the remaining 25 schools were contacted by Dr. Joanne Broggy. The schools selected were nationally distributed to allow for population generalizability (Fraenkel and Wallen 2003). The teachers who completed the survey were required to be teachers of Junior Certificate science. The reason why teachers of Junior Certificate science were sought was because it was felt that within this cycle there was better opportunity for students to engage in the use of scientific inquiry through Part B of the syllabus (see section 2.1.1).

4.5- Phases of Data Collection

Figure 4.3 provides a synopsis of the research phases:
4.5.1 Phase One- Setting the Scene

For CoRe construction to be viewed as a professional learning opportunity, it was the author’s contention that the PSTs needed to have some experience at developing the CoRes, a view which is echoed in the research on this lens (Hume and Berry 2013). Therefore when the CoRe was adapted in phase two to include more of an inquiry focus, the PSTs already had experience at developing CoRes. Another reason for introducing the CoRe to the PSTs in phase one was to develop a foundational understanding of the PSTs’ inquiry orientations and use this to give direction to proceedings in phase two.

The author does acknowledge that groups of 11, 11 and 12 are particularly large but due to time constraints, the PSTs were only available at limited times, therefore larger groups were required. Each group developed a CoRe on the topic of the particle theory. This process was repeated the following week with the topic of genetics. PSTs engaged in a six week placement where a number of them taught one or both of these topics.

Upon return from placement, the participants constructed a CoRe on the two topics again, in order to gain insight into whether or not their orientations towards scientific inquiry had developed over the course of the six weeks. The author gave particular
attention to having participants who had taught one or both topics whilst in the school to come to these post-teaching practicum CoRe workshops. As Nilsson (2008) suggests, student teachers need to be involved in real classroom situations in order to reflect on and learn from concrete examples.

By the end of phase one a number of changes in the methodology were decided upon:

- Smaller groups were necessary as the experience from phase one showed that some PSTs tended to dominate while others did not contribute to the discussion.
- Participants were filtered by giving them the option of withdrawing from the study before phase two commenced.
- On analysis of the data, it proved difficult to identify aspects of inquiry from the CoRe. Modification of the CoRe in future endeavours was necessary so that it would specifically relate to inquiry. This would make inquiry more visible and allow for more straightforward analysis in relation to professional development around the use of inquiry. It would also explore the potential for using the scaffolded PLC as a means to develop inquiry orientations. The seventh question in the CoRe scaffold was altered as follows:

  **From-** Teaching procedures and particular reasons for using these to engage with this idea
  **To-** Teaching procedures with specific reference to teaching through inquiry

Other studies have focused on targeting each component of PCK in relation to the practice of scientific inquiry ((Nargund-Joshi and Liu 2013) however this author focused on adapting one pedagogical prompt associated with the component of “knowledge of instructional strategies” to scaffold the PSTs thinking. The author did make it clear however that scientific inquiry orientations can be found within all prescribed components of PCK.

**4.5.2 Phase Two- Adaptation of the CoRe**

**Continued CoRe development**
The participants, who were now in the third year of their ITE programme, were broken up into smaller groups (x3) according to the subjects that they wished to cover. For example one group focused on physics topics, while the other two groups focused on either biology or chemistry topics. All PSTs chose topics they felt would be difficult to teach in practice. CoRe workshops ran over the first semester and second semester of their third year in the ITE programme. It would have been ideal to have all groups complete an equal number of CoRes but due to reasons beyond the author’s control it was not possible in the tight window that was available each semester. Participants often had extra tutorials, meetings or fell sick which delayed the CoRe workshops to the following week in many cases. Also to allow the participants to concentrate on their studies, the CoRe workshops for each semester ceased when the participants wanted to focus on their studies, in all cases approximately halfway into the semester. Table 4.4 shows the topics chosen by each group:

Table 4.4: Topics chosen by the PSTs in phase two

<table>
<thead>
<tr>
<th>Group</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (n=5)</td>
<td>Respiration</td>
</tr>
<tr>
<td></td>
<td>The Nervous System</td>
</tr>
<tr>
<td></td>
<td>The Immune System (this CoRe was not completed)</td>
</tr>
<tr>
<td>Group 2 (n=4)</td>
<td>Respiration</td>
</tr>
<tr>
<td></td>
<td>Chemical Reactions</td>
</tr>
<tr>
<td>Group 3 (n=3)</td>
<td>Mechanics</td>
</tr>
<tr>
<td></td>
<td>Modern Physics</td>
</tr>
<tr>
<td></td>
<td>Heat</td>
</tr>
</tbody>
</table>

The author began each of the CoRe workshops in phase two by presenting PSTs with exemplars of published CoRes showing specific examples of inquiry orientations from the CoRes developed by Loughran et al. (2006). This was carried out in order to emphasise that even though the teaching procedures prompt was now adapted to have a greater inquiry focus, inquiry orientations could be found throughout the CoRe.

Phase two was completed by having PSTs share their experiences of being involved in the PLC both from the perspective of their developing inquiry orientations
through social construction as well as the additional professional learning experiences they believed were attributed to this involvement. They were also asked to study an existing CoRe they had developed themselves as well as a published CoRe from Loughran et al. (2006) for evidence of inquiry. At the beginning and end of phase two, the PSTs were asked to write down what they believed scientific inquiry to look like in practice, to capture their living educational theory (Whitehead 1989) of scientific inquiry.

4.5.3 Phase Three- Understanding Inquiry Action in the Classroom

A number of PSTs were observed whilst out on their fourth year teaching practicum experience (n=4). As well as this, PSTs developed lesson plans before teaching a particular CoRe topic. Due to the fact that PSTs had to teach one of the CoRe topics and more specifically a particular aspect from the CoRe in order to develop a PaP-eR, there was restrictions as to what classes could be observed and which lesson plans could be utilised in the collection of the data. Table 4.5 outlines the topics and the source of data collection for PaP-eR development:

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Number collected</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation of class</td>
<td>4</td>
<td>Respiration (n=2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>States of matter (n=1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heat (n=1)</td>
</tr>
<tr>
<td>Lesson plan</td>
<td>22</td>
<td>The Particle Theory (n=12)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Respiration (n=2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanics (n=8)</td>
</tr>
</tbody>
</table>

Three PSTs were also interviewed after teaching to reflect on the observed lesson; two PSTs had taught respiration while one taught content related to the Particle Theory.

**Action of Scientific Inquiry Survey**

This survey was distributed to the PSTs after their teaching practicum experience and to the in-service teachers in the months of November and December (2012). This will be discussed in more detail in the following section.
4.6 Quantitative Data Collection- Survey Distribution

Selection of Survey on the Action of Scientific Inquiry

This survey was originally developed by Campbell et al. (2010) and was known as the Principles of Scientific Inquiry- Teacher (PSI-T) survey. It was adapted slightly to the Irish context with the rephrasing of some of the statements. The reason why the author chose to use an existing survey on the action of scientific inquiry was due to the fact that the process of developing this survey involved a thorough refinement process using a panel of experts in the area of scientific inquiry to review the items, which established content validity within the survey (Campbell et al. 2010). Also the five categories which made up the survey reflected the five features of inquiry which this author has used to develop the coding scheme to analyse the qualitative data. This survey has also been used by others with Dudu and Vhurumuku (2012) successfully adopted the survey to look at the instructional strategies of teachers engaged in teaching practical investigations. Two open ended questions were added to the survey as Bryman (2008) recommends including open ended questions as closed ones tend to be easier to answer and do not provide as much detail.

Additional Participants: PSTs and In-service Teachers

To further extend the idea that this study influenced the practice of these PSTs it was necessary to do a comparison with a control group who were not involved in the intervention to determine change as a result of the intervention. For validity in the results, it was necessary that the control group must share the same composition in terms of background and experience as the group receiving the treatment (Tuckman and Harper 2012). Therefore, it was decided to compare with the remaining PSTs in the 4th year cohort of the BSc degrees with Concurrent Education (n=29).

In-service teachers (n=94) mentioned previously also completed the survey, again for comparative purposes and to determine if inquiry orientations develop naturally with classroom experience. This was important to determine the effect this practice or lack of practice could have on future PSTs understanding of inquiry (apprenticeship of observation). In total 135 participants completed the survey with the response rate for the PSTs standing at 65% (there were 63 PSTs in total registered in Year 4 of the ITE programme) and the response rate for in-service
teachers at 69% which were acceptable response rates according to the Mangione (1995) classification of response rates. The latter response rate was calculated based on the number of schools who agreed to take part in the study versus the number of schools who returned the completed surveys. 47 schools had agreed to have the survey given to them but with 32 schools sending back the survey, the response rate of 69% was calculated.

It is recognised that these sample sizes are fairly small for two reasons. The first reason is that there was only a window of a week to distribute the survey to the PSTs after they returned from their teaching practicum experience. It had to be distributed in a tutorial class which a number of pre-service science teachers chose not to attend. This was the last tutorial of the semester and the author could have waited until the following semester to perhaps get a better response rate but as this was under two months later, the author felt that the PSTs would not be able to recall their practice on teaching practicum sufficiently to allow for an accurate response.

The small number of in-service teachers is actually consistent with the samples sizes of similar surveys with 88 in-service teachers completing the survey distributed by Campbell et al. (2010). The reason for this small sample size is due to the on-going difficulty in getting teachers to complete surveys in Ireland (Fitzpatrick 2013). In total the response rate was from 32 schools out of the 85 schools contacted with an average of 3 teachers from each school returning their completed surveys.

For recruitment of the in-service teachers, initial contact was made with the principal of the school and if they agreed to allow the survey to be sent out, a point of contact within each school was identified. This point of contact was responsible for distributing, collecting and returning the surveys. Each school who agreed to take part received an envelope in the post with the surveys, information sheets, consent forms, a return stamped addressed envelope and a cover letter for the point of contact. A number of schools (n=20) completed the survey and returned it within 2 weeks, however the remaining schools (n=12) returned the survey after a follow up call.
**Information Sheet:** An information sheet was given to both the PSTs and in-service teachers. This information sheet contained brief details on what this survey was investigating together with information on how to complete the survey and the approximate time it would take to complete. Information was also given on the potential benefits of being involved in this research study and also detailed the confidential nature of the data. Contact details of the primary researcher were also given if the participant had any queries in relation to the survey.

**Consent Form:** Each participant had to consent to taking part in the study and was obtained by signing a consent form. Participants were advised that if they wished to withdraw their participation from the study at any time, they were free to do this. They were also informed that they were under no obligation to complete the survey.

**Cover Letter to Point of Contact:** The package delivered to each school contained a cover letter for the point of contact offering instructions on the dissemination, collection and return of the surveys. Cohen *et al.* (2011) stressed the importance of giving the administrator of a survey clear instruction; therefore they were each supplied with a cover letter containing information on the study, their role as the contact person and contact details of the author if they required additional information.

**Piloting the Survey:** Surveys need to be “accurate, unambiguous and simple to complete…piloting is vital” (Gray 2004, p.205). The action of scientific inquiry survey was therefore piloted prior to distribution with a number of pre-service (n=6) and in-service teachers (n=8). As mentioned, the survey contained closed and open questions. The closed questions took the form of twenty statements with a Likert scale response system with the following responses: almost never, seldom, sometimes, often and almost always.

The survey also contained a selection of open questions which allowed the researcher to clarify answers to closed questions and to generate ideas (Gendall *et al.* 1996). The purpose was to firstly understand what the participants defined scientific inquiry to be in practice and secondly to get an idea of what enabled or prevented
them from using inquiry in their classroom. Also research has shown that providing adequate space for participants to write their responses results in them writing more words and offering more ideas when responding to open-ended questions (Gendall et al. 1996). Therefore when designing the survey, three quarters of the last page of the survey were dedicated to answering the two open-ended questions.

The validity of the PSI survey used in this study had been tested previously in the literature through content analysis, testing for internal consistency using Cronbach’s coefficient alpha which was 0.91 and through exploratory factor analysis which measured if the instrument items were grouped together correctly to measure the principles of scientific inquiry. The open-ended questions added to the study were developed in collaboration with three critical friends. This existing survey was then piloted in the Irish context to establish feedback and small changes to wording were advised by the pilot group.

4.7 Ethical Considerations

It is the role of the researcher to act in a morally responsible way. According to Kvale and Brinkmann (2009) a morally responsible behaviour in research is more than just abstract ethical knowledge and cognitive choices; it reflects the moral integrity of the researcher, their sensitivity and their commitment to moral issues and action.

It was necessary to give the participants pseudonyms when presenting the data. It was important that the participants be given an information sheet on the research and a consent form that they needed to sign if they wished to take part in the research. Once the sessions were complete, participants still had the chance to withdraw their involvement. It was imperative for the researcher to inform the participants of their right to withdraw and this was indeed highlighted on the consent form and information sheet given to each participant. This study received ethical approval

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11 In the presentation of the findings in chapter 5, the PSTs who remained on in the study for phase two or who were observed were given pseudonyms. The remaining participants were referred to as a PST within their particular group i.e. PST-Group A
from the Ethics Board within the University of Limerick (See Appendix A for sample information sheet and consent form).

4.8 Data Analysis- Qualitative Data

A reflexive approach to analysis requires navigation between the paths of realism and relativism, deconstruction and reconstruction (May and Perry 2014). It essentially forces the researcher to internalise what is a true representation of social reality in a bid to break down and interpret the meaning of interactions between participants as they construct their reality. Analysis of data involves some kind of transformation of data into “clear, understandable, insightful, trustworthy and even original analysis” (Gibbs 2007, p. 1). With this in mind it is imperative that the published findings are accurate and representative of the field of inquiry (Kvale and Brinkmann 2009).

Before beginning the process of analysing the data, it was necessary to transcribe all of the audio recordings. The quality of transcription is paramount to ensuring all the necessary information can be extracted from the interview proceedings. Etherington (2004) speaks of the importance of the researcher transcribing their own material so that they can remain close to the speakers’ meaning. This will create a reflexive positioning where the researcher is aware of their own personal responses and how they in turn use these responses. Transcriptions are constructions from a conversation that took place (i.e. the interview) to a written text (Kvale and Brinkmann 2009). The CoRe workshops were transcribed verbatim as were the classroom observations and interviews (individual and focus group).

Gillman (2000) notes the importance of not tempting to rush into the analysis and theorisation of the data at an early stage and stresses the importance of a case study researcher keeping an open mind during all stages of analysis. A case study database is also advised (Yin 2009), therefore the utilisation of N-Vivo allows for all the data to be synthesised into one place which in turn would allow for accurate coding and comparison of data. However as Wilkinson and Birmingham (2003, p.75) advise, a researcher needs to be cautious when using computerised analysis packages as “it cannot think for itself and contextualise words as a researcher might”. Therefore it is
important to only use the analysis software as a place for organising data to allow the researcher to immerse themselves in the data analysis.

Both thematic and discourse analysis were used at varying stages in the data analysis process and will each in turn be discussed.

**Thematic Analysis**

A thematic analysis approach (Braun and Clarke 2006) was utilised to analyse the CoRes, lesson plans, interviews, living educational theory of inquiry, open-ended survey questions and observations as this approach was seen as being most useful with helping to gain an understanding of meanings. This approach identifies themes which capture something of importance to the data in relation to the research question (Gray 2014). Braun and Clarke (2006) consider two forms of thematic analysis, inductive and theoretical. The former allows for themes to emerge from the data themselves and provides for open coding of the data (used for the semi-structured interviews and open-ended survey questions). While theoretical thematic analysis emerges from the researcher’s theoretical stance where this framework directs the coding of the data (used to analyse the CoRes, living educational theory of scientific inquiry, lesson plans and observations). The coding scheme pertaining to this analysis will be discussed in due course.

**Discourse Analysis**

The interactions between the pre-service teachers within the PLC (RQ.2) were analysed using discourse analysis. In order to answer part of this research question, the author sought to understand how the interactions between the pre-service teachers facilitated them constructing an understanding of scientific inquiry, therefore analysis of the dialogue between the participants was necessary. A discourse provides a frame of reference, a way of interpreting the world (Burr 2003). Therefore discourse analysis rejects the view that language is simply a medium which reflects “reality”, it understands a person’s constructs which are embedded in socially constructed situations (Gray 2014), i.e. the PLC within the current study. It can also be used to investigate the processes of social construction (Philips and
Hardy 2002) and is therefore key to a study focused on the social construction of reality.

4.8.1 Conversion of the audio transcripts to the CoRes
Hitchcock and Hughes (1995) note that a typical feature of qualitative data is the presence of vast quantities of seemingly unmanageable data. To that end it was necessary to transform the data from the transcripts into more manageable material by filling in the data around the CoRe scaffold. It is important to note that after each CoRe was developed, it was reviewed for approval by the cohort of PSTs who were involved in the CoRe workshops. This is referred to as a member check (Etherington 2004) where participants check that the researcher’s interpretations are correct.

4.8.2 Coding
Coding is the arrangement of data into a systematic order for the purpose of categorising the data into specific themes (Saldana 2013) which ultimately gives the researcher a focus for thinking about the text and its interpretation (Gibbs 2007). The construction of the thematic coding system followed a framework analysis approach in which the researcher builds up a list of key thematic ideas developed from reviewing the literature and reading some of the transcripts before applying codes to the text (Gibbs 2007).

The thematic coding system reflected some of the components of PCK as described by Magnusson et al. (1999) with an extended focus on instructional strategies. Previously, a number of researchers using the CoRe tool in their studies (Williams and Lockley 2012; Hume and Berry 2011) have analysed their data using the PCK model conceptualised by Magnusson et al. (1999) as their guiding framework. To that end, the author in the current study chose to follow on this approach because of the extent to which it has been used in relevant studies. To uncover scientific inquiry thinking, the data was coded for inquiry using the features of inquiry action described by Campbell et al. (2010) all from the perspective of the student doing the following:

1. Asking questions/framing research questions
2. Designing investigations
3. Conducting investigations
4. Collecting data
5. Drawing Conclusions

The reason why these components were used was to increase the validity of the data analysis during the triangulation process. Having both the qualitative and quantitative data analysis looking for the same features increases the validity of the process (Cohen et al. 2011).

Table 4.6 reveals the coding scheme used for the analysis of the CoRes, lesson plans, living educational theory of scientific inquiry and classroom observations.

Table 4.6: Coding scheme used in the analysis of research questions 1, 2 and 3

<table>
<thead>
<tr>
<th>Category</th>
<th>Subcategory (where necessary)</th>
<th>Related code</th>
<th>Research Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientations towards Science Teaching</td>
<td></td>
<td>Beliefs about Scientific Inquiry</td>
<td>1,2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Values related to Scientific Inquiry</td>
<td></td>
</tr>
<tr>
<td>Knowledge of alternative instructional strategies</td>
<td>Didactic, teacher-led instruction</td>
<td>Teacher talk</td>
<td>1,2,3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Textbook</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Whiteboard</td>
<td></td>
</tr>
<tr>
<td>Knowledge of scientific inquiry</td>
<td>Innovative teaching strategies</td>
<td>Project-based learning</td>
<td>1,2,3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Design-based learning</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Problem-based learning</td>
<td></td>
</tr>
<tr>
<td>Knowledge of scientific inquiry</td>
<td>Asking questions</td>
<td>Thinking about questions</td>
<td>1,2,3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Refining questions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Predicting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Designing investigation</td>
<td>Designing</td>
<td>1,2,3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evaluating</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adapting</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Teacher</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student</td>
<td></td>
</tr>
</tbody>
</table>
The author decided to code for frequency when looking for the features of inquiry as opposed to coding for incidence as this would give a better indication of the importance given to the concepts in the text (Wilkinson and Birmingham 2003). The author developed the coding scheme and then tested it by immersing themselves in the data to examine how well it helped to answer the research questions. The coding scheme was then given to a co-coder for consultation. Appropriate adaptations to the framework were made and analysis commenced using this validated coding scheme.

**Open Coding used to answer the remaining research questions**

Step 1- The audio was transcribed and during this transcription process, points of interest were highlighted by the author. In relation to the survey, the author during the initial analysis noted similarities in the participants’ responses.

Step 2- Specific themes then were developed from these points of interest and using N-Vivo, the data was sorted according to these themes.

4.9 Data Analysis- Quantitative Data

The quantitative data was analysed using Statistical Package for the Social Sciences (SPSS) version 20. For the PSI survey analysis, it was decided to combine the responses “almost never and seldom” into “rarely” and the responses “almost always
and often” into “frequently” with the other response remaining as “sometimes”. This was as a result of some initial tests where the difference in size between the cohorts was affected by the small representations in some of the cells. This decision was made in consultation with a statistician.

Of interest to the researcher was the description of the non-parametric data for frequencies, percentages and mean of the sample. The data was first analysed for descriptive frequencies and then cross-tabulation was conducted with the different cohorts in the study. Chi-square tests were carried out for each of the twenty questions asked in the survey to understand whether there were significant differences between the cohorts. In statistical analysis, the researcher must consider the alternative hypothesis and the null hypothesis. The null hypothesis in this case would be that there is no statistically significant difference between the cohorts for actions of scientific inquiry. If the hypothesis is statistically significant, this null hypothesis is rejected and the alternative hypothesis is accepted; there is a statistically significant difference for action of inquiry between the cohorts.

It was decided to get an average perspective of the responses for eighteen of the twenty questions. If the responses to these questions were “frequently” then this revealed a positive response to the action of inquiry. The remaining two questions were geared towards the teacher carrying out the task, which would not be seen as an essential feature of inquiry. A One way Anova test was carried out to evaluate statistically significant differences between the cohorts in relation to their average action of inquiry. It was found that there was a significant difference of \( p=0.002 \), therefore accepting the alternative hypothesis; that there is a statistically significant difference in relation to the average action of inquiry between the cohorts. However this test did not identify with which groups there was a difference, therefore a number of other tests were carried out (Tukey HSD, Bonferroni and Tamhane) and these revealed that there was a significant difference between the case study PSTs and the other two cohorts. More interestingly, there was no significant difference between the non-case study PSTs and the in-service teachers. The \( p \) value represents the statistical difference between groups and if the \( p \) value is \(<0.05\) then this shows statistical difference. If the value is less than 0.01 or 0.001 this is even stronger
evidence in favour of the alternative hypothesis. Table 4.7 outlines the P-values between the different cohorts:

Table 4.7: P-values for the average action of inquiry between cohorts

<table>
<thead>
<tr>
<th>Teacher compared with</th>
<th>Significant difference (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) PST not in study (n=29)</td>
<td>PST in study</td>
</tr>
<tr>
<td></td>
<td>In-service teacher</td>
</tr>
<tr>
<td>(2) PST in study (n=12)</td>
<td>PST not in study</td>
</tr>
<tr>
<td></td>
<td>In-service teacher</td>
</tr>
<tr>
<td>(3) In-service teacher (n=94)</td>
<td>PST not in study</td>
</tr>
<tr>
<td></td>
<td>PST in study</td>
</tr>
</tbody>
</table>

The author does recognise that there were vast differences in terms of the sample sizes however during analysis the data was presented according to the percentage figure representative of the individual cohorts. For example, if 50 in-service teachers chose a particular response and 5 PSTs involved in the study chose the same response, this was represented as 53% and 42% respectively.

4.10 Summary of the Limitations of the Study

The main limitations of the study will now be presented with reference to how action was taken to prevent these impacting on the key findings from the study.

Limited number of PaP-eRs developed

The small number of PaP-eRs developed would be seen as a limitation of the study but it was largely outside the control of the researcher due to logistical reasons, performance pressure and time limits mentioned previously. However in presentation of the findings the author has been clear to only tentatively offer conclusions drawn from the PSTs enacted PCK.

Sample Sizes in the Qualitative Data

Only small cohorts were available to engage in the CoRe development after the six week teaching practicum experience due to time constraints and exam pressures. Also the requirement was that the PSTs had taught either the particle theory or
genetics while on school placement. The author counteracted this by analysing and presenting the CoRes developed by the same PSTs before and after the teaching practicum experience. Before the pre-practicum CoRes were developed, a number of PSTs had been assigned their topics by their respective schools and so efforts were made to place these in the same group. Another limitation was the disproportional size of the groups in phase two; this was the case due to timetabling, subject preference and other logistical issues. However all groups showed evidence of developing inquiry orientations so the author does not believe this to be an issue when focusing on the overall aim of the research study.

The dropouts may be viewed as a limitation that can affect the internal validity of the findings (Yin 2012). However it is important to note that the dropout of PSTs occurred after phase one only. The research question attached to phase one was only answerable through the findings within that phase. The findings from phase one mainly informed the direction of phase two but did not directly link with the PSTs’ responses in the different phases. In other words, no pattern was examined between the first two phases. Boys et al. (2003) suggest that attrition rates are only an issue to internal validity if the researcher is seeking patterns between different phases within a study, for example if a researcher includes pre and post-tests as their research methods. Therefore it can be considered that the attrition rates did not overly affect the authenticity of the findings within the current study.

Additionally it can be argued that those who remained on in the study were able to commit their participation which suggests that they provided full and positive engagement with the CoRe workshops. This may not have been the case for those who wished to drop out of the study after phase one. So in a sense having some PSTs withdraw their participation can actually be viewed positively in the context of a study so heavily focused on human experience and response.

**Issue of Generalisations**

It must be noted that there have been few case studies of generalisation reported in the research literature (Murakami 2013). Stake (1995) considers the notion of “petite generalizability” (p.7) where consideration is given to how these generalisations are
reflective of a specific case in a particular situation. Indeed Stake furthers this idea by suggesting the notion of particularization not generalization where the researcher in their endeavours comes to understand a particular case and is not concerned with how it is different from others but what it does, what is unique about it (Stake 1995). Qualitative research in general lacks the potential for generalisations but the findings from such research can be rich given the in-depth study of human mind and action.

**Sample Sizes in the Quantitative Data**

The disproportional representation of cohorts within the survey collection may be viewed as a limitation. It was decided that in order to get as many respondents as possible, the author would strive to collect as many surveys as possible, particularly from the in-service teachers with the aim of gaining a national representation. However the author believes that this disproportion was recognised in the analysis of the data by getting the percentages representative of each group (e.g. 6 of the case study pre-service teachers (out of 12) was represented as 50% but 14 out of the 28 non-case study group were represented also as 50%) and so does not affect the findings from the survey. Concerns over the reliability of presenting data in this way were alleviated through consultation with a statistician.

Finally, the author had intended on getting a baseline representation of scientific inquiry in Irish post-primary schools however the sample size of 94 does not mirror a nationally representative figure when compared with other baseline investigations. So while the survey data does provide a comparison with the case study cohort, it does not necessarily provide a baseline, national representation of teachers’ practice. This limitation is reduced in significance with the focus of the research question on comparisons between cohorts not in gaining a baseline representation.

**4.11 Chapter Summary**

This chapter can be summarised as follows:

- The ontological positioning of the author is a realist and a pragmatist
- The author holds a worldview of the importance of social constructionism both from the perspective of research and knowledge generation
- A qualitative mixed methods design was used in this study
- Research methods included the use of interviews, CoRe workshops, lesson plans, classroom observations and a survey
- The author's awareness of the potential data threats because of her biases, interests and role was put forth as well as how the author sought to maintain an objective position throughout the study process and subsequent write-up
- Validity and reliability tests were presented
- Ethical considerations were made
- Description of the site and participants were outlined
- Limitations of the study were considered
- This study includes three key phases (1) Introduction to a PCK lens- Setting the Scene (2) Using an adapted PCK lens within a PLC to allow for the social construction of inquiry orientations and (3) Determining whether the perceived developing inquiry orientations have translated into classroom practice.
Findings Part A: Setting the Scene: Exploring the Pre-service Teachers Foundational Inquiry Orientations
5.1 Introduction
The following chapter explores the PSTs’ orientations towards scientific inquiry, embedded within their PCK, prior to, during and after a six week teaching practicum experience. Pre and post-practicum CoRes, as well as classroom observations pertinent to the two topics, the particle theory and genetics, are presented individually. As mentioned in the previous chapter, the participants were divided into three groups. The author has chosen to focus on a Particle Theory CoRe developed by one group of PSTs before and after their teaching practicum and a Genetics CoRe developed by another group of PSTs. Presentation of the other CoRes are excluded on the basis that members of the other groups either (1) were not available after their teaching experience to engage in the CoRe workshop or (2) they did not teach either topic while on their practicum experience. These are available for view however in appendix B. Where appropriate, dialogue extracts from the other group workshops held before the six week classroom experience are included.

All of the CoRes were reviewed by the PSTs to determine whether they were an accurate representation of their contributions during the workshops. The focus of this chapter is to present a foundational understanding of the PSTs inquiry orientations.

5.2 Particle Theory CoRe developed pre teaching practicum (Cohort A)
Table 5.1 presents the CoRe developed following the extraction of the key content from the transcript. The author led the discussion by presenting the pedagogical prompts after each Big Idea was considered. Following the presentation of the CoRe, analysis of the PSTs’ orientations towards scientific inquiry are explored in more depth.
Table 5.1: Particle Theory CoRe developed before teaching practicum experience (n=12) – Cohort A

<table>
<thead>
<tr>
<th>What do you intend students to learn about this idea</th>
<th>Everything is made up of matter</th>
<th>States of matter</th>
<th>Changes of State</th>
<th>Elements, Compounds and Mixtures</th>
<th>How elements bond together to make compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different arrangement of solids, liquids and gases in particles.</td>
<td>● Three states of matter</td>
<td>Why do they change: what causes them to change? How they can change. How different materials/chemicals will have a different way of changing state.</td>
<td>● Everything is made up of them</td>
<td>Elements do not break down but compounds do. How do compounds break down.</td>
<td></td>
</tr>
<tr>
<td>It helps them to know the properties of the states of matter.</td>
<td>Basis for future information.</td>
<td>Some experiments require water only to evaporate - e.g. salt and water mix. Boiling point.</td>
<td>They have done matter already so now it can be broken down further. Everything is made up of elements, compounds and mixtures.</td>
<td>Basis for future chemistry. Hard to understand how all the things around them are made of elements, compounds etc. but now can show how things are made up of elements and they join together to make compounds. Things do not exist by themselves but all around them are chemicals and reactions happening all the time.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Everything is made up of matter</th>
<th>States of matter</th>
<th>Changes of State</th>
<th>Elements, Compounds and Mixtures</th>
<th>How elements bond together to make compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulties/limitations connected with teaching this idea</td>
<td>• Abstract</td>
<td>• Abstract—cannot see gas or the particles in general</td>
<td>Different chemicals freeze at different points. Hard to show other chemicals: easy to show water.</td>
<td>Low prior knowledge: trying to explain that all atoms are the same would be confusing. They cannot see them. Definitions are similar therefore would be hard to remember. Very abstract—difficult to relate to.</td>
</tr>
<tr>
<td>Knowledge of students thinking which influences your teaching of this idea</td>
<td>• Prior knowledge</td>
<td>• Abstract—cannot see gas or the particles in general</td>
<td>• Relate to daily life</td>
<td>• Prior Knowledge</td>
</tr>
<tr>
<td>Other factors which influence teaching of this idea</td>
<td>• Expectations of the students</td>
<td>• Abstract—cannot see gas or the particles in general</td>
<td>• Concrete to abstract examples</td>
<td>• Misconceptions</td>
</tr>
<tr>
<td>Teaching Procedures (and particular reasons for using these to engage with this idea)</td>
<td>PowerPoints/ICT: better than reading out of book. Giving examples of each, ice for solid, water for liquid and steam for gas so they can visually see it.</td>
<td>• Concrete to abstract examples</td>
<td>Demonstrations: as many as you can. Show kettle with steam: ask questions about what is happening, get them working and figuring it out and get them to</td>
<td>Use Lego: different colours and different arrangements to show elements, compounds etc. Use models: to build up molecules Show food samples</td>
</tr>
</tbody>
</table>

• Abstract

• Prior knowledge

• Zone of proximal development

• Concrete to abstract examples

• Misconceptions

• Expectations of the students

• Concentration levels of students at different times of the week

• Motivation

• Age

• Ability

• Concrete to abstract examples

• Prior Knowledge

• Length of Class Age

• Time and length of the class

• Prior knowledge

• Mixed ability students

• Resources available to show the ideas or experiments

• Resources

• Ability

• All of the other factors mentioned for the other big ideas
Specific ways of ascertaining students’ understanding/confusion around this idea (include likely range of responses) | Ask questions: e.g. true or false questions. | Get them to demonstrate: using marbles. Get students to pretend that they are the particles: arrange themselves in a solid or a liquid or a gas. | Ask for examples of different things changing state. Put up problem on board: ice cream melting/ what is happening here, why is it happening. | Get them to arrange things into whether or not they are elements, compound or mixtures e.g. oxygen and a book. | Ask questions: recap questions and higher order/lower order questions-makes them think outside the box.
5.2.1 Orientations towards Scientific Inquiry

There were some orientations towards constructivist practices but the extent to which these were identified and expanded upon were limited. Interestingly all three groups focused on the abstract nature of the topic as being a potential difficulty or limitation, however pedagogical considerations around this were limited. Hanauer et al. (2009) would consider that scientific inquiry can help students develop a conceptual understanding for more abstract concepts, however this was not considered in the discussion. Visual representations such as showing students actual samples and having images on PowerPoint were contemplated however how these could be used to alleviate the potentially abstract nature of the topic were not discussed. Cohort A mentioned the need to consider the students’ zone of proximal development but this response was not elaborated upon with practical examples. Thereby suggesting a defined understanding of the construct without a deep understanding of how it relates to student learning.

Also with cohort A, there was some evidence of inquiry-based learning (design-based learning) in mentioning the use of models and Lego. However the defined features of scientific inquiry were not evident in the CoRe apart from one example where students had to observe a kettle to develop an understanding of the changes of state. Cohort C also mentioned the use of Lego to illustrate solids, liquids and gases and models to show atomic structure. A comparison with the CoRe developed by cohort B indicates that they would use project based learning for visual learning “Showing steam and showing frozen items- so they can visually see examples- give them a project to construct examples at home” (Extract from the Particle Theory CoRe- Cohort B). They referred to the use of a demonstration with observation showing a “liquid taking the shape of the container” (Extract from the Particle Theory CoRe- Cohort B). Indeed a PST from cohort B further explored the need to use demonstrations in the classroom:

“Being able to demonstrate some of the physical and chemical properties... in a classroom, not being able to show them... it’s a lot harder for people to understand something if they are not shown” (PST-Cohort B)
This suggestion does evoke a degree of reference to scientific inquiry (observation) but there was no allusion to the remaining key features of scientific inquiry such as predicting and drawing conclusions. Also this response appears to emphasise the teacher “showing” as opposed to the student “doing” which again evokes teacher-led orientations. When one compares this with the above CoRe from cohort A, there was more emphasis on the students engaging in research and project based learning.

The strongest reference to the practice of scientific inquiry came from cohort C when they suggested “have students research and come back and tell you what they found out in groups and have them do experiments on the different properties” (Extract from the Particle Theory CoRe- Cohort C). This shows awareness of students researching information and using this information to engage in experiments, both of which would represent features of scientific inquiry. There is also a degree of focus on the social construction of knowledge here by having the PSTs working collaboratively in groups. This was one of the few examples in the CoRe workshops where reference was made to group exploration.

In all, the three cohorts failed to connect the teaching procedures with student learning as they did not give reason to why these strategies could be used to engage with the Big Ideas. They tended to state certain procedures without showing evidence of careful consideration for these. Additionally cohort A spoke of the fact that students “have seen a lot in their daily lives...need to link to real-life”. This shows orientations towards the students observing and drawing conclusions (features of scientific inquiry). Also one of the PSTs, Sam, identified the need to “give them a reason to want to learn, give them practical applications” (Sam). It can be interpreted here that Sam considers the need to link with real-life applications which is seen as an important connection for learning authentic science through scientific inquiry (Dass et al. 2005). However this was not extended on in the discussion of pedagogical strategies.

Cohort A demonstrated predispositions towards the teacher having the power control in the classroom with comments such as “show ideas and experiments” or “demonstrations- as many as you can”. Also during the discussion of the other
pedagogical prompts, there were ideas which reflect teacher-led learning. For example “trying to explain that all atoms are the same would be confusing” (PST-cohort A) suggests teacher explanation in the learning process as opposed to the focus on student-led thinking pertinent to the practice of scientific inquiry.

As scientific inquiry is also reflective of how scientists study the natural world and propose explanations based on evidence, there was no inherent association with modelling the work of a scientist in the construction of the CoRe. An obvious place would be where the PSTs speak of relating to daily (real) life but the mention of science external to the classroom was not considered. Therefore it can be suggested that they connect authentic science only with real-life without considering the daily practices that scientists engage in to develop new knowledge.

5.2.2 PaP-eRs developed related to the topic of the Particle Theory
The following section offers windows into classroom practice with the aim of relating aspects of the developed pre-practicum CoRes to the enactment of processes reflective of scientific inquiry during a six week practicum experience. Three PSTs (Jason, Aishling and Mary) were observed teaching the particle theory. The findings presented will demonstrate two key features (1) the variation in the approaches used and (2) the limited orientations towards scientific inquiry.

**PST One (Jason): Electron Configuration**
The following lesson was based on the topic of electron configuration. Interestingly the PSTs included this in their discussion of the third pedagogical prompt (*what else do you know about this idea that you don’t intend students to learn about yet*). Jason however believed that electron configuration came within the topic of the particle theory. The extracts below reflect a largely didactic lesson.

**Orientations towards Scientific Inquiry**
The lesson was teacher-led with the whiteboard being the main resource utilised in the lesson as evident from the below extract:

*He acknowledged that there were difficulties in (students understanding of) the theory around the atom, electrons and protons and he began to ask questions on*
what atoms were and what was in them. With the answers stated, Jason wrote them up on the board i.e. protons, neutrons and electrons...sometimes writing up his own answers... Next Jason drew a Bohr diagram of the oxygen molecule and filled it in in response to students’ answers... He constructed an empty table on the board to be filled in in response to students’ answers on the charges of the three subatomic particles.

(Extract from Field Notes)

This teacher-led activity is again representative of the general theme of teacher control echoed in the CoRe above. While the mention of whiteboard as the only resource is given, this is not necessarily a bad thing if students are engaged in developing their understanding of the content; however this was not the case in the lesson. Jason did try to ask questions to direct the students thinking but tended to write the perceived “correct” answer without focusing on the students’ responses. Interestingly in the pre CoRe the use of questioning was considered solely as an assessment activity rather than a tool for developing new knowledge so his approaches did not echo the espoused ideas put forth during the CoRe workshop.

In all it can be considered that there was little evidence of scientific inquiry from this lesson.

PST Two (Aishling): Diffusion
The following extract comes from a lesson observed on the topic of diffusion. The only mention of diffusion in the developed CoRe was in relation to a teaching procedure that could be used to teach the Big Idea- States of Matter. However no clear connection was presented in either the CoRe or the observed lesson on how the concept of diffusion can be used to teach students about the states of matter. Aishling also gave a follow up interview in which she reflected on the lesson as a whole and on her use of scientific inquiry.
Orientations towards Scientific Inquiry

There was potential, particularly with the last activity on diffusion, for the lesson to have evidence of inquiry however as the below extract suggests, it was partial inquiry at best:

_Aishling asked what happened to the gas- the students advised that smell could be smelt by people in the other side of the room. Aishling asked a volunteer to spray perfume and asks students to note if they could smell it. She then asked students why they could smell it- class finished with no discussion._

(Extract from Field Notes)

There was evidence of the students predicting the outcome but there was no reference to them collecting data, observing phenomenon and drawing conclusions from the data collected (i.e. proposing explanations based on the evidence derived from their work). The activity also appeared rushed (~4 minutes given) as it was carried out towards the end of the class. The rushed nature of the exercise suggests the limited attention she considered necessary to give to the concept. However Aishling did suggest in the follow up interview that perhaps she should have begun diffusion in the following lesson:

“Am, maybe if I had more time I maybe wouldn’t have introduced diffusion because it was very brief now we did go over it in the next lesson am so I suppose they got the idea and then we were through it in more detail”

(Aishling)

Here Aishling is reflecting on the success of the activity and appreciates the need to spend time teasing out the students’ understanding of concepts instead of rushing through them and allowing only for surface learning. So in a sense she is showing some orientations towards the underpinnings of a scientific inquiry approach. This suggests the importance of reflection in developing one’s PCK and in turn their inquiry orientations. If, for example, Aishling did not reflect on this lesson she may not have positioned herself to consider alternative practices to enhance student learning.
Students did not ask any questions during the class and therefore did not set about answering these questions through investigation. In general, unlike Jason, Aishling did not engage in questioning as a tool to direct students towards learning new material and in turn placed emphasis on questioning as an assessment activity.

**Reflection on the Lesson**

Aishling’s lack of awareness of the importance of developing a deep conceptual understanding of the particle theory can be illustrated when she, in response to a question by the author, shares her belief about the importance of asking questions (which could facilitate deep learning and would be considered pertinent to the process of scientific inquiry):

“*Am, a certain amount like sometimes they’d ask questions and then they’d just go way off topic. Some of the questions are more helpful for the class*”

(Aishling)

Here Aishling is showing her concern about students asking questions and suggests that some questions were irrelevant. This response implies that Aishling is concerned with covering the required material without giving students a chance to engage in additional learning using questioning as the platform for knowledge generation.

She believed that students were “*enthusiastic, interested and there was good participation*” but tended to speak too loudly. She quickly adds to this by suggesting that “*they were talking on topic so they were all kind of enthusiastic about what we were doing*”. Here Aishling is portraying a sense of internal conflict where she recognises that students are engaged and enthused yet is conflicted with the volume of noise in the classroom. However the silent classroom does not necessarily correlate with effective learning and indeed research suggests the importance of collaborative discourse in a learning environment (Zhang 2008). Aishling’s misgiving suggests a weak understanding of the environment that can facilitate student learning and appears to be concerned with the potential classroom management issues attached with personal exploration (construction) of new knowledge.
Reflection on the use of Inquiry

Aishling considered that she used inquiry in the observed lesson through her use of questioning and by having students predicting the outcome. But she did recognise that using inquiry is lesson dependent:

“Am, maybe with my questioning...asking them to predict what was going to happen. Maybe I could have used a bit more...depends on the lesson... I think with the right class, with the right activities it’s very useful

(Aishling)

Here the place of questioning is considered but from the teacher’s position as opposed to the student position and gives value to teacher questioning rather than student questioning, the latter of which is key to an inquiry habitus. It can be implied that because this response is teacher focused it is evidence of the power relations that can take place in a classroom (Donnelly et al. 2014). Also interestingly the author did not see evidence of the students predicting during the class which suggests a certain disconnection between what Aishling thought happened in the classroom and what was observed. Correctly she suggested that inquiry should not be carried out in all classes and this is verified in the research (Darling-Hammond 2008). Such awareness intimates an understanding of the practicalities of using a scientific inquiry approach in the classroom. She also reported on the need for students to develop their enactment of scientific inquiry:

“Am ya I think it should be introduced, then they’d grow, they’d kinda get better at it and that so, simple things, not too far from what they know now and it would be more constructive”

(Aishling)

Here Aishling suggests the importance of introducing inquiry in a more structured manner initially. Again the literature would support this claim (Bell et al. 2005).

In all, Aishling does give some interesting insight into the use of inquiry in certain lessons and the process of introducing the approach but her initial thoughts on how she enacted inquiry did not mirror the author’s observations.
PST Three (Mary): Properties of Solids, Liquids and Gases and Diffusion

This lesson related to two key concepts in the particle theory; properties of the states of matter and diffusion. Apart from the mention of properties in the second pedagogical prompt (why is it important for students to know this) when discussing the Big Idea of “Everything is made up of Matter”, properties of the states of matter were not emphasised in the CoRe. Also the only mention of diffusion was in relation to a teaching procedure used in the discussion of the Big Idea of “States of Matter”.

Orientations towards Scientific Inquiry

There was evidence of inquiry at the level of confirmation during the balloon and weighing scales activity (showing that gas has mass). However it was very much coming from the teacher, the teacher did the demonstration, the teacher advised that air was being blown into the balloon and that this was a gas and the teacher worked out the weight of the gas. This is shown in the below extract:

Mary asks how block of wood can be weighed. Students reply by saying it can be weighed using scales. Mary asks about how a liquid would be weighed- she probed until correct answer was stated...A student suggests using a gas metre. Mary is not sure “I do not know what a gas metre is”. Mary shows students apparatus of a balloon and weighing scales. Mary then did a demonstration...Student calls out weight of balloon and writes it on the board. Student blows up balloon and the teacher informed the students that air was being put into the balloon. Mary did not press this further. Mary offers what the mass of the gas is instead of having the students work it out for themselves.

(Extract from Field Notes)

Here Mary is leading the discussion and not taking the opportunity to explore the students’ understanding. She tends to provide the answer and make declarative statements such as “there is so much gas in the air it cannot be measured without putting it in a balloon” without exploring this idea with the students. It can be considered that the practice of scientific inquiry both by a scientist and a student in the classroom is an ongoing process which allows for the formulation of new questions from knowledge generated (Reiff et al. 2002) however this was not evident in the lesson.
Also when the students were asked to discuss what the properties of solids, liquids and gases were, students did not have any examples of these to observe in order to draw conclusions. Mary asked the students to work in pairs to discuss what they perceive to be the properties of the states of matter but a number of them referred to their textbook to help them, therefore stifling the opportunity for personal construction of knowledge through collaborative learning. Mary did a demonstration of a liquid flowing (a deviation away from the original lesson plan) when it became obvious that students were struggling yet she supplied the information to the students. There was potential to show diffusion with an investigation but there was only oral discussion on this, again led by the teacher. Thereby it can be intimated that the activities were very much under the teacher’s control where the students were passive recipients of information. Also Mary, towards the end of the lesson, proposed that the students were asking “stupid questions” as they continued to ask questions during the discussion of the properties of solids, liquids and gases. For example one of the students asked “why are the gas particles so much smaller?” and another asked “how is oxygen compressed into a cylinder?” Questioning is key to creating an inquiry classroom and Mary’s reaction intimates a sense of restriction in terms of what she perceives to be important knowledge for the students to know.

**Summary of Observations**

It must be noted that these PSTs are still novice trainees and it is not surprising that they have yet to develop the skills. Aishling in particular made some statements which reflect an understanding of inquiry, namely in the reference to questioning and predicting, however such statements tended to be from the position of the teacher. Their responses and actions did not actively allow for an environment conducive to the practice of scientific inquiry and similarly to the discussion in the CoRe workshop, there was no reference to the work of a scientist and how a scientist would study the natural world.
5.3 Particle Theory CoRe Post-Practicum

The post-practicum CoRe (Table 5.2) does show some progression in terms of the quantity of information provided within the CoRe. A discussion on particular content will be explored in more detail in the section after the CoRe is presented.

Table 5.2: Particle Theory CoRe post practicum (n=8)

<table>
<thead>
<tr>
<th>What Matter is</th>
<th>Properties of Solids, Liquids and Gases</th>
<th>The structure of Solids, Liquids and Gases</th>
<th>Changes of State</th>
<th>The less emphasised areas of the Particle Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What do you intend students to learn about this idea</strong></td>
<td>Definition of Matter- anything that takes up space and has mass.</td>
<td>Properties and examples. Structure of the solids, liquids and gases. Similarities and differences.</td>
<td>To draw the structure of each and be able to say why they are shaped a certain way.</td>
<td>What makes something change and why and how it changes. What is happening to the particles.</td>
</tr>
<tr>
<td><strong>Why is it important for students to know this</strong></td>
<td>It is everything. It is in their everyday life.</td>
<td>Need to be able to see it to visualise it.</td>
<td>It happens at home every day.</td>
<td>Diffusion is more important as students can see it happening every-day and it is interesting and shows how particles move around.</td>
</tr>
<tr>
<td><strong>What else do you know about this idea (That you do not want students to know about yet)</strong></td>
<td>The structure of the molecules/ the properties of molecules. Changes of state.</td>
<td>• Changes of State</td>
<td>Change of state- the movement of particles when they change state.</td>
<td>• Sublimation</td>
</tr>
</tbody>
</table>

• Diffusion
• Sublimation
<table>
<thead>
<tr>
<th>Difficulties/limitations connected with teaching this idea</th>
<th>What Matter is</th>
<th>Properties of Solids, Liquids and Gases</th>
<th>The structure of Solids, Liquids and Gases</th>
<th>Changes of State</th>
<th>The less emphasised areas of the Particle Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficult to convey. Confusion between mass and weight.</td>
<td>Difficult to convey. Confusion between mass and weight.</td>
<td>Hard to understand compression, because even though a solid cannot be compressed, you can compress a ball.</td>
<td>Students asking questions that were beyond the scope of the information needed.</td>
<td>• Difficult terminology</td>
<td>The word sublimation is hard to understand and there is not an example every-day.</td>
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<tr>
<td>Abstract- cannot understand that everything is made up of matter. Cannot picture this in their head.</td>
<td>Abstract- cannot understand that everything is made up of matter. Cannot picture this in their head.</td>
<td>Existing misconceptions. Should not follow the book directly as the layout can be confusing. Misconceptions that stem from the textbook. Advanced English.</td>
<td>Content knowledge of the teacher</td>
<td></td>
<td>Hard to explain diffusion in a scientific way.</td>
</tr>
<tr>
<td>Trying to understand the words- matter and mass. Would confuse the meaning of with colloquial meaning.</td>
<td>Trying to understand the words- matter and mass. Would confuse the meaning of with colloquial meaning.</td>
<td></td>
<td>Visualisation of the structure.</td>
<td></td>
<td>It would be difficult for students to put things into their own words.</td>
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</table>

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<tr>
<th>Knowledge of students thinking which influences your teaching of this idea</th>
<th></th>
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<tbody>
<tr>
<td>They will be thinking things like does everything have mass. Cannot see gas, so how can you weigh it. Does not really take up space because you can fit so much around it.</td>
<td>How can there be gaps between gas particles since there are carbon dioxide and oxygen in the air. Gases all react with each other and are joined so they must be joined together.</td>
<td>They will be thinking “I can’t see the structure of this. How do you know it looks like this”? It’s very abstract.</td>
<td>Students understanding the process of changing state. Previous knowledge. How they have observed things at home. previously- observation of the students.</td>
<td>They will be thinking:</td>
<td>• Why does a solid not diffuse? • Does every liquid, gas diffuse? • How quickly does it happen?</td>
</tr>
<tr>
<td>Other factors which influence teaching of this idea</td>
<td>What Matter is</td>
<td>Properties of Solids, Liquids and Gases</td>
<td>The structure of Solids, Liquids and Gases</td>
<td>Changes of State</td>
<td>The less emphasised areas of the Particle Theory</td>
</tr>
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<tr>
<td>Ideas from other teachers.</td>
<td>Classroom management: could not use group-work straight away. Resources.</td>
<td>General knowledge • Students imagination • If they understand the previous ideas. • Cognitive Ability</td>
<td>Previous difficulties understanding structure and new words.</td>
<td>Prior Knowledge- relating to new information • Seeing the links between the two</td>
<td></td>
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<tr>
<td>Acknowledging the difficulties students would have with the topic.</td>
<td>• Interest • Prior Knowledge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other factors which influence teaching of this idea</td>
<td>Teaching Procedures (and particular reasons for using these to engage with this idea)</td>
<td></td>
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<tr>
<td>Open discursive environment: Let them ask a lot of questions- the more questions they are the better idea you get of their understanding.</td>
<td>Real-life examples: Box with skittles and ask students how you would make a solid and they would squash the skittles to one side and for a liquid it would be further apart. Then have students put the skittles into containers to see if they change shape to fit the container.</td>
<td>Examples: Example like a solid like someone sitting at a match- sitting squashed together. On the hill they have more room-liquid and the gases were the lads on the pitch moving around, more space and faster.</td>
<td>Inquiry through questioning and visual demonstrations. Show students a piece of ice and ask questions around its melting. Give students the example of clothes drying for evaporation.</td>
<td>Examples: have students find examples of diffusion. Demonstrations: demonstration of diffusion using perfume</td>
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<tr>
<td>Peer teaching: if one person asks a question, have another one try to answer it.</td>
<td>Animation: with hotplate, beaker and piece of ice and weighting scales. Would show the mass</td>
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<tr>
<td>Brainstorm with examples.</td>
<td>Diagrammatic representations.</td>
<td>Use of Lego: a blue block represents one building block, a red block another etc. They can be put together in different combinations to make up the varying structures of</td>
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of the ice and would then show the change of the structure etc. when the ice melts as the particles begin to spread out.

**Outdoor activity**
where they had 5 minutes to find 20 things that are a solid, liquid and gas and have to weigh them all.

**Teacher talk:** you cannot go straight into inquiry, need to understand prior knowledge.

**Create Facebook profile** of each state of matter.

the states of matter. After this, the teacher can make the jump by saying that everything in the world is made up from different particles.

**Give them a story/scenario**- like what happens when you fry an egg what happens to the structure.

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| Specific ways of ascertaining students’ understanding/confusion around this idea (Include likely range of)| **Word game:** have a list of words and have students say whether they are solid, liquid or gas. | **Rapid fire questioning.** Get one person to explain a concept or | • Peer teaching  
• Pair Work  
• Higher and lower order questions: they | • Questioning  
• Worksheets  
• Coming up with questions themselves | Questioning: see if they can link up to previous ideas by questioning.  
Concept mapping. |
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| responses | gas.                      | have them come up and draw the structures on the board. | will tell you if they do not understand it. Constantly ask questions | • Group-work - set up according to mixed ability  
• Test |
5.3.1 Orientations towards Scientific Inquiry

The PSTs from Group A met again post-practicum and developed another Particle Theory CoRe having gained some classroom experience. In general they included more innovative teaching strategies such as the use of peer teaching and design-based learning during the discussion on the teaching procedures pedagogical prompt. However they did believe that teacher talk was necessary before doing inquiry to uncover misconceptions:

“You have to do a bit of teacher talk; you cannot go straight into inquiry you have to give them something to feed off...to assess whether or not they have misconceptions”

(Aishling)

Interestingly Aishling, during her interview stressed that she should use inquiry more so in a sense she is contradicting herself here by giving a response which is the antithesis of inquiry-based orientations.

In the discussion of the fourth Big Idea (Changes of States), there was specific mention of inquiry through questioning and visual demonstrations. Again this approach is teacher-led with the students only watching the teacher as opposed to carrying out the process for themselves. This would be referred to as the confirmation level of inquiry where the teacher dominates the discussion and the activity. Reflecting back on the classroom observations also, this level of teacher control is significant which implies the PSTs’ inability to give the power over to the students (Donnelly et al. 2014). Another example of inquiry orientations is the suggestion that students could be shown ice melting and asked to describe what is happening. This reflects partial inquiry (observation) as the defined features of inquiry are not obvious in the description. Another suggestion which could be inquiry-led involves demonstrating diffusion by spraying perfume. However, similar to the previous example, this suggestion lacks specific reference to the defined features of inquiry where the students are actively developing explanations based on evidence.
In the discussion related to how they would demonstrate that gas has mass, Aishling revealed the impact on students’ learning through the use of visual representations “you put it (the balloon) on the balance and they really liked that …when I asked them questions in the next class they could remember…gases do have mass” (Aishling). This response is one example of the PSTs relating back to their practicum experience, of which there were several examples (this will be explored in the next section), and allows for the inclusion of ideas that were not considered in the CoRe pre-practicum. However, again the above response does show evidence of teacher direction with the teacher both doing the investigation and asking the questions. This response is also contradictory to an earlier inclusion where the group as a whole identified the importance of having the students ask questions. Therefore a pattern is emerging of different PSTs having different orientations towards inquiry.

The PSTs’ orientations towards scientific inquiry were particularly evident as they discussed the difficulties/limitations around teaching the Big Ideas (prompt 4). For example, they propose that one difficulty is having students asking questions beyond the scope of the information needed. This shows orientations reflective of adhering to the existing syllabus and not allowing students to explore ideas beyond what they are required to know. Again this is the antithesis of inquiry-based practices. They also consider that diffusion is hard to explain in a scientific way which again implies teacher explanation to arrive at a prescribed definition of diffusion. They also suggested that it would be difficult for students to “put things into their own words”. This shows a weak understanding of the outcome of processes such as inquiry, where students formulate their own explanations and in turn develop their personal understanding of the content. In other words they are not fixed by simple definitions.

Interestingly the potential language difficulties and the abstract nature of the topic were not explicitly considered as the PSTs discussed potential teaching strategies. Again this suggests a weak understanding of the link between potential difficulties and how these can be addressed through careful choice of pedagogical processes.

Positively they consider prior knowledge, namely linking prior knowledge to new knowledge, as a factor that influences the teaching (prompt 6) of the less emphasised
areas of the particle theory. This does show orientations towards constructivist practices such as inquiry. They also considered the importance of needing to know about the properties/changes of state (prompt 2) as it is part of their everyday lives. Inclusions such as this imply that learning science for life should be the focus and not on learning science for syllabus completion. They referred to observation at home and what they have learned from this (prior knowledge) as something that would influence their teaching of the Big Idea of “Changes of State”. Observation is key to an inquiry process and the PSTs here are linking observation with the generation of knowledge.

Interestingly, the PSTs mentioned classroom management as a factor which influences their teaching of the second Big Idea (prompt 6). Classroom management had not been vocalised in the pre-practicum CoRe but was seen to be an issue in the classes observed thereby suggesting that the PSTs now are influenced by this in how they select and enact their teaching procedures.

**Experience on Teaching Practicum**

The group continuously referred back to their teaching practicum experience as they developed the CoRe, particularly when they discussed the difficulties/limitations of teaching the idea and the teaching procedures and assessment procedures. For example Sean related back to his placement experience when discussing the difficulties/limitations which students may have with the Big Idea of “What Matter Is”. He revealed that “Some of the kids when I was doing stuff on matter, they kept asking, does this have matter in it, that sort of thing” (Sean). This response from Sean suggests that (1) the students had difficulty in understanding what matter is and (2) again the focus on the teacher by saying “when I was doing...” which hints towards teacher-led practices and not towards the collective generation of new knowledge.

Sean however did share his belief that “…they love that, being able to ask questions cause they get them thinking, see what we’re doing and try to think of something in their own life” (Sean). Sean was not observed during teaching practicum however the insights he shares contrasts with those experienced by the author during the
classroom observations of Aishling and Mary where the opportunities were not explored to answer questions. This suggests their different experiences as students which influenced their apprenticeship of observation (Lortie 1975).

Aishling felt that group-work was difficult to undertake due to discipline issues in the class:

“I did it one day with am my first years and am it didn’t work cause when one group would be done, they’d interrupt everyone else so it was very hard to control that lot and they weren’t really used to it in the school”

(Aishling)

Here Aishling is highlighting two areas of concern; the first is reflective of the ability of the teacher to successfully use co-operative learning because of possible classroom management issues which can arise from using group-work. The second concern was related to students’ lack of experience at using group-work. This will be explored in greater detail in the discussion chapter however it signifies the importance of focusing on students changing practice in professional development opportunities.

Sandra considered the misconceptions that students may have, which she identified while teaching a particular group of students:

“They were like that can’t happen because there’s carbon dioxide and oxygen and everything in the air and they all react with each other and they all make big bonds, they’re all joined to each other so there can’t be gaps in between them so the air in the room must be completely filled just like a solid…they got completely off the wall!...

(Sandra)

Here Sandra outlined a misconception that students had in her class but did not explore this further to consider how she would address this to alter their conceptions. An experience such as this intimates a complete lack of understanding of some of the foundations of chemistry yet Sandra did not communicate concern or identify how she would address this.
Aishling revealed how the textbook she used whilst on her placement had substantially less detail than other textbooks and when she tried to give the students extra notes, they wondered why she was doing this:

“When I was giving them notes and stuff they were like Miss this is not in our book at all and they were like why do we need to know this”

(Aishling)

Again this suggests the learning that students have experienced previously and the essential learning crutch that they associate with the textbook which, it can be considered, acts as a deterrent to using alternative teaching strategies. It raises the question of what students consider to be valid knowledge and where the source of this knowledge comes from.

Similar to Aishling in her follow up interview, Sandra revealed the dilemma that she was confronted with in the classroom in relation to having control over the class and the perceived necessity of having the students not talking in the class:

“You’d be afraid of them talking sometimes cause it’s like oh if they are making a load of noise, the class is out of control and you’re not controlling them or whatever...but it’s good to get them to talk to each other and it’s good to let them talk to you because that’s how they learn you know”

(Sandra)

This silence in the class would be seen as counter to the inquiry approach wherein students are actively involved in discussion with the voice of the student dominant over the teachers. However Sandra here is identifying a concern over how the perceived noise level could be construed and associated with lack of classroom management skills.

**Summary of the PSTs’ inquiry orientations**

Before teaching practicum: all three groups displayed weak orientations towards scientific inquiry and it can be described as partial inquiry at best. Those observed in the classroom, not only lacked inquiry orientations but rebuked actions which mirror
inquiry, e.g. the absence of questioning by Aishling and the perceived “stupid questions” mentioned by Mary. There was a greater reference to inquiry, and constructivist approaches in general, after teaching practicum but it was general inquiry-based learning at best and lacked the defined features of scientific inquiry.
5.4 Genetics CoRe Pre Teaching Practicum (Cohort A)

Table 5.3 presents the CoRe developed following the extraction of the key ideas from the transcript. In the section following the CoRe, exemplars related to orientations towards scientific inquiry are discussed more thoroughly.

Table 5.3: Genetics CoRe developed before teaching practicum experience (n=11)

<table>
<thead>
<tr>
<th>What do you intend students to learn about this idea</th>
<th>Genes, chromosomes, genetic crosses</th>
<th>DNA</th>
<th>Base Pairs</th>
<th>Dominant/recessive genes and the crosses</th>
<th>Protein Synthesis</th>
<th>Mutations</th>
</tr>
</thead>
<tbody>
<tr>
<td>To understand what genetics is.</td>
<td>What it does</td>
<td>Structure of the base pairs: ATCG</td>
<td>What is RNA.</td>
<td>Inherited and non-inherited diseases and why people get them.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genetics is the study of genes.</td>
<td>What it is made up of</td>
<td>Hydrogen bonds</td>
<td>Why is it different to DNA- how does it work with DNA.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How everyone is unique/different.</td>
<td>Where it is found</td>
<td>An explanation of what these are.</td>
<td>Importance of it- that it occurs everywhere</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How we inherit different traits from our mother and father.</td>
<td></td>
<td></td>
<td>mRNA etc. and transcription.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Why is it important for students to know this</th>
<th>So they can understand why they have certain characteristics.</th>
<th>Because it is the unique make up of every person.</th>
<th>Develops their understanding and their knowledge and will have them understand the concept more.</th>
<th>Big enough topic in genetics and need to be able to do crosses to understand which gene comes through.</th>
<th>Will help them understand how their body works- that it is the way your cells build up.</th>
<th>They may know people with Downs Syndrome etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Might motivate and interest them.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genes, chromosomes, genetic crosses</td>
<td>DNA</td>
<td>Base Pairs</td>
<td>Dominant/recessive genes and the crosses</td>
<td>Protein Synthesis</td>
<td>Mutations</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
| What else do you know about this idea (that you do not intend students to know about yet) | - Dominant/recessive genes  
- Transcription  
- Protein synthesis  
- Genetic engineering. | Bases- replication. | What they are made of- their molecular structure. | - Linked genes  
- Colour blindness/down syndrome and other mutations | Genetic engineering. |

| Difficulties/Limitations connected with teaching this idea | A lot that cannot be explained in detail- scraping the surface.  
Hard to visualise.  
Being aware that there is an adopted child in the class, potentially sensitive- let the student volunteer. | It is such a small thing that people do not think of.  
You are not going into structure so it might be difficult to supply them with enough information for them to understand how important it is. | / | | |

| Knowledge about students' thinking which influences your teaching of this idea | Thinking of their own hair colour- teach to themselves.  
Think it is boring- need to work hard to motivate them.  
Perceived to be very | Watching programmes like CSI about DNA.  
If they have red hair but their parents have black hair it might be difficult for them to understand- recessive | Why A only binds to T etc. What is A, T, C, and G?  
Some students do not do chemistry so will find the bonding difficult. | Background prior knowledge: A farmer would have heard of recessive genes in cows and which crossed cows give the best yield. | Students may be switched off if it is covered too fast. |

<table>
<thead>
<tr>
<th>Protein Synthesis</th>
<th>Mutations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic engineering.</td>
<td>/</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Protein Synthesis</th>
<th>Mutations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic engineering.</td>
<td>/</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Protein Synthesis</th>
<th>Mutations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic engineering.</td>
<td>/</td>
</tr>
<tr>
<td>Other factors that influence your teaching of this idea</td>
<td>genes etc.</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>----------</td>
</tr>
<tr>
<td>• Ability</td>
<td>• Age</td>
</tr>
<tr>
<td>• Prior knowledge</td>
<td>• Ability</td>
</tr>
<tr>
<td>• Resources available</td>
<td>• Resources</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teaching procedures (and particular reasons for using these to engage with this idea)</th>
<th>Models.</th>
<th>Observation activity: how many people how brown/black hair and ask why most people have a certain hair colour.</th>
<th>Draw out mechanism simply on the board and explain it.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual aids: e.g. Videos.</td>
<td>Models.</td>
<td>Practising crosses. Examples of celebrity families.</td>
<td>Video: pausing it at different sections with the teacher explaining what happened in each section.</td>
</tr>
<tr>
<td>Get them to look at their own lives e.g. what their own brothers/parents have.</td>
<td>Models.</td>
<td></td>
<td>Varied coloured chart.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses)</th>
<th>Scenario: what is happening here and why? Organise a list of traits into inherited and non-inherited.</th>
<th>Games: true or false game.</th>
<th>Build double helix in groups: peer teaching.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Summary: students in groups write down everything they know.</td>
<td>Games: true or false game.</td>
<td>Build double helix in groups: peer teaching.</td>
</tr>
<tr>
<td></td>
<td>Lower order questioning.</td>
<td>Games: true or false game.</td>
<td>Build double helix in groups: peer teaching.</td>
</tr>
<tr>
<td></td>
<td>Participation</td>
<td>Games: true or false game.</td>
<td>Build double helix in groups: peer teaching.</td>
</tr>
</tbody>
</table>

| | Labelling diagram of protein synthesis. Video but no sound this time and get students to explain. | List a number of diseases and ask if they are inherited or non-inherited. |
5.4.1 Orientations towards Scientific Inquiry

There was limited evidence of scientific inquiry apart from a reference to an observational activity in the fourth Big Idea looking at the hair colour in people to decide what the dominant and the recessive genes refer to. There was only one reference to an experimental approach with the suggestion of a teacher demonstration related to a prescribed experiment set out in the Leaving Certificate Biology Syllabus. There was also mention in the fifth Big Idea (*Protein Synthesis*) of the teacher providing explanation while the students watched a video on protein synthesis which again is the converse of student-led inquiry. By comparison, cohort B included the use of observation as a way of comparing similarities and differences in order to determine what traits can be inherited or environmentally controlled. This activity relates partially to the inquiry process. This same cohort considered experimentation but again related it to a cookbook prescribed mandatory experiment (confirmation inquiry) but one of the PSTs did believe that “*something is not real until you see it***” (PST- cohort B). Sandra considered that there were no practical experiments that could be carried out if teaching this at junior cycle level but confusingly claimed that students learn best when they are engaged in hands on activities:

“*there’s no practical side to it, there’s not, there’s no genetics experiments for the Junior Cert... nothing you can, they’d learn things best if they were doing things with their hands or seeing it for themselves but it’s just a case of PowerPoint and You Tube, you know written stuff, they are not really active participants***”

(Sandra)

The suggestion that inquiry has to be practical in nature is misinformed as something can be inquiry if data is analysed (paper and pencil inquiry), no practical investigation has to take place (Bell *et al.* 2005). Also Sandra is suggesting that because there is no prescribed experiment, it is not possible to consider an investigation as a learning activity. She does recognise the need for students to be active participants in their own learning but does not consider this a possibility unless it has been set out in the syllabus. This implies that Sandra’s experience with science as a student was restricted to the contents/activities set out in the syllabus.
which again puts forth the argument that PSTs’ experiences as students influences their PCK. Similarly the PSTs in cohort C believed that there was limited experimental work that could be carried out with this topic and “that there is only one for Leaving Cert. the extraction of DNA” (Anne) but they did suggest students researching material for themselves as an alternative strategy.

Prior knowledge of students was considered by cohort A (prompt 5) which, similar to the post-practicum Particle Theory CoRe, shows constructivist orientations but this was not extended upon when discussing possible teaching procedures. They also noted the importance of students developing their own understanding and knowledge (with reference to the Big Idea of Base Pairs) and this implies a personal construction of knowledge. They proposed the teaching of this Big Idea through the use of models but the process of developing models and how this links with their personal construction of knowledge was not explored.

Cohort A presented the abstract nature of the topic but one PST, Edel, suggested that the lack of experimentation set out by the syllabus resulted in this: “cause like you can’t do a lot of experiments with them for Junior Cert. you can’t really and you know you can’t really show them, it’s very hard to show them and they learn by seeing”

(Edel)

This response conveys Edel’s lack of awareness of how the topic can be presented through investigative exploration and suggests a lacking conceptual understanding of the content. It can be argued that if Edel understood the science she would be able to consider ways of facilitating students learning through scientific exploration.

As outlined above there were a number of references to the use of a model which was very much missing from the Particle Theory CoRe. Both areas of science can be represented using models as descriptors but it was only with the Genetics CoRe that such depictions were offered. However similar to the Particle Theory CoRe there is a lack of reasoning given to why such strategies are employed to enhance student learning.
5.4.2 PaP-eRs developed related to the topic of Genetics

**PST one (Kate): Mutations, Dominant and recessive genes**

This lesson is focused on the Big Ideas of Mutations and Dominant/Recessive Genes. Kate used project based learning as a pedagogical approach in this lesson. However this was not one of the suggested approaches consigned to the original CoRe. Also the reference to interesting facts relating to cloning had not been described in the CoRe. The use of higher and lower order questioning referred to in the CoRe was enacted in the lesson.

**Orientations towards Scientific Inquiry**

In the latter half of this lesson Kate presented the class with an activity to be completed over the course of a week in which students had to undertake a project where they had to research and find information relevant to any topic in genetics which would be of their own choosing. This is an example of project based learning which is under the family of inquiry-based learning. The below extract highlights the struggles that students had when they were beginning this activity:

...a project that Kate was setting them on genetics in which they had to pick their own topic. This was to be done by researching the particular topic... She required them to do it on a computer so for the remaining 20 minutes the students were asked to brainstorm ideas for the project. She asked students to come up with one relatively unknown fact to be included in the project. After 5 minutes into this activity, Kate put up guidelines on the whiteboard which were as follows: 2 pages, neat and pictures. After it became obvious to Kate that the students were struggling to come up with any ideas/information, she gave examples of what the project could be on (cloning, mutations etc.).

(Extract from Field Notes)

This was the only evidence of inquiry orientations from the lesson but it related to general inquiry-based learning as opposed to scientific inquiry. The project was scaffolded to some degree as Kate outlined the basic requirements for the project, i.e. to come up with one relatively unknown fact. However the students could choose the genetics topic that was of interest to them, in essence they were given the opportunity to frame their own research questions. It was noted that the students had
difficulty thinking of a topic so Kate offered some guidance with this. Again this illustrates the issue of teacher control and the need to provide students with an answer at the first sign of student confusion. It also highlights the potential difficulty students may encounter as they engage in alternative strategies. The other approaches used in this lesson were the use of PowerPoint and a video showing interspecific and intraspecific breeding.

**PST Two (Brian): Inherited traits and DNA**

The content of this lesson would fall under the Big Idea of Genes, Chromosomes and Genetic Crosses. The teaching procedure of using a video to teach this Big Idea was not observed in this lesson however the second teaching procedure (*getting students to relate to their own lives*) was used as a pedagogical approach in the lesson. DNA was also introduced in this lesson where Brian reasoned for the need to include visual representations of DNA. Instead of using a model (which was suggested in the CoRe), a pictorial presentation of DNA was used.

**Orientations towards Scientific Inquiry**

This class was largely focused on interactive, pair-work where there was an emphasis on relating the topic to everyday life. An example of inquiry could be observed in the lesson however it would be viewed as structured inquiry due to the teacher control in the activity:

...Next Brian set about instigating an activity with the group. He assigned a scorekeeper and gave this student a set of instructions of what to do. He asked the boys to fold their left arm over their right arm and the boys were asked to put up their hand if they were able to do this. The number of boys who raised their hands was recorded by the score keeper. The same was repeated for the following:

- Asking to clasp hands and see who has their right thumb over their left thumb
- Roll tongue
- Hair on back of hand
- Hair on middle digit

Brian informs the students that the possession/non-possession of all these traits is genetic...

(Extract from Field Notes)
It was very much guided by Brian and did not have the defined features of inquiry like predicting and drawing conclusions from the data, observation was the main feature noted. Brian tended to readily give the answer away. For example, he got two students to stand at the top of the class and the rest of the class had to observe their eye and hair colour and decide what eye and hair colour their offspring could potentially have. This activity was virtually completed by the teacher- the teacher supplied the answer and drew a diagram to represent this on the board. This again suggests the power relations (Donnelly et al. 2014) and the explicit teacher control that can be observed when trying to enact such inquiry-oriented activities. Opportunities for more student-led activities were often replaced by a didactic deliverance of fact as the following extract shows:

.... Brian asks students if they know what this term stands for- students do not know but he informs students that they don’t need to know but writes it up on the board anyway (Deoxyribonucleic Acid is spelt incorrectly). He draws a picture of it on the board and informs students that it produces proteins. He informs students that the whole body is made up of DNA and the structure goes from the body- system-organ-tissue-cells-DNA (“from little to large”).

(Extract from Field Notes)

Here the opportunity for the students to ask questions does not take place. The students are told what DNA is without the opportunity to develop their conceptual understanding of the construct. Brian does not develop their thinking through questioning, probing and redirecting their thinking, the students were very much recipients of information.
5.5 Genetics CoRe Post Teaching Practice

Next the Genetics CoRe which was developed after the PSTs’ teaching practicum is presented. Table 5.4 reflects the CoRe developed by some members of cohort A. Visual comparison shows a marked difference in terms of the quantity of information provided by the cohort however the section after the CoRe provides particular exemplars of developing orientations towards scientific inquiry.

Table 5.4: Genetics CoRe developed after teaching practicum experience (n=10)

<table>
<thead>
<tr>
<th></th>
<th>Some genetic characteristics are inherited and others are not</th>
<th>The concept of chromosomes, their origin, number and function</th>
<th>The structure, history and role of DNA in genetics</th>
<th>Using Mendel’s Laws to show how different traits are inherited</th>
<th>Protein Synthesis, transcription and translation</th>
<th>Ethics of Genetics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What do you intend students to learn about this idea</strong></td>
<td>They would already know that you inherit your parents’ hair/eye colour but you want them to know how it happens.</td>
<td>In every cell in the body there is a nucleus (brain of the cell) and in the nucleus we have chromosomes and on the chromosomes they have genes. To link this to topics they have already done. Fertilisation. Function of the</td>
<td>The role of DNA in genetics. The history of DNA - general knowledge. What DNA stands for. Its function and</td>
<td>Definition of Mendel’s Law. Explanation of his pea experiment. Personal information about Mendel. Phenotype/genotype. What an allele is. Basic crosses. Basic ratios.</td>
<td>RNA. Shape of DNA and the Helix and what happens when it unwinds, when the strand separates and two more form. Forming amino acids. Codons. Types of RNA. Process of transcription</td>
<td>There are conflicts between people in genetics: There are grey areas- stem cell research, surrogate mothers, genetic screening etc. GMO and genetic engineering.</td>
</tr>
<tr>
<td>What else do you know about this idea (that you do not intend students...)</td>
<td>Diseases: genetic disorders.</td>
<td>The x and y chromosomes.</td>
<td>Crosses. Electrophoresis. Difference between DNA</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>What causes the inherited</td>
<td>Girls are xx, boys</td>
<td>Crosses.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Advanced ratios</td>
<td>DNA profiling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Advanced Mendel’s laws</td>
<td>Ethics of DNA</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Why is it important for students to know this | It will clear up for them what can be inherited and what cannot be inherited, it can satisfy their own curiosity. Good for students to get to know who they are. | Foundation of living things. For students to know where they came from: why they are the way they are. It is the building block of biology. | Found commonly in the media- the idea of DNA in forensics and how everyone has a unique fingerprint. For themselves. | For students to know why they have blue eyes etc. Building on from their existing knowledge from the Junior Certificate. It is about life in general. It broadens understanding. | Linking it with other chapters: they have done proteins in the food chapter so can now learn where it comes from. To develop a broader understanding of the work of DNA and the cell. | Could affect their everyday life. It’s relevant. Interesting ending for this chapter. |

| Some genetic characteristics are inherited and others are not | The concept of chromosomes, their origin, number and function | The structure, history and role of DNA in genetics | Using Mendel’s Laws to show how different traits are inherited | Protein Synthesis, transcription and translation | Ethics of Genetics |  |  

<table>
<thead>
<tr>
<th>Difficulties/Limitations connected with teaching this idea</th>
<th>Characteristics like right down to genes, sex linkage.</th>
<th>Are xy. Chromosomal disorders.</th>
<th>and RNA Different substances = GCAT. Hydrogen bonding between GCAT.</th>
<th>Difficulties/Limitations connected with teaching this idea</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is difficult to explain in such a simplified way- without going into too much detail.</td>
<td>Going into too much detail.</td>
<td>Vocabulary.</td>
<td>Language.</td>
<td></td>
</tr>
<tr>
<td>Sensitivity- some students may have something in their family.</td>
<td>Getting confused between chromosomes and genes.</td>
<td>A lot of detail: the structure alone would take several classes.</td>
<td>Confusing content.</td>
<td></td>
</tr>
<tr>
<td>Teachers own knowledge.</td>
<td>You cannot pick chromosomes up and show them to students.</td>
<td>The history of DNA could be boring.</td>
<td>Teachers’ need to revise material before covering it.</td>
<td></td>
</tr>
<tr>
<td>Topic is broad and confusing: you do not want to give them the wrong information.</td>
<td>Spellings of the words.</td>
<td>Similar wording: confusing.</td>
<td>Relating the idea back to chromosomes.</td>
<td></td>
</tr>
<tr>
<td>Abstract.</td>
<td></td>
<td></td>
<td>Similar wording: e.g. transcription and translation.</td>
<td></td>
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<td></td>
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<td></td>
<td>Knowing when to draw the line with the detail you give.</td>
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<td></td>
<td></td>
<td></td>
<td>Complex content.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>A lot of detailed information.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Difficult vocabulary.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Confusion between transcription and translation.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For difficult topics like this, it would be hard to use inquiry, just go through everything slowly and explain it in its simplest terms.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Abstract.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Asking of questions the teacher does not know.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Religion may play a part: do not want to offend anyone or their beliefs.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Have to ensure you, the teacher, are impartial to any beliefs.</td>
<td></td>
</tr>
<tr>
<td>Knowledge about students’ thinking which influences your teaching of this idea</td>
<td>Some genetic characteristics are inherited and others are not</td>
<td>The concept of chromosomes, their origin, number and function</td>
<td>The structure, history and role of DNA in genetics</td>
<td>Using Mendel’s Laws to show how different traits are inherited</td>
</tr>
<tr>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td>They may think a person gets their personality traits from their parents but this is really from yourself.</td>
<td>They would find it difficult to grasp that there are millions of cells.</td>
<td>Natural curiosity because it is everyday living and is found so much in the media.</td>
<td>You have to think back to how you felt when you were doing it.</td>
<td>They would struggle to grasp the idea.</td>
</tr>
<tr>
<td>Feed off their interests.</td>
<td>Would prefer to see concrete examples.</td>
<td>Ensuring they know the basics before going on to this.</td>
<td>Boring: not a lot you can do with it</td>
<td>Having an open classroom environment.</td>
</tr>
<tr>
<td>They want to be more involved in their own learning.</td>
<td>Students get confused with numbers.</td>
<td>Do not appear to make it difficult for students: this would put them off.</td>
<td>Need to reinforce DNA to give them confidence.</td>
<td></td>
</tr>
<tr>
<td>They might “slacken off” when they hear big words.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other factors that influence your teaching of this idea</th>
<th>Teacher knowledge</th>
<th>/</th>
<th>Teachers’ confidence.</th>
<th>Same factors as per the previous Big Idea.</th>
<th>/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students dislike of science: might influence/distract others.</td>
<td>Time of the class: is it first thing Monday morning or last thing Friday workshop.</td>
<td>Ensuring the teacher knows all the content knowledge.</td>
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<tr>
<td>Prior knowledge: whether they have done reproduction or not.</td>
<td>Motivation of the class.</td>
<td>Ability.</td>
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<tr>
<td>Stage of Cognitive Development</td>
<td>/</td>
<td>Trying to teach in a way that is helpful for</td>
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<tr>
<td>Teaching procedures (and particular reasons for using these to engage with this idea)</td>
<td>PowerPoints.</td>
<td>Video or imagery.</td>
<td>Videos and models of DNA: do experiment after to see it on a small scale.</td>
<td>Simple crosses to explain why they have blue eyes, for example.</td>
<td>Video: go through it slowly and stop when students are confused.</td>
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<td></td>
<td>Inquiry Activity: have a picture of two different races and ask students to observe and discuss what is inherited and non-inherited.</td>
<td>Building their own models using plasticine: have them do it themselves or in a group- get them thinking for themselves.</td>
<td>whatever</td>
<td>Teacher explanation is necessary.</td>
<td>Ask students first what they know: have an open discussion.</td>
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<tr>
<td></td>
<td>Classroom Discussion.</td>
<td>Bring in a pair of jeans and have students cross them over and show on it the various parts of the chromosome: let students do it</td>
<td>Online game with structure of DNA and nucleic acid: they have to match up pairs of nucleic acids.</td>
<td>Give examples of phenotype characteristics.</td>
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<td></td>
<td>Mind map- In groups come up with three ideas of inherited and non-inherited.</td>
<td>Forensic science module: scenario with murder scene</td>
<td>Forensic science module: scenario with murder scene</td>
<td>Get them to explain the difference between phenotype and genotype.</td>
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<td></td>
<td>Have them develop a definition of Mendel’s Law in their own</td>
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<tr>
<td><strong>Specific ways of ascertaining students’ understanding or confusion around this idea (include likely range of responses)</strong></td>
<td><strong>Questioning</strong></td>
<td><strong>Misconceptions worksheet</strong></td>
<td><strong>Purpose questions.</strong></td>
<td><strong>Doing crosses.</strong></td>
<td><strong>Worksheets.</strong></td>
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<tr>
<td><strong>Questioning:</strong> ask random students. Ask them straight out if they understand. The “traffic light” game. “Answer and questions game”. Picture of a person</td>
<td></td>
<td>3 wrong answers and 1 correct answer.</td>
<td>Rebuilding DNA model.</td>
<td>Teacher draws a cross on the board and students tell them what to do.</td>
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<tr>
<td><strong>Group presentations:</strong> devise presentation that they would give to primary school students explaining the idea. Labelling</td>
<td><strong>Red and blue counters:</strong> get 23 counters of each colour and have them work around the idea of there being 46 chromosomes. and they have to interview characters and view their DNA profile. Have them come up with mnemonics. Show CSI clip. Have them come up with their perfect crime: what they would do to make sure their DNA is not found.</td>
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<tr>
<td><strong>Role play:</strong> one student is a nucleic acid and one is a hydrogen bond and have them match up.</td>
<td><strong>Higher order questioning.</strong></td>
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<tr>
<td><strong>Worksheets.</strong></td>
<td><strong>Questions:</strong> Rapid fire question. <strong>Projects:</strong> where they have to research a specific stage of the transcription/translation process.</td>
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<tr>
<td>with their interests/personality traits listed and ask students to decide what characteristics are inherited and non-inherited.</td>
<td>chromosome diagram. Filling in their own characteristics and genes in a chromosome diagram and put these on show for the class.</td>
<td>Question new content but also content they would have covered previously.</td>
<td>Tests. Quizzes: with a prize for the winner.</td>
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<tr>
<td><strong>Worksheet:</strong> of a person with arrows coming out and ask students to label the inherited and non-inherited characteristics.</td>
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5.5.1 Orientations towards Scientific Inquiry

The number of suggested instructional strategies increased markedly in comparison with the CoRe developed before teaching practice. There was some reference to general inquiry-based learning strategies namely having the students engage in project work. Interestingly they placed project-based work as an assessment strategy and not as a learning strategy when discussing the 5th Big Idea. Overall the level of inquiry appeared to reflect towards more teacher-led inquiry practices, at a level of confirmation or structured. This is despite responses such as that presented by Clara who suggested that the teacher should “try to get them to come up with an idea themselves without you having to tell them” (Clara) and by Grace who implied “they want to be more involved in their own learning” (Grace). Both PSTs are showing an awareness of the importance of student-led inquiry but this was not emulated in the discussion on potential instructional strategies.

There was no evidence of the key features in scientific inquiry such as the use of prediction, students designing their own procedure or students drawing conclusions from the data observed. The cohort even intimates the importance of teacher explanation as a pedagogical approach. For example Grace believed that for some of the more difficult content, you just had to go through everything slowly and you could not use inquiry, you the teacher would have to explain everything in its simplest terms:

“For difficult topics like this...hard to use inquiry activities...just have to go through everything slowly and explain it in the simplest terms”.

(Grace)

This suggestion by Grace provides an interesting insight into her beliefs about science teaching in terms of how she would respond to the teaching of difficult topics. She identifies that for such topics, student-led inquiry was not an option. However the literature suggests that it is for such topics that scientific inquiry facilitates in developing an understanding (Fellows 1994).
Similar to the CoRe developed pre-practicum, the PSTs suggested the use of models to facilitate learning. Indeed they associated the use of models with experiments when discussing the possible teaching procedures for Big Idea 3. An interesting addition to this CoRe was a remark made by Edel who prescribed to a belief representative of inquiry orientations “try and get them to learn themselves like, get them instead of you telling them everything” (Edel). Such remarks had not been given previously however it does contradict activities suggested in the teaching procedure section of the CoRe, specifically having the teacher give the explanation.

Positively the PSTs spoke of the ethics of genetics and within this considered the conflict between scientists in different areas of research. This was the only example in all of the CoRes developed where reference to the work of scientists was given. However this was in some way diluted by the mention of why it is important to link the Big Idea of Protein Synthesis, Transcription and Translation with other “chapters”. Considering the Big Ideas as certain chapters is antithetical to the practice of scientific inquiry where the focus is on new knowledge generated and does not place consideration on learning according to certain chapters. However with the first Big Idea they propose that it is important for students to learn this (prompt 2) to satisfy their own curiosity which is an agreed objective of scientific inquiry (Blake and Howitt 2015). They considered an inquiry process when discussing the teaching of Big Idea 1 where students had to observe and note differences between two pictures. This would be viewed however as partial inquiry as key features of inquiry were not apparent. Classroom discussion related to Big Idea 1 and 6 was given as a potential teaching procedure but this was not extended upon to include the other features of inquiry- e.g. proposing explanations from evidence. Interestingly they considered students developing their own “definition” of Mendel’s Law which does show intimations towards student-led practices but again it is unclear how the students would derive this definition, i.e. was it from an inquiry process?

They again place emphasis on the difficulty in explaining the content without going into too much detail. This was evident with reference to the first, second and fourth Big Ideas. There was also mention of the worry relating to giving students incorrect information. Similar to the other CoRes there is a focus here on teacher explanation.
and adhering to the contents of the syllabus as opposed to having students actively construct their own understanding. They also consider students asking questions that the teacher may not know the answer to (Big Idea- *Ethics of Genetics*) as a difficulty/limitation. There was an opportunity here to have students engage in research to formulate explanation but this was not provided as a possibility in the discussion.

The issue of the teachers’ content knowledge came up in the discussion of Mendel’s Laws and this intimates that the teachers’ knowledge can be a factor that influences their teaching of this idea. While the PSTs did not directly say it inhibited them from using inquiry, it can be implied that content knowledge plays a role in deciding how they would teach a particular idea.

**Experience on Teaching Practicum**

There was repetitive reference to their teaching practicum experience as they developed the CoRe some of which did illustrate constructivist orientations. For example, Edel shared that she had twins in her class and she used these students to show similar characteristics in order to explain inherited and non-inherited characteristics to “*get them more involved themselves*” (Edel). This response gives an insight into the importance of having students involved in their own learning which shows constructivist orientations.

**Summary of the PSTs’ inquiry orientations**

In all the PSTs do show some orientations towards scientific inquiry embedded within their PCK both in terms of their espoused (namely within the post-practicum CoRe) and enacted practices. However it can be argued that the level of scientific inquiry is very much at the confirmatory/structured level of inquiry and mirrors partial inquiry at best. It can be suggested however that the interactions with the group do provide some evidence that the PSTs have a foundational understanding of inquiry but conversely this understanding of inquiry is not being connected with how they would teach the Big Ideas.
5.6 Main Themes related to PCK Development

The following points provide a summary of the main themes identified from this chapter and seek to signpost for the reader the main points that will be discussed in the discussion chapter:

- Failed to connect teaching strategies with student learning- in all of the CoRes they did not consider how particular strategies could be used to engage with the ideas.
- Classroom practice often did not mirror the content of the CoRe. For example, in relation to the teaching strategies (pre-practicum CoRe) that can be used to teach the Big Idea of elements, compounds and mixtures, the use of visual representations such as Lego and models were given yet in Jason’s observed lesson he focused on declarative statements rather than using visuals. Also classroom management tended to stifle inquiry-driven practices.
- The PSTs associated practical work and learning through the visual as being key to student learning but did not extend on these ideas or think deeply about how to engage students in learning. They make comments such as “80% of learning is done through the visual” but do not extend upon this almost rhetorical comment.
- While there was some development of PCK, it was still very much low level but what was interesting was the extent to which the cohort related to their teaching experience in the CoRe post-practicum. The Genetics CoRe appeared to show greater development thereby illustrating the topic specific nature of a teacher’s PCK.
- There was at times an apparent disconnect between the responses to the pedagogical prompts. For example, the PSTs considered the importance of making the material interesting as a factor that would influence the teaching of a particular Big Idea yet when they considered teaching strategies they did not reflect back on this. This intimates that the PSTs struggled to make links between the different components of PCK.
- The orientations towards scientific inquiry were very much at the confirmation level of inquiry. Any mention of inquiry was not extended upon to give concrete representations of the features of scientific inquiry.
classroom observations there was also a tendency towards the PSTs giving the answer away which is antithetical to authentic inquiry practice. Overall they failed to reflect the practice of a scientist in their discussions and their belief that authentic science is only mirrored by real-life applications would be inaccurate.

- The PSTs perceive scientific inquiry to be solely representative of a practical investigation yet there are many inquiry-based activities that involve students in analysing data, drawing conclusions etc. without the practical engagement in investigations.

- Interestingly the PSTs did not explicitly refer to their experiences as a student. Also reference to their experiences did not automatically result in related content being added to the CoRe. This suggests a certain disconnection between experiences as a student and how it influences their PCK.
Findings Part B: Exploring the Affordances of the CoRe in the Professional Development of PSTs
6.1 Introduction

The following chapter will explore the affordances for the adapted CoRe as a vehicle towards enhancing the PSTs developing scientific inquiry orientations (RQ2.) within a professional learning community (PLC). It will also look at additional professional learning experiences reported by the PSTs (also RQ2.). How these potentially blend with the developing inquiry orientations will be examined in the discussion chapter. The main aim in the reporting of these findings is to openly examine how knowledge was socially constructed through the dialogic interactions between the participants as they developed their respective group CoRes.

As a reminder, the data from three different cohorts will be presented here. The PSTs within the different cohorts and the topics they developed a CoRe on are given in Table 6.1.

Table 6.1: List of cohorts, CoRe topics and PSTs

<table>
<thead>
<tr>
<th>Cohort</th>
<th>CoRe Topic</th>
<th>PSTs (pseudonyms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Respiration</td>
<td>Aishling</td>
</tr>
<tr>
<td></td>
<td>The Nervous System</td>
<td>Mary</td>
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<td></td>
<td></td>
<td>Grace</td>
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<td></td>
<td></td>
<td>Sandra</td>
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<tr>
<td></td>
<td></td>
<td>Clara</td>
</tr>
<tr>
<td>B</td>
<td>Respiration</td>
<td>Rebecca</td>
</tr>
<tr>
<td></td>
<td>Chemical Reactions</td>
<td>Kate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anne</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clare</td>
</tr>
<tr>
<td>C</td>
<td>Modern Physics</td>
<td>Edel</td>
</tr>
<tr>
<td></td>
<td>Heat</td>
<td>Sean</td>
</tr>
<tr>
<td></td>
<td>Mechanics</td>
<td>Sam</td>
</tr>
</tbody>
</table>

6.2 Participants Living Educational Theory of Inquiry (Pre PLC Intervention)

It was necessary to get an initial understanding of the PSTs’ conceptualisation of scientific inquiry in order to determine to what extent their living educational theory (Whitehead 1989) of scientific inquiry developed over the course of the phase two. The PSTs were asked to write on paper how they would define scientific inquiry. The initial conceptualisations are presented below and will be compared in due course (section 6.8) with those presented towards the end of phase two. One of the
participants (Clare) was not available so the following section documents the conceptualisations for eleven out of the twelve remaining PSTs:

Rebecca

“Learning based on asking questions. Get students to follow the scientific method-

1. Propose a hypothesis
2. Test said hypothesis
3. Analyse Results
4. Make Conclusions

It involves asking questions to find the most logical answer that fits in with what you already know”.

This definition reflects some of the key features of scientific inquiry, for example having the students frame a research question, carry out an investigation and draw conclusions from the analysis of results. However it does lack reference to some of the key features of inquiry like designing investigations and collecting data. Out of all of the definitions given by the PSTs, the above definition most closely resembled scientific inquiry.

The remaining definitions suggest understandings reflective of general inquiry-based learning as there is no reference to the key features of scientific inquiry. More specifically there is a lack of reference to the investigative feature of scientific inquiry.

Sam

“Process of reasoning, understanding and the figuring out a concept; using prior knowledge, peer activities, discovery tasks and logic. Where the students are actively involved in their understanding which leads to deep understanding which will be beneficial in the future. The teacher in this process is more of a facilitator and asks thought provoking questions to promote understanding and reasoning”.

Here Sam considers scientific inquiry to involve a process where students are actively engaged in their own learning with the teacher acting as the facilitator. The idea of the student being actively involved in constructing their own learning is
pertinent to the inquiry process but this definition lacks any reference to scientific inquiry and indeed the learning of science in general. Interestingly Sam recognises that such processes lead to deep understanding but appears to be uncertain about the design of such inquiry-led activities.

Sean

“The above definition would refer to general inquiry-based learning where the students research information, analyse the information and give justification for their choices. However there is no reference to having students frame their own research question, design their own investigation or indeed decide what data should be collected and it therefore lacks reference to scientific inquiry.”

The next series of definitions are grouped together as they all include similar features in terms of their conceptualisation of scientific inquiry.

Aishling

“IBL covers the concept of allowing students to come up with and try to comprehend the certain topic without having to be told by the teacher. IBL draws on students’ prior knowledge in order to try and develop their knowledge of the current topic. It tries to defer away from teacher-led learning and more too student-led”.

Grace

“IBL is based on the idea that pupils learn by applying prior knowledge to the subject area and using this knowledge to explain and understand more detailed concepts, a less “Chalk and Talk” approach and a more student oriented approach”.

Sandra

“IBL promotes critical thinking among students. It requires them to use their prior knowledge to further their understanding of a topic. It encourages students to take
some responsibility for their learning. It promotes understanding and deep learning”.

Definitions four to six speak of the constructivist approach to teaching where students build on their prior knowledge. This idea of students constructing their understanding based on their prior knowledge is intimately linked to scientific inquiry. However the defined features of scientific inquiry are not present.

The next series of definitions are also grouped together as they resemble each other in terms of the focus on general inquiry-based learning as opposed to scientific inquiry:

Mary
“This is students figuring things out for themselves and coming up with their own conclusions on things with varying levels of involvement from teacher/supervisor or whoever”.

Clara
“IBL is allowing students to form their own concepts, ideas etc. about a topic. It is about learning from pieces of information and being able to connect the dots and piece the information together to form their own ideas. It is having students ask as many questions about a topic and discover for themselves what something means from exploring ideas”.

Edel
“Activities that actively involve students in the topic. Getting the students to visualise a new topic and to teach themselves and others, the concepts. They learn through questioning what they already know and new information. They also learn by doing and seeing. IBL should allow the students to use their own ideas and misconceptions to learn new concept/topic”.
Anne

*See what students know. Do not give them info; let them gather the NB points. Discovery learning- Teach each other- students learn better- gets them involved (not teacher-led).*

Kate

“*IBL is getting students to come up with information by themselves or in groups with little input from the teacher. I think it is beneficial to the students as they will remember something better that they came up with themselves*”.

These definitions (seven to eleven) suggest a definition more representative of general inquiry-based learning. The students being actively involved in their own learning is a consistent theme amongst the definitions. Awareness of the importance of inquiry for promoting critical thinking and developing a deeper understanding are included and the idea of constructivism is also seen throughout the definitions. Only one of these six definitions (given by Clara) specifically refers to the importance of questioning within an inquiry-based activity. Indeed specific reference to the features of scientific inquiry and the learning of science in general are missing. It must be remembered that the author asked the participants to define scientific inquiry, yet a number of them kept referred to general inquiry-based learning. So it can be hypothesised that the PSTs in general show misunderstandings in terms of what scientific inquiry actually reflects in classroom practice.

6.3 Interactions within the PLC

The following sections details more specific examples of the interactions between the PSTs within their PLC.

PSTs’ Initial Struggle

This section reports on the author’s interpretation of the perceived struggles identified between the PSTs as they interacted at the beginning of phase two after the adaptation was made to the CoRe scaffold. When asked to put forth suggestions of how they would teach the topic of respiration, the first pedagogical approach considered was the use of teacher talk. Indeed Sandra struggled to think how she would teach the first Big Idea (*The difference between respiration and breathing*).
using inquiry “I don’t know, I can’t think of an activity though” (Sandra) with Aishling implying that inquiry would not be possible with this topic “there doesn’t seem to be a huge amount of scope to do [inquiry]” (Aishling). Again Aishling is providing a more negative stance on the use of inquiry.

Mary added that it was too early to approach the topic through inquiry “it’s still kind of early on so you can’t really, there’s not much there” (Mary). This response by Mary is interesting as it suggests that she is uncertain as to its use in constructing new knowledge, even foundational knowledge related to a particular construct. The literature would suggest that scientific inquiry is best positioned to introduce new material (Harris and Rooks 2010) therefore Mary’s assumption would be seen as inaccurate. Sandra suggested that she would progress through this section quickly without giving emphasis to using an inquiry-oriented approach “I would fly through this section” (Sandra) which hints at Sandra’s focus on time and perhaps syllabus completion.

Interestingly despite her sometimes negative representations of inquiry it was Aishling who provided the first example of an inquiry-based activity. The activity considered by Aishling reflected students having to design their own procedure:

“Limewater- blow into it to show Carbon dioxide- to show effects of breathing. Have them come up with their own procedure, do it themselves and explain what they are doing”

(Aishling)

This would be seen as an essential feature of inquiry (Campbell et al. 2010). When Aishling suggested an inquiry-oriented activity (and this was verified by the author as being inquiry) the other PSTs revealed that they could now see how an inquiry activity could be carried out, yet they failed to consider inquiry-oriented activities in the remaining development of the CoRe. There were only four other references to inquiry-oriented activities in the CoRe workshop on the topic of respiration. One was reflective of students conducting an experiment to show that respiration releases energy and another was to show that heat is produced by respiration. Both of these suggestions were also given by Aishling. Grace suggested an activity where students
had to “... analyse the diagram”. Aishling also mentioned the use of a bell jar as a model for the lungs. This suggestion revealed partial inquiry as the students were asked to observe the model but again the key features of inquiry were not made explicit.

Mary, in the discussion of how to assess the students understanding of the idea, believed that one could use a guided inquiry approach with the teacher giving the students guidelines of what to do:

“in a sense you could do an inquiry led activity again. Give them a set of guidelines to set them through the experiment and how they get to the end result and you can assess the process as well as the product”

(Mary)

This response is interesting as Mary is suggesting inquiry can be used an assessment activity. New knowledge should be generated through the use of inquiry so does not fit as an assessment activity. However there is some positive attachment to this response as Mary is talking about the process model of learning which is associated with inquiry practice.

There was also evidence of cohort B struggling to consider the teaching of respiration through inquiry. An example was given by Kate who suggested that students could predict what happens in the lungs during breathing “they could form their own ideas and their own opinions” (Kate) but then “you give them the answer they can see their mistakes” (Kate). While prediction would be seen as a precursor to inquiry, the idea of the teacher giving students the answer with no experimental approach identified shows a lack of understanding as to what constitutes inquiry. Also with Kate suggesting that the teacher can give students the answer so they can see their mistakes hints at a focus on the perceived correct (set) answer and not on the exploration of students’ understandings through inquiry. In all there was only one reference to an inquiry-oriented activity (see section 6.4).

Rebecca showed a lack of awareness of inquiry as she described how a bell jar could be used to exemplify breathing “obviously you do it after you’ve gone through what
happens in the lungs” (Rebecca). Having the experiment come after the students have been presented with the material by the teacher is counter to a constructivist and indeed inquiry-focused approach. However when Rebecca mentioned this, another pre-service teacher (Clare) advised that she used the bell jar activity before covering breathing and “they were able to figure out and tell me what was happening” (Clare). This exchange shows some evidence of the PSTs beginning to have an open dialogue as they try to consider how they would teach through inquiry.

The initial struggle was not as evident with cohort C with almost automatic consideration for teaching the topic through inquiry however the suggestions were dominated by Edel, over the other members of the group. For example, the below extract shows Edel sharing a teaching activity with Sean agreeing but not elaborating on the suggestion:

**Edel**- “I’d say if they went to find the scientists themselves it would be more inquiry-based”.
**Sean**- “Ya”.
**Edel**- “But in terms of the class and if you want a timeline for variety”.
**Sean**- “Ya I suppose you’d nearly have to give it to them”.
**Edel**- “Or like say “find someone by tomorrow” and “who do you have” “ok well you can’t do him, find someone else”.
**Sean**- “Ya that’s logical”.

It can be suggested that Sean felt the need to contribute to designing this activity but did not have an understanding of how to consider approaching the design of the activity. More positively, it does indicate the developing supportive group dynamics where Sean is encouraging Edel to develop her thinking.

The majority of suggestions for the Modern Physics CoRe reflected a general inquiry-based learning approach. There was also an average of 30 seconds pause each time the PSTs were asked to consider a teaching procedure using inquiry, thereby suggesting the need for extended time to make explicit their internalised ideas. When the cohort developed the Mechanics and Heat CoRe not only was there
a greater reference to inquiry but all participants equally contributed throughout the discussion.

**Evidence of Collaboration between PSTs**

**Cohort A**

During the development of the respiration CoRe with cohort A, Aishling was essentially the only pre-service teacher who suggested activities reflective of the inquiry approach (apart from Grace who suggested an activity that could be considered partial inquiry). However in the development of the Nervous System CoRe, more PSTs were offering their suggestions. So while quantitatively, the development of this CoRe did not offer more inquiry activities than the previous CoRe (see section 6.4), the suggested activities were given by various members of the group. Four PSTs worked together to consider an activity around developing an understanding between the central nervous system and peripheral nervous system (Big Idea 1). The following extract reveals the dialogue that took place to create this activity:

**Grace**- “Like just throw out the question about touching something and why...”

**Clara**- “Or just give them a bowl of hot water, something like that, stick their hand in that, and they say it’s hot and you say how do you know”.

**Interviewer**- “Going back to what Clara said about the bowl of water, you said stick your hand in there, so you haven’t given them a question yet and would you say... What do you think of this, have them come up with a question? How would you approach that”?

**Clara**- “I don’t know, do you know the way... I’d just give them a bowl... I don’t know”.

**Sandra**- “If he moved his hand, or if he/she moved their hand, you’d say... why did you do that? And ask the class... why do you think he moved his hand and they might say it’s hot miss and why do you think it’s hot or why do you...”

**Mary**- “How do you know it’s hot”.

**Sandra**- “Ya”.

**Mary**- “Could say I felt it was hot”.

**Sandra**- “Ya”.
Grace- “It’s like why did you feel it?”

Mary- “But what did you feel it with?

... With my finger... but how do you know... how do you know that your finger knows!!”

Sandra- “Ya ya... push out to maybe answer questions a bit”.

Sandra- “They could then put it in ice cold water or something”.

Grace- “Lots of different stimuli”.

Sandra- “Ya”

The above extract shows how Clara initially struggled to think deeper about how she would approach this activity however Sandra facilitated her in developing an inquiry-oriented approach. This was a noted example of the PSTs involving themselves in a PLC. It must be considered however that Clara did not continue developing this activity after her reported struggle to extend the activity. Nonetheless in the next example she was involved in constructing the activity:

Sandra- “They’d need to do research on it themselves”.

Mary- “Ya it’s the kinda thing you’d have to get them to do research on”.

Unison- “Ya”.

Sandra- “You could do group work one could take one part and another do another part of the brain”.

Rebecca- “Like a jigsaw”.

Clara- “Jigsaw ya and then really research it, if you could get a computer lab or a double class or something”.

Here the PSTs are moving from having the students engaged in individual work to engaging in co-operative learning. Again, as before, the PSTs are feeding off each other’s suggestions and extending them to develop a research-based activity using a jigsaw methodology. A third example of collaboration with cohort A can be seen in the next exchange where Grace is struggling initially and Clara helps her to provide ideas of how the concept of the central nervous system could be presented to the students:
Grace- “I don’t know I just don’t think you can say to someone, this is the central nervous system if you don’t...”

Clara- “Well you could introduce it by saying, if you touch something, how do you know that you’re touching it”.

Sandra- “Ya”.

Clara- “And then you can say it goes through your peripheral into the central nervous system up to the brain. So like the brain would be part of it”.

Grace- “Ya that’s true”

Here the supportive environment is also represented by the positive reinforcements that both Sandra and Grace are giving as the activity is developed. Evidence of interaction between Grace and Clara can also be seen in the next exchange:

Grace- “You could make a model, you could get them to make!!”

Interviewer- “How would you go about that now”?

Grace- “I suppose...”

Clara- “A wire...”

Grace- “You could give em a piece of wire, a piece of insulator am...”

Clara- “Ya you could put 2 things, one with insulation, one without insulation...”

Grace- “Ya or you could give them like all the components in front of em and try to get them to make like...”

With the above exchange, Grace is struggling to begin with but helps to present an idea of how to teach about myelin sheath once Clara provides some initial support.

Cohort B

Another example of professional collaboration was evident with cohort B when they discussed how they could approach teaching about compounds and mixtures through inquiry (structured inquiry) in which Rebecca expanded on Kate’s suggestion:

Kate- “You could give them like Oil and Water and you could give them examples of compounds, you could see look break that up, don’t break that up like they’d be able to take oil out of water. Mixtures can separate, compounds can’t”.
Rebecca- “You could even put the word up on the board and definitely probe them... It’s in there somewhere but you just have to keep probing and try to get it to come out”.

While this exchange is missing some of the key features of inquiry, it can be described as structured inquiry where Rebecca is building upon Kate’s initial thoughts.

Evidence of Affective Support between PSTs in Cohort B

During the development of the Chemical Reactions CoRe, another example of collaboration was evident in the dialogue below:

Kate- “Get them to do a titration, acid/base and then just to see when it goes the colour change, put in the universal indicator and when it changes, you know”?
Rebecca- “Ya definitely”.
Kate- “It’d introduce them slightly into titrations, maybe they’ve done it, maybe they haven’t, you know”?
Rebecca- “Definitely”.
Kate- “You get them to try and formulate their own experiment, lead them to that one”.
Rebecca- “Or you could give em the apparatus, they mightn’t have used a lot of it before but they might have seen...”
Kate- “Get them to try and figure out how they would prove...”
Rebecca- “Ask them then what’s after happening here (after the colour change), kind of probe them with questions, why was there a colour change... get each group to present their findings and say “tell me what happened here” Have a class discussion on it”.

Here both PSTs were working together and contributing equally to the design of the activity. This activity is more representative of guided inquiry as having students designing their own investigation is promoted. Mutual support can also be seen in this extract where the PSTs are encouraging each other’s responses. For example Rebecca a number of times gave positive reinforcements (ya definitely) which it can
be suggested acts as an encouragement for Kate as she considers the activity. This support would be noted as an affective support rather than evidence of the PSTs engaging in collaborative cognitive engagement.

**Cohort C**

Professional collaboration was also evident with cohort C as shown during a discussion related to the teaching of a Big Idea ([To understand the history of radioactivity, how radioactive atoms differ from non-radioactive atoms](#)) in the Modern Physics CoRe:

**Sean** - “*The debate thing about “should we have nuclear power in Ireland?” like expand on that and getting them to like go on about fission and fusion reactions. Get them to do a project maybe on... you could have em present”.*

**Sam** - “*Everyone has to ask a question or 2 questions*”.

**Edel** - “*They could give feedback, give each other feedback. at the end of, after if they did a project together at the start, at the end of the whole topic of modern physics, you could go back to it and see can they build on it and see do they have any more questions*”.

Here all three PSTs within the cohort built on their peers’ suggestions as they developed the activity. What is particularly interesting here is the emphasis given to having students ask questions and formulating new research questions based on preliminary findings. This emphasis shows a developing awareness as to the importance of questions in the enactment of inquiry.

An example from the mechanics CoRe illustrating professional collaboration is shown in the next exchange:

**Sean** - “*They could have a ramp and there is a car and it is attached to a Ticker tape, you just like let it go, how do you...*”

**Sam** - “*You show that the dots, the ticker tape timer it punches the...*”

**Sean** - “*Like every 0.2 of a second*”.
Sam- “Ya like 0.2 of a second put you see that like slowly, the gaps between dots gets bigger because the tape is moving faster cause the tape is attached to the car”.

Sean- “So like if you pushed it, you could show its accelerating because in the beginning they were only like a centimetre apart but now they’re two centimetres apart”.

Sam- “You get them to do it”.

Sean- “Ya, you’d have to explain how the timer works but then you could kind of let them off”.

This extract suggests that when Sean was struggling, Sam continued on teasing out how the activity could be carried out and Sean followed on from Sam’s support to continue developing the activity. What is also interesting here is the focus given towards the students making choices about how the data should be collected. The teacher control alluded to in phase one appears to be transitioning to more student-led control.

**Existence of Contrasting Discourse towards Inquiry**

While the supportive environment was evident from the previous section, there were also instances where the PSTs contradicted each other during their interactions. For example, during the development of the Nervous System CoRe an exchange happened between two of the PSTs, Sandra and Grace. Sandra considered how perhaps having a Dropbox file set up where the teacher distributes PowerPoint slides to the class before the lesson:

“Or you could get them to look at, do you know the way some of the lecturers put up their PowerPoint beforehand. Teachers could do that as well for their subject so if they wanted to see what was on the class tomorrow they could look at the PowerPoint or...”

(Sandra)

Almost reactionary in nature, Grace interjected by pointing out that “*that’s not inquiry*” with Sandra responding with “*oh ya*”.

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Two PSTs from Group B also showed evidence of contrasting viewpoints. During the discussion on the teaching of the second Big Idea (There are 3 different types of acid reactions) in the Chemical Reactions CoRe, Rebecca considered one approach but this was advised against by Kate:

**Rebecca**- “Oh you could go along the lines of like boiling water so and then it goes to gas and back down to boiling water again, would that make any sense, no”?

**Kate**- “It might complicate things a bit too much cause you’re going into states of matter and all that craic”.

Here Rebecca is searching for some confirmation from Kate that her idea is appropriate, this shows evidence of using the support of another PST. Kate is confident to oppose her idea which shows that she is comfortable to express an alternative view within this PLC.

During the development of the Modern Physics CoRe, Sean highlighted the importance of students researching things for themselves in terms of increasing interest levels in students:

“I suppose you could get them to research it cause do you know it is, you could find it interesting learning about”

(Sean)

Sam believed that she would not spend too much time on the topic and so disagreed with having the students research new information because the particular content was “only a teeny tiny bit” (Sam).

These examples of divergent dialogue where participants are opposing each other’s viewpoints is interesting and telling as it was not observed in phase one. This potentially shows their developing self-efficacy, that they now have belief in their opinion that they can express contrasting perspectives. However the above exchanges were the only evidence of divergent thinking during the CoRe workshops.

**6.4 Evidence of Scientific Inquiry from the adapted CoRe**
While the previous section (section 6.3) reported on the interactions with the PLC, this section provides examples from the interactions showing evidence of inquiry orientations within their discussions as they constructed their respective CoRes. Tables 6.2a, b and c report on exemplars taken from the completed CoRes and are focused on both partial and full inquiry. They are presented according to the different cohorts and their respective topics.

Table 6.2a: Episodes of scientific inquiry from CoRes developed with cohort A (N=5)

<table>
<thead>
<tr>
<th>Topic</th>
<th>Number of inquiry-related orientations</th>
<th>Features of inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Respiration</strong></td>
<td>5</td>
<td><strong>Conducting investigation</strong> - They could also do the experiment where they show that heat is produced by respiration in the form of energy and when they see that energy is produced in respiration versus the carbon dioxide being produced in breathing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Conducting investigation</strong> - Students do an experiment that shows that respiration releases energy - ask them how would we show that energy is released and guide them but they should be able to know the experiment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Designing, justifying and conducting investigation</strong> - Experiment to show respiration using Limewater - blow into it to show carbon dioxide which results from breathing. Have them come up with their own procedure, do it themselves and explain what they are doing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Analysing data</strong> - Have them analyse a diagram.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Observation</strong> - Have students observe a bell jar with lungs to show breathing.</td>
</tr>
<tr>
<td><strong>The Nervous System</strong></td>
<td>4</td>
<td><strong>Collecting data</strong> - Get them to research - taking different parts of the brain to research on.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Designing investigation and observing, collecting data and drawing conclusions</strong> - Give them a bowl of water, see what they do with it and question them. Get them to try and describe what’s happening in the body…Use of different stimuli for pain, temperature, pressure.</td>
</tr>
</tbody>
</table>
Investigate at different stations. Share experiences of investigations in groups.

**Collecting data**- Questions on board- write up questions that students have on the board and answer them as the topic progresses by having students investigate answers online.

**Collecting data and drawing conclusions**- Test reflexes- followed by discussion.

<table>
<thead>
<tr>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Respiration</strong></td>
</tr>
</tbody>
</table>
| Reference to the key features of inquiry with some evidence of guided inquiry- “have them come up with their own procedure”. There were other parts of the CoRe that had the potential to be an inquiry-based activity- like the use of a jar to show breathing, however the group did not elaborate on this idea. The emphasis on students drawing conclusions, which is a necessary activity if students are to engage in worthwhile analysis, was also not considered.

The Nervous System

There was numerically a decrease in the examples of scientific inquiry, though similar to the other CoRe, there was some reference to the key features of scientific inquiry. Though not reported here, the PSTs did consider a number of activities reflective of general inquiry-based learning which shows constructivist orientations.

**Table 6.2b: Episodes of scientific inquiry from CoRes developed with cohort B (N=4)**

<table>
<thead>
<tr>
<th>Group B</th>
<th>Number of inquiry-related orientations</th>
<th>Features of Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiration</td>
<td>1</td>
<td>Conducting investigation and drawing conclusions- Bell jar of the lungs. One person breathing in through it and then someone else can go around and say what’s happening here now? Ask them to explain it.</td>
</tr>
<tr>
<td>Chemical Reactions</td>
<td>5</td>
<td>Conducting investigations- Use oil and water to show a mixture. Get students to do it themselves.</td>
</tr>
</tbody>
</table>
Conducting investigations- Determining if something is an acid or a base. Give them litmus paper and have them identify unknown samples.

Drawing conclusions and generating new questions- If you got them to try and think right we’ve done this one way, how do you think you would be able to show a direction, show a change in direction?

Designing investigations, conducting investigations and drawing conclusions- Acid base titration using universal indicator showing colour change. Get them to formulate what to do. Then probe them with questions. Give them a comparison between acids and bases and water and bases. Get groups to present their findings.

Designing investigations, conducting investigations and drawing conclusions- Thermo Flask experiment- get them to figure it out. Compare against water. Thermometer in a flask and stop watch.

Get them to see what happens in a reaction, is heat given in or taken off: does the thermometer reading increase or decrease. Then get them to do their own report.

Summary

Respiration

Guided inquiry was observed in the respiration CoRe however this was only limited to one activity so while they did present an inquiry focused activity, comparison with other CoRes suggests a weak orientation to the practice.

Some evidence of guided inquiry where students were designing their own investigation. There was no reference to students framing their own research question however. If this was the case, the activity would be considered open inquiry. The cohort believed that inquiry could be used to teach throughout this topic “you could do everything through inquiry”. They also recognised that “lack of lab practice” may be a difficulty/limitation with teaching the Big Idea of “There are 3 different types of acid reactions”. There were some activities given which had the potential to be an inquiry-based activity, such as “Demonstration showing acid/base reaction” but the lack of detail meant it was difficult to determine whether this was to be an inquiry-based approach. However when compared with the respiration CoRe, there is apparent greater reference to inquiry.
Table 6.2c: Episode of scientific inquiry from CoRes developed with cohort C (N=3)

<table>
<thead>
<tr>
<th>Topic</th>
<th>Number of inquiry-related orientations</th>
<th>Features of Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern Physics</td>
<td>6</td>
<td><strong>Collecting data</strong> - Research on why Ireland does not have a nuclear power station.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Drawing conclusions and generating new questions</strong> - Discussion following a video demonstration around the experiment: why one particle is going one way etc. Get them to come up with new questions that they have after looking at the video. Have them research answers themselves.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Observation and comparison</strong> - Get them to observe and compare between a radioactive cell and a non-radioactive cell</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Designing investigation, conducting investigation, comparison and drawing conclusions</strong> - Experiment showing photoelectric effect - get them to devise as much of the experiment as they can. Give them time to adapt procedure. Get them to discuss what is happening. Have a control also to compare against.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Conducting investigation and drawing conclusions</strong> - Geiger Muller Tube experiment - get students to go around the classroom and note background radiation - have a discussion on any findings.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Conducting investigation</strong> - Give them the word Lepton and get them to research it.</td>
</tr>
<tr>
<td>Heat</td>
<td>12</td>
<td><strong>Conducting investigation</strong> - Research on the boiling of water in cooking.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Conducting investigations and observation</strong> - Touch experiments: Touch different objects in their hands to see if they heat up quickly with your body temperature.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Designing and conducting investigations</strong> - Show and tell: have them come up with different ways to show the difference between heat and temperature in everyday life.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Designing investigations</strong> - Get them to devise an activity that they would teach to a fourth year class.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Conducting investigations and comparison</strong> - Use of</td>
</tr>
</tbody>
</table>
calorimeter to demonstrate latent heat. Have one group of students do the experiment incorrectly and compare results with someone who did it correctly.

**Conducting investigation and observation** - Something changing state and monitoring it with a thermometer.

**Conducting investigation, observation, collecting data and drawing conclusions** - Give students a blank thermometer and have them graduate it themselves by putting them in ice, room temperature and in boiling water.

**Designing and conducting investigations** - Convection in a liquid - they could have the pint glass of water and then pour in some blackcurrant and then they have to watch it going round with little convection currents. Have them do it without telling them what to do.

**Predicting** - Ask them to draw a graph that they think it will look like.

**Conducting investigations and comparison** - Convection in a gas - get little window boxes which contain glass, a candle and 2 chimneys. The candle is at one and you put a smoking taper or something and smoke comes in. You can see the smoke kind of drifts over to the candle, the candle is pushing it out.

**Conducting investigation, observation and drawing conclusions** - Get them to test what’s better, black or white - you have a container here and you put boiling water into it and then away from it you have a thermometer and you notice that even though the thermometer is nowhere the boiling water, it gets hotter because it’s sends out radiation.

**Designing investigations and comparison** - Have students come up with ways to show the difference between heat and temperature in every-day examples.

**Conducting investigation** - On conductors and Insulators: You have your box and there are holes in it, you’d put different lengths of the same material: you put a glass rod, wood, glass, copper, steel, plastic. Then you put boiling water into it, close it and then there’s tacks you stick on the end of it with Vaseline and they heat up and the Vaseline melts as the rod heats up so the tack will fall off.
Designing, conducting investigation and drawing conclusions from data- Bring them outside, on a flat stretch and roll a ball to prove to them that it is always going to be moving until it meets an object. Try to find a way of getting them to come to this and get them to try it out to see if it happens or get them to explain what an external force would be. Get them to describe and then get them to tell you why they think it happened.

Designing and conducting investigation- Get them to devise an experiment to show water pressure- 2 holes in a bottle and water is not coming out as far from the top to the bottom because of the pressure on the bottom. Show them this experiment and then they have to come up with another one.

Designing and conducting investigation- Collapsing Can experiment- show them apparatus and have them come up with a procedure.

Observation and drawing conclusions- Show them the foundations of a house. Have a small tray with dirt in it and place a big book on it, you will see it starting to sink but if you have match sticks underneath to support the book, the book won’t sink. The teacher should show it to them and then ask them why it sinks first but doesn’t sink when there are match sticks put under the book.

Predicting results and designing investigation- Demonstrations like beer mat over a pint glass or a small ball can be moved up into a glass without touching it by spinning the glass or 2 beer mats and a euro coin. You can move the euro coin from one beer mat to the other without touching it by using a brandy glass as the vehicle. Have them come up with suggestions of the outcome or how to move the ball or the coin.

Predicting results and designing investigation- Gets them to think of all the possible pieces of information that can be gotten just from these 2 values.

Bring them outside and have them do races.

Analysing data and drawing conclusions- Make up a set of results like in a fake newspaper article and have them analysis the data then and from the analysis of the data, get them to come up with a conclusion.
Framing research question, designing and conducting investigation- You have a ramp with a car attached to a little ticker tape timer. You let the car go and you show the dots (the ticker tape punches every 0.2 of a second so the closer the dots are, the slower the car is moving). You show the difference between when you let the car go of its own accord and when you push it. The teacher has to explain how the timer works but you could let them off to. Have them come up with the research question. Do not tell them why they are doing the experiment but explain why it works and then ask them what is happening here and why are they different.

Designing investigations and justifying conclusions- Have them come up with an experiment to present their work to the class. Have them present what they came up with and why they came up with it and give reasoning behind.

Summary

Modern Physics

Some reference to scientific inquiry in which the level which was guided inquiry. For example, the fourth activity had many of the key features of inquiry. The idea of students having debates was also a key feature in this CoRe. Debating would be seen as a key feature of how one can communicate results in an inquiry activity.

Heat

Guided Inquiry featured prominently. Also the cohort displayed a habit of mind centred on the idea of students thinking creatively and critically “Could be thinking creatively and critically- need to foster this and let them direct the class”. This awareness of self-directed learning through creative and critical thinking are two indicators of the cohorts’ thinking directed in an inquiry-based manner.

Mechanics

Open and guided inquiry featured prominently. Some structured inquiry. The idea of creativity in the choice of methodology was also considered by the cohort a number of times in this CoRe workshop (three times) from the viewpoint of students needed to engage in creative activities but also from the viewpoint that a limitation may be the teachers lack of creativity. Interestingly, one way of ascertaining students understanding or confusion around the Big Idea of “Understanding where the formulas for linear motion come from, how to adapt them and how to apply them”, was to ascertain the students’ success in designing, evaluating and proving their work. This showed an understanding of how one can assess having used an inquiry-based approach. Another example of this came
from a discussion of the same Big Idea where the cohort suggested “have them come up with an experiment to present to their class, have them present what they came up with and why they came up with it and give reasoning behind it”. All of these would suggest the cohorts understanding of having students designing an investigation and giving reasoning behind the data they collected.

The three tables appear to suggest that the PSTs are developing a greater awareness and orientation towards the use of scientific inquiry. They also highlight that, generally speaking, the frequency of inquiry orientations developed as the participants continued to engage in the CoRe workshops. Cohort C showed a more profound development than the other two cohorts. Interestingly while cohort A did not show quantitative accounts of development, they still considered a number of activities through inquiry in the development of both CoRes.

6.5 Awareness of Existence of Inquiry in Published CoRes and PaP-eRs

Section 6.5 and 6.6 draw on the responses from the PSTs during a PLC session where they revisited a Particle Theory CoRe that was developed in phase one as well as a CoRe and PaP-eRs published in Loughran et al. (2006). The PSTs were appearing to apply their understanding of scientific inquiry when they were engaged in developing the CoRes; however it was of interest to the author to see if they could identify inquiry-oriented activities from developed CoRes and PaP-eRs. This would provide for further proof as to whether or not their orientations towards scientific inquiry were advancing in terms of their ability to recognise examples from an existing artefact.

With the published Particle Theory CoRe, the PSTs recognised the predict-observe-explain model as being representative of inquiry-based practice. Clara believed that there was a greater number of inquiry activities suggested in the CoRe developed by Loughran et al. (2006) and that “they have been doing inquiry for a while” (Clara). However Clara did not elaborate on this idea. Apart from these brief vignettes, there was no reference to evidence of inquiry in the published CoRe despite the author
revisiting the question a number of times. It can be suggested that the PSTs engaged less with the published CoRe because they did not develop it themselves.

The PSTs were then asked to analyse a set of PaP-eRs. Firstly the suggestion was given that the PaP-eR was “student-led the whole time” (Kate) and this in turn allows the teacher to “see what they understand and their misconceptions” (Clara) and that:

“She (the teacher who developed the PaP-eR) asks a lot of questions all of the time, she gets them to do everything themselves... she’s constantly trying to get them to think deeper kinda about it... the teacher responds with “another question” and therefore tended not give the answer away readily.”

(Mary)

Interestingly it was Mary who when observed in phase one considered the students to be asking “stupid questions”. Is she developing an understanding of the importance of questioning in facilitating student learning?

Two PSTs observed some of the defined features of inquiry when they propose that “She (the teacher) gets them to justify their own answers and give reasons why” (Clara) and she “incorporates discussion into her lessons...the students can learn from each other” (Grace) thereby giving credence to group collaboration in facilitating learning.

The above collection of responses shows some awareness of what constitutes inquiry. However as alluded to above, the PSTs did not explore the content of the CoRe as much as the author had anticipated and they therefore vocalised limited reference to inquiry as upon inspection that author could see several examples of inquiry such as:

- Models are used in science to explain phenomenon
- Observation- dry ice sublimating- what’s happening
- Probes of student understanding
- Historical research
This leads to the assumption that the PSTs were more readily able to recognise scientific inquiry from narrative classroom accounts of practice over espoused exemplars of scientific inquiry. The reason for this assumption is that there was a marked difference in the PSTs contributions when they had to look at the narrative accounts from the developed PaP-eRs.

6.6 Reflecting on the Particle Theory CoRe to show enhanced Inquiry Awareness

This section draws on the responses from the PSTs having revisited the post-practicum Particle Theory CoRe in phase two. The objective here was to identify whether or not the cohort did demonstrate enhanced inquiry awareness through examination of an already constructed CoRe. One pre-service teacher, Edel, revealed that she thought the CoRe was “good” and that there was “a lot in it”. The latter response suggests a focus on including as much detail as possible without credence given to the quality of that content. All the other PSTs agreed with her, however Sam did point out that it was “probably more didactic” but you could see “elements of there trying to be inquiry” (Sam). Aishling felt that there was a lack of critical thinking in the CoRe and that there was limited reference to inquiry:

“Like we are telling the students lots of things but they are not really discovering anything like in inquiry-based learning you know, finding out for themselves”

(Aishling)

Aishling here recognised the issue of teacher control that the author has suggested previously. Also Rebecca identified the need for students not to focus on always getting the answer correct, that they could learn more by getting the answer wrong:

“...they might learn more by giving the wrong answer and feel comfortable giving the wrong answer because the whole class learns from every mistake”

(Rebecca)

Rebecca here identifies a key part of the inquiry process; that is removing the assumption that the focus should be on students getting the perceived “correct”
answer only. This is the first instance where a PST vocalises such a belief as previously other PSTs, such as Kate and Clara, have emphasised the importance of arriving at the perceived “correct” answer. Rebecca’s contribution suggests a certain transition and because the other PSTs did not vocalise alternative beliefs the assertion can be made that the PSTs are beginning to change their orientation towards what scientific inquiry reflects in the classroom.

Sam thought that the latter end of the CoRe included more reference to discover learning but that there was still adapted thinking needed to make it more student-led. She offered a suggestion for how a demonstration showing diffusion could be more student focused:

“Take the demonstration with the spray, but get them to come up with that. Don’t mention that. Get them to come with it themselves and don’t just spray perfume in the back of the classroom. Try and probe them rather than just doing that... don’t just stop it there”

(Sam)

Sam’s suggestion is indeed more student-led as the focus is on having students designing and conducting the investigation with the role of the teacher serving as the facilitator, probing the students. Also Sean considered how he would change another teaching procedure to be more inquiry focused “Start and ask them does air have mass. Get them to try and come up with a way to show it does” (Sean). Sean in this instance recognises how an activity could reflect high level inquiry by simply posing a question to the students. Sam identified also how this activity could be carried out in a more structured way where students had to choose from apparatus on show to them:

“Or you could probably put a couple of things on a table and say these are apparatus, what would you use? But have a few things that they wouldn’t use”

(Sam)

Here Sam is considering the importance of having students develop the skills in making experimental choices, in this case, what apparatus could be used to address the question. It is interesting to note that many of the contributions are coming from
Sam despite her initial reservations at the beginning of phase two: are her orientations towards science teaching evolving?

Clara recognised that a description of a teaching procedure in the CoRe which involved the teacher telling students the answer before asking them was indeed not an inquiry focused approach. When PSTs were asked overall how they could make the teaching of the topic more intellectually challenging, Aishling advised that “if there was more student-led inquiry they’d be more engaged in it and maybe critically think about it” (Aishling). Here Aishling is identifying the importance of inquiry in making the material more challenging with the students engaged in critical thinking, however she did not give a suggestion of how to do this by considering a particular approach which could be used.

All PSTs in the group recognised that the teacher needed to be comfortable with the content in order to teach the topic using inquiry with Grace adding "just because you’re doing the teaching doesn’t mean you know everything…you have to go a do a lot of research” (Grace). Here Grace identifies the need for a teacher to continuously seek to improve their knowledge with all PSTs agreeing that being uncomfortable with a particular topic would prevent them for teaching through inquiry. The idea of weak content was intimated as being a reason for the cohort not actively engaging in inquiry during the classroom observations and it appears here that the PSTs are corroborating this assertion.

6.7 Verbalised Influence of this Study on their developing Inquiry Orientations

The analysis of the exchanges between the PSTs suggested the value in using a learning community as a vehicle to support each other. Also the analysis of the CoRes does suggest that the PSTs were developing a greater awareness of scientific inquiry orientations. They also verbalised this at the interview held at the end of phase two. Participants suggested that by being involved in the CoRe workshops had helped them think more through inquiry. Clare summarised this view point by proposing that engaging in this study enabled her to learn beyond what was taught in the lectures to the extent that she believed that the PSTs in the study had a better knowledge than the other PSTs of how to teach effectively:
“Well the first thing I realised was, don’t teach how you were taught and don’t stick to the syllabus. ... Use other ways - like use inquiry [be]cause even when we’re thinking about how you’d use inquiry, I suppose we’re kind of inquiring ourselves, getting creative! And ... I remember so much more from these workshops than I would from a lecture, something like that. And just when you talk about it, it’s kind of like, you know, that the effects of that type of teaching will be much better than the didactic... we have a better knowledge”

(Clare)

The same pre-service teacher revealed how she has used the experience to her benefit when developing schemes of work:

“I did it yesterday and I banged it out so quickly but I was using inquiry and I wasn’t just like this is going to be introduced today, we’re going to talk about this, I was kind of thinking of ways that we had talked about in our workshops”.

(Clare)

She suggested that she was now thinking of “a lot more of them (the students) being involved and giving them time to actually think rather than just listen”. Responses such as this add to the growing assertion that the PSTs are more formally considering the role of the student having control. Sandra intimated that involvement in the CoRe workshops “gets you to think about things” with Sam expanding on this notion by suggesting that involvement made you think about things “but in a different way though” (Sam). This response by Sam provides the assumption that involvement has allowed her to explore alternative ideas that perhaps would not have been the case if she was not part of the PLC.

Grace considered that she now thinks about how content can be taught through inquiry as opposed to more didactic means “I wouldn’t even think twice about handing out a sheet, you immediately think how can approach this using inquiry” (Grace). Comments such as this suggest that Grace is developing a schema more representative of constructivist orientations towards teaching. Clara revealed how easy it is to now think about an activity through inquiry:
“You think for two or three minutes and straight away you have some sort of activity coming on, straight away like and like before for teaching practice I’d sit there for like ages going there’s no activity for this... and like I wish we’d done this in first year”

(Clara)

Clara went further with this idea by proposing that time constraints should not be an issue when engaging in inquiry activities “You can do it in the exact same amount of time and they’ll remember it better” (Clara). Finally, Edel added to this discussion by reflecting on how her involvement in the CoRe workshops had made her think more creatively, which would not have been the case otherwise: “It’s kind of made me think more creatively as well cause I would have just thought like I did, like how I was taught in school”.

(Edel)

This comment gives leverage to the construct of the apprenticeship of observation (Lortie 1975) and provides insight into how her experiences as a student would influence how she would potentially teach if it was not for her involvement in the CoRe workshops. It can be suggested that involvement has resulted in her developing more creative pedagogical approaches to teaching. Clara also provided evidence of how developing the CoRes have made her consider the teaching of the concept removed from the crutch that the textbook can often give a teacher: “The more you do the CoRes the more you think, oh we could do this. I mean it might not be related to the book, not thinking about what comes next in the chapter. We think more about the sequence of how a student would understand the topic best instead of what comes next in the chapter”

(Clara)

This comment also suggests a confidence in teaching according to her belief about how students learn best and not by the confines of the textbook.
6.8 Participants Living Educational Theory of Inquiry (Post PLC Intervention)

At the beginning of phase two, the PSTs involved in the study were asked to offer their own definition of scientific inquiry (section 6.2). The following section reveals the definitions given by the PSTs at the end of phase two. All of the definitions will be presented firstly, followed by a critique and comparison with those given at the beginning of phase two:

Rebecca
“Students have more responsibility for their learning. They engage in investigative processes where they try to discover results and experiments. Students try to discover the steps for investigations, enables them to make mistakes and unearth their misconceptions. Students think more about the steps involved in investigations if they are in control of the pathway the experiment can take”.

Sam
“Research based on observations. It may be experimental work, field work, reading etc. It requires critical thinking and promotes discovery learning”.

Sean
“Scientific inquiry is getting students actively contributing to their learning. Questioning/probing them to encourage them to learn the how and why and not just the facts. To have them design their own investigations, questions, etc. so they feel actively involved in the information being presented”.

Aishling
“Scientific inquiry is when a pupil takes responsibility for their own investigation/experiment. They uncover rather than just do the work. It allows deeper learning and pupils will remember it more. It would involve group-work, pupils trashing ideas out between each other and trying different ways/techniques”.

Grace
“Allowing students to come up with scientific information on their own using prior knowledge and drawing their own understanding and conclusions from it”.

Sandra

“Answering questions through asking questions- students developing their own techniques to answer their own or their peers’ questions”.

Mary

“Scientific inquiry is using pupils’ prior knowledge and demonstrations, applications etc. in order to formulate a conclusion/opinion on a topic. It is taking what they know to developing their unknown”.

Clara

“Encourages students to explore the prior knowledge and ideas about a topic before the teacher “spoon-feeds” information. It makes students responsible for their own learning and helps relate the topics being taught to everyday life”.

Anne

“To me scientific inquiry is the use of developed skills to interpret, investigate and predict scientific outcomes using their prior knowledge, theory, data collected and investigative skills”.

Kate

“Scientific inquiry relates to guiding students towards the answer through questioning and encouraging them to discover things for themselves”.

Most of above definitions contrast significantly to those presented at the beginning of phase two, namely definitions 1, 2, 3, 4, 5, 7 and 9. These definitions refer to the investigative process while also referring to key features of scientific inquiry. The remaining definitions 6, 8 and 10 while having constructivist orientations do not necessarily refer to the key features such as having students draw conclusions and engaging in activities. Interestingly many of the definitions started with using the correct term “scientific inquiry” while the earlier definitions of inquiry were referred
to as “inquiry-based learning”, despite the author asking the PSTs to define the former. The newer definitions are also more relevant to the defined features of scientific inquiry. For example, Sam emphasises the use of observation and interestingly speaks of the use of reading as well as experimental work and field work. Engaging in reading to draw out key pieces of data would be viewed as inquiry practice and identifying this as being part of inquiry suggests a fuller understanding of the process. A number of PSTs (n=3) present questioning as key to the scientific inquiry process and such reference was missing from the original definitions with only one pre-service teacher offering this as a feature of inquiry. The PSTs all revealed their own unique definition of scientific inquiry and though different in terms of language used, the definitions were very much in line with the key features of scientific inquiry. For example, Anne presents the use of predicting and interpreting data and again these would very much resemble the scientific inquiry approach. These key features were largely absent from the original definitions provided by the PSTs.

However it must be noted that none of the definitions consider the association between the practice of a student in the classroom and that of a scientist in the laboratory.

6.9 Evidence of Orientations considered the Antithesis of Inquiry

While it can be argued that the PSTs do show enhanced orientations towards inquiry, there was still evidence of discourse which could be considered the antithesis of inquiry-oriented thinking.

During the development of the Nervous System CoRe with cohort A, Clara considered that “they [students] need to know that” which suggests that students have to come to a perceived correct answer. It can be argued that inquiry allows for the exploration and development of students’ knowledge and during this, students may encounter productive failure which models what happens in the everyday laboratory setting. Therefore a focus on arriving at the perceived correct answer shows a lack of understanding of real scientific practice. This position can also be argued when two of the PSTs, Clara again and Mary suggest that there is “very little on senses [in the
textbook]” (Mary) and “senses hasn’t come up on the Leaving Cert. in an exam yet, has it?” (Clara). Both responses to the pedagogical prompt “difficulties/limitations with teaching this idea” provide some evidence of the focus on the syllabus and the summative examinations. Indeed when Mary was observed in phase one she mentioned how students asked “stupid questions”. This positions her orientations away from the importance of asking questions, which is connected with the practice of inquiry. Clara again in this discussion also considered that the students “always ask stupid questions” which Sandra agreed with.

Sandra’s understanding of inquiry was also put into question during the development of the Nervous System CoRe where she said having students “giving examples” (Sandra) was inquiry. It can be considered that this is devoid of the features of scientific inquiry. The same PST considered that in order to teach the second Big Idea (to understand the difference between the motor, sensory and interneurons and their structure) “you maybe explain it a little bit” (Sandra). This quote suggests the power relations existing in the classroom and the perceived need for content to be explained to students rather than them constructing their own understanding of the scientific concept. Again this was extended on further when Sandra said: “You’d probably have to do a small bit of chalk and talk with them as well…show them a diagram really and introduce the words”.

(Sandra)

While the other two groups did show orientations considered the antithesis of scientific inquiry, it must be recognised that cohort A provided more examples than cohorts B and C. However Sam in particular in cohort C displayed orientations lacking an inquiry disposition. For example, during a discussion around how they would teach heat energy, she suggested that “if you showed them just a picture of a pot on a gas cooker, you could point out the flames are the heat energy” (Sam). This example alludes to the teacher telling the students what they are observing instead of providing them with the chance to draw conclusions from their own observations. Her beliefs about science teaching were also reflective at times of definition based presentations of science. She suggested that they need to know the definitions as “that’s what they are going to be asked at the end of the day” (Sam). This comment
by Sam suggests her focus towards the summative examinations, particularly on the articulation of definitions in the exams which negates the idea of students formulating their own understanding of the concept. Sam however during the review of the original Particle Theory CoRe at the end of phase two (section 6.6) did show positive orientations towards inquiry.

There were several examples where PSTs discussed scientific inquiry as fun but lacked reference to its importance in facilitating student learning. For example, Sandra again expressed “...you can’t, realistically you can’t be doing fun things with every...” (Sandra). Here Sandra perceives the practice of inquiry as being fun rather than a vehicle towards learning science. This was also evidenced by Grace who during the discussion of assessment strategies said:

“At the end of it, once you have everything done, you kinda have to give em a test. You can do fun things but at the end of the day, if they can’t write down what they know, it’s no good to them...obviously holistic education and development but they have to sit their Leaving Cert so they need to be able to write stuff.”

(Grace)

This again echoes the perceived fun element of inquiry but also shows a certain disconnect between the practice of inquiry and how to assess learning through inquiry.

With all three cohorts, there was no reference to how a scientist works or how the practice in the classroom should model the work of a scientist therefore misinterpreting the nature of authentic scientific practice.

6.10 Additional Professional Learning Experiences

The PSTs also reported on a number of additional professional learning experiences reported through their involvement in the learning community. They can be summarised as follows:

**Lesson Planning Tool:** The CoRe tool helped them when they were planning for lessons.
Seven PSTs revealed that thinking of the Big Ideas associated with a particular topic and subsequently asking themselves the framed questions, helped direct their thinking to how they would represent this material for better student understanding. An example of how the CoRe can be used as a lesson planning aid is given by Clara who suggests that:

“If you were to take 5 people from the class that do (Involved in the study), and 5 that don’t do this and have only experienced teaching practice ah I think this gives us the opportunity to constantly...its becoming second nature to us so its constantly in our minds, that’s how we think now. Whereas for them I think they’d struggle at more to write a lesson plan”

(Clara)

Clara believed that members of the case study group were at an advantage in terms of their lesson planning abilities because of their involvement in the study. She suggested that the CoRe scaffold was now embedded in their thinking.

Kate proposed that involvement in the CoRe workshops made her “think where it’s going to go wrong before it goes wrong” (Kate). Aishling expanded on this point with reference to how her approach to lesson planning has changed:

“You think differently when you’re planning like so. Your approaches to the lessons are different and your approach to what questions you ask, how you ask your questions”

(Aishling)

This contributes to the idea that the CoRe scaffold could be used as a facilitation tool when designing lesson plans. Again Aishling is stressing the importance of questioning which she also intimated at during the interview in phase one. She now considers that the CoRe can help her plan for the questions she would explore during activities.

**Documentation of Progress:** Three PSTs revealed that involvement in the CoRe post-teaching practicum (phase one) felt like a progress report where they were able to identify how they had developed over the course of the six weeks. Rebecca
believed that involvement in the CoRe workshops allowed her to reflect on her first teaching practicum experience and see the progression she had made in terms of her understanding of inquiry:

“The CoRe enabled me to reflect on my second year teaching practice and it made me realise how little student lead activities I used. Finally, I now am also aware of the benefits of “Injury Based Learning” and how it benefits my students”

(Rebecca)

Here Rebecca is solidifying the perceived lack of inquiry orientations put forth from the analysis of the CoRe workshops in phase one. While the PSTs did report on their progress, the author would caution against the extent of this progress as discussed with reference to RQ1.

**Avenue to Share Ideas:** The group setting that was associated with the CoRe workshops allowed PSTs to share ideas and justify their own ideas. This in turn led them to consider their chosen pedagogical approaches with more consideration for how and why these approaches would foster student learning. One participant Rebecca mentioned how they were “now thinking as teachers” (Rebecca). Indeed review of the CoRes would appear to hint at the PSTs beginning to think deeper about how they would facilitate student learning. This hypothesis is vindicated by responses such as that given by Edel who suggested that her involvement in the CoRe workshops allowed her to direct her thinking away from the contents of the textbook:

“The more you do the CoRes the more you think, oh we could do this. I mean it might not be related to the book…We think more about the sequence of how a student would understand the topic best instead of what comes next in the chapter”

(Edel)

Here Edel is sharing how she now considers ideas which may not necessarily reflect the contents of the book but sees this as a positive thing as she is focused on the sequence of how students would understand the content which may not mirror the layout of the textbook.
Sean considered that being involved in their learning community allowed them “To come together and discuss it because you know each of us has ideas of something else, different experiences, and different ideas... we can bounce ideas” (Sean). Here Sean is explicitly referring to how involvement within a leaning community can provide an avenue to share ideas influenced by past experiences.

Mary added to this view by making reference to how her involvement in the study will help on her teaching practicum experience “great ideas now for teaching practice” (Mary). Clara expanded on this by saying that before she would, in her first teaching practicum experience, just “hand out a hand out and go through it, I was desperate for coming up with things but I think like for this teaching practice I’ll be ten times better” (Clara). It appears from this that the initial CoRe workshops (pre-practicum) did not influence her practice but has since found the experience to be a worthwhile endeavour because of the ideas it has generated for her. She expanded further by revealing that it was from involvement in the discussion environment “how often do we sit around at home and talk about this like you wouldn’t talk about ideas really with your friends” (Clara). In totality the responses above confirm that the PLC in which the PSTs found themselves in aided them in their professional formation through the generation of new ideas related to instructional strategies.

Indeed Edel revealed they were not just coming in every week and talking about it and forgetting about it “we’re actually starting to use it in practice... in our schemes of work and in our lesson plans...so when we got out...we use everything especially the inquiry I think” (Edel). Clara revealed her wish that “we did this in first year like”. The latter comment here suggests that Clara understands how the study has facilitated her in her developing learning and stresses the wish that she had begun such explorations earlier on in her ITE programme. This is understandable considering the novice nature of their teaching and learning capacities as they move from being apprentices in the classroom.
In all, it can be proposed that the responses given by the PSTs suggest the value they place on being involved in the CoRe workshops. It can also be argued that their reported experiences facilitate and complement their developing inquiry orientations.

**Professional Development Aid:** All PSTs revealed that involvement in this study has helped them in their professional development. Sean expressed how involvement in the study had helped him to become a better teacher “I’d say I wouldn’t be half as good as I was now if I didn’t do it because it made me more aware of what teaching was” (Sean). Again while it is difficult to ascertain the accuracy of such a statement it is important to note that Sean believes it has facilitated him in his professional formation. Whilst Mary considered that engagement in inquiry activities increased her content knowledge because of the required level of content knowledge that is needed if one is to teach through inquiry:

“I thought they hugely (the CoRe workshops) increased my CK, my content knowledge afterwards was so much better after teaching in inquiry. You have to know it so much better if you are going to...”

(Mary)

Here Mary is showing awareness of the importance of content knowledge in facilitating an inquiry-based activity which would suggest she understands the importance of a teacher’s knowledge base in facilitating student learning. She is also suggesting that her content knowledge had improved because she chose to teach through inquiry. Mary would have had underdeveloped content knowledge as evident from her classroom observations in phase one so interestingly she believed that involvement has facilitated in this knowledge development. Kate considered how she would have developed as a teacher if she had not been part of this study “I wonder about what way I would go about teaching if I wasn’t doing this” (Kate). This comment suggests that Kate did not believe she received the training to make her a competent teacher from her ITE programme alone.

The group reflected on the positive influence which engaging in the CoRe workshops had. An example of this came from Edel who acknowledged that “some people are just more creative than others. Like some people are really good at
thinking of things” (Edel) and the group environment of the CoRe workshops catered for this. This comment by Edel again illustrates the perceived advantages of working within a PLC.

All PSTs revealed that involvement in the study made them more aware of the complexities of teaching. Sean suggested that teachers often stick to the same teaching approach because some students succeed regardless of the approach:

“So many teachers try to teach how they were taught because it worked for them, why would it work for someone else (they might be thinking). So obviously if you had success with this sort of way you’d be more inclined to go ok this actually works”

(Sean)

Sean’s contribution again relates back to the apprenticeship of observation construct considered by Lortie (1975) and he suggests that as students the techniques of their teacher worked for them so novice teachers may be unaware of alternative strategies that can enhance the learning of all.

Developing the ability to think critically: Rebecca suggested that involvement in the CoRe workshops helped her to develop her critical thinking skills. She believed this was a struggle for her initially having become accustomed to didactic teaching from her post-primary education:

“Also, as a student myself who was spoon fed, I really felt this affected me when I came to college and I still struggle a bit today to stand on my own two feet, study wise”

(Rebecca)

Here Rebecca is considering how involvement allowed her to inquire into her own learning and start to become accustomed to not being given the answer away by the perceived person in power (the author). This comment also suggests that Rebecca can use this new way of thinking for herself in her other coursework. Indeed Aishling believed that involvement in the study had diverted her away from using didactic approaches to teaching where “you weren’t just focused on transmitting information... you were concerned with teaching” (Aishling). Grace considered that,
from the study, she had learned that the role of the teacher was to facilitate the students learning “you’re there to facilitate, not there to do the work”. These comments are suggesting the move away from teacher controlled activities (which were very much the norm in phase one) to giving the control and the power over to the students.

Kate revealed how involvement in the study has made her think more about her students and how the activities you develop can benefit students “I think you think more about the students as well. You think about how they benefit from it” (Kate). Sean felt that developing the CoRes was more useful in phase two because of the number of CoRes they constructed “I remember just trying to do it in second year; it was much easily this time around” (Sean). This view was expanded upon by Sam who believed that in phase one she felt frustrated and wanted to be given the information instead of trying to construct the CoRe without the input from the author:

“I remember feeling really frustrated in second year because I didn’t really know what I was doing and I just wanted to be told what to do but now I enjoy having the figure things out myself with the help of the others”

(Sam)

Sam was one of the PSTs who had particularly negative feelings towards the use of inquiry as a way of learning. It can be hypothesised that such feelings came from Sam’s initial frustrations at the process. Both these comments also justify the need to develop a number of CoRes on different topic areas as the ability to articulate PCK through CoRes comes with practice (Hume and Berry 2013).

**Developing Confidence:** The collaborative environment that the CoRe creates resulted in Rebecca developing the confidence to speak within a group environment, something which she was not comfortable with at the beginning of her involvement in the CoRe workshops:

“I also found, I gained confidence whilst participating in the group because when I started this programme I wasn’t very comfortable speaking in a group... now I have
confidence in my opinions, even if people do not agree with them or they are against
the norm”

(Rebecca)

This is an interesting comment as it implies that working in a PLC can not only
foster a teacher’s developing knowledge but can facilitate in developing life skills
such as the ability to work confidently in a group setting.

The use of the CoRe in ITE: All PSTs felt that the CoRe approach should be
integrated into the ITE experience in a more formalised manner with Sean
suggesting its inclusion within a subject pedagogics module:
“I think it should be brought into part of a module especially in the pedagogy
modules cause to be fair some of them are kind of light on teaching strategies, just
even the awareness of the CoRes do you know this is something you can find”

(Sean)

Here Sean is suggesting that the part of the ITE programme focused on pedagogies
did not offer insight into the diverse range of teaching strategies but he considers that
an awareness of the CoRe can promote PSTs to inquire into their own learning. Sean
felt that the traditional approach, where PSTs were given examples of teaching
strategies, were adequate but he did contend that they were not instrumental in
helping them to teach more effectively:
“We were made aware of a list of resources and resources usually point to things the
teacher does like literally the odd one might be good like an activity but the majority
of em is just PowerPoints or exam papers or notes which are grand like you can
have some of those but they are not going to help you teach any better. Whereas this,
you actually come up with strategies... If you are taught through inquiry you might
apply it in the classroom”

(Sean)

Here Sean is exploring the effectiveness of actually inquiring into his own learning
and developing his own understanding, as opposed to being supplied with the
information. This again is intimately linked with the inquiry process in the
classroom. Sean is experiencing what it is like to do inquiry and the uncertainty and productive failure that can come with this. The PSTs also considered that the CoRe workshops could be used as an assessment tool to show a teacher’s professional development.

All PSTs felt that involvement in the study had extended their learning beyond what they have learned in the course. Sam considered how their ITE catered more for the development of content knowledge with less emphasis on teaching the content “we’re given more content knowledge and it’s not geared towards your teaching at all. It’s bad like” (Sam). Indeed in terms of the construct of PCK, Clara advised that “it was only mentioned once in a lecture”. PSTs also offered alternative areas of teacher knowledge for which a CoRe could be adapted to facilitate development. For example, Clara believed that there could be a focus on teaching mixed ability groups whilst Sam considered an emphasis on literacy and numeracy.

6.11 Main Themes related to the use of the CoRe as a Professional Development Aid

The following points provide a summary of the main themes identified from this chapter and seek to signpost for the reader the main points that will be discussed in the discussion chapter:

- The CoRe tool and the environment in which it is created (within a PLC) appear to influence the PSTs developing inquiry orientations. This can be suggested based on analysis of the interactions between the PSTs within their respective cohort, the exemplars of scientific inquiry from the developed CoRes and the vocalised influence of the CoRe on the developing inquiry orientations as reported by the PSTs. However it must be considered that the developing inquiry orientations were more prominent with cohort B and C suggesting that with cohort A, this PLC did not influence the PSTs’ orientations as much as the other two cohorts. Also it must be remembered that as this is a case study, the focus is mainly on the entire cohort but review of the transcripts does suggest that as the PSTs continued to be involved in their respective learning communities, the articulation of ideas became more balanced. For example, for the first CoRe developed by cohort A (respiration) and cohort C (modern physics), individual PSTs, namely
Aishling and Edel tended to vocalise their ideas more than the other members of the PLC. However this lessened as the PSTs gained more experience within the learning community.

- The PSTs were less able to recognise inquiry-oriented practices from CoRes published by Loughran *et al.* (2006) which implies that while they are developing the skill of articulating inquiry within their own contexts they are not able to view the practice from an observer’s lens.

- The PSTs were able to reflect on the Particle Theory CoRe developed from phase one and accurately recognise changes they could make to the CoRe based on their evolving knowledge of inquiry.

- Comparisons between the unique definitions of inquiry given in the beginning and end of phase two suggest that the PSTs have their own living educational theory of scientific inquiry which can influence their practice greater than the propositional forms of theory (Whitehead 1989). There was a stark contrast in terms of the inclusions of the defined features of inquiry with the definitions presented at the beginning of phase two which hint at the unique experience and deep learning which each pre-service teacher gained from their involvement in the study.

- As well as this, the PSTs have reported the additional professional learning influences which it can be suggested tie in with their developing understanding of scientific inquiry (this will be explored in greater detail in the discussion chapter). For example, they considered the CoRe to act as a lesson planning tool which could invariably complement planning inquiry activities.

- There were some examples of the PSTs showing negated understandings of scientific inquiry. Interestingly these examples tended to come from certain PSTs, e.g. Clara, Sandra and Sam.
Findings: Part C
Exploring the Transition from Theory into Practice
7.1 Introduction

While the previous chapter focused on the perceived developing inquiry orientations (espoused development) this chapter will look at the PSTs practice of scientific inquiry in the classroom, more specifically during a ten week practicum experience (RQ3.). Following on from this section a comparison is made between this case study cohort and two other cohorts (pre-service and in-service teachers) in terms of their use of scientific inquiry in the classroom. Within this latter section an exploration of the perceived barriers towards enacting scientific inquiry is also presented (RQ4.). The reason why the final findings chapter focuses on practice is due to the complex transition between espoused and enacted habits of mind. Therefore it was crucial to ascertain the degree to which the PSTs make visible their decision-making in the classroom.

7.2 RQ3 How do the Perceived Developing Inquiry orientations successfully translate into Actual Classroom Practice?

This section draws on the some of the key findings from the action of inquiry survey, lesson plans, observations and interviews related to the teaching of various CoRe topics while on their fourth year teaching practicum experience. It will look at the evidence of individual PSTs’ reference to inquiry. Four PSTs submitted lesson plans: Rebecca (x3), Clara (x8), Edel (x8), and Kate (x4). Four PSTs were also observed: Sean, Kate, Rebecca and Clara. Sean, Rebecca and Kate were available for interview after they were observed by the author. These semi-structured interviews focused on the PSTs reflection of the lesson, specifically towards their perceived action of inquiry. Where appropriate, comparisons have been presented between individual PSTs’ lesson plans and classroom observations of the relevant topic.

7.2.1 Action of Inquiry Survey Responses

Section 7.3 (RQ4.) draws on a comparison between the case study cohort of PSTs, the non-case study cohort and in-service teachers. This section however will present the findings of the case study PSTs only and will show the percentage responses to each of the statements from the survey. As a reminder all twelve PSTs completed this survey on the week they returned from their 10 week practicum experience. The results demonstrate that the cohort, by and large, did engage in inquiry-driven activities in the classroom on a frequent basis. However the findings presented in
Table 7.1 suggests that some of the key features to inquiry were applied in the classroom more frequently than others.

## Table 7.1: Action of inquiry for the case study PSTs in the classroom (n=12)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Frequently</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students formulate questions</td>
<td>40%</td>
<td>60%</td>
<td>0%</td>
</tr>
<tr>
<td>Students research questions are used to determine direction and focus of practical work</td>
<td>20%</td>
<td>30%</td>
<td>50%</td>
</tr>
<tr>
<td>Time is devoted to thinking about and refining the research question</td>
<td>0%</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Time is devoted to evaluating and adapting procedure</td>
<td>10%</td>
<td>10%</td>
<td>80%</td>
</tr>
<tr>
<td>Students design their own procedure</td>
<td>0%</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>Students justify procedure</td>
<td>0%</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>Students given step by step procedure</td>
<td>40%</td>
<td>20%</td>
<td>40%</td>
</tr>
<tr>
<td>Students conduct own procedure</td>
<td>10%</td>
<td>20%</td>
<td>70%</td>
</tr>
<tr>
<td>Teacher conducts procedure</td>
<td>50%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>Students actively participate in investigations</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Students have roles during investigations</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Students determine data for collection</td>
<td>20%</td>
<td>40%</td>
<td>40%</td>
</tr>
<tr>
<td>Students take details notes and observe</td>
<td>20%</td>
<td>40%</td>
<td>40%</td>
</tr>
<tr>
<td>Students understand the importance of collecting data</td>
<td>0%</td>
<td>10%</td>
<td>90%</td>
</tr>
<tr>
<td>Students decide what data to collect</td>
<td>10%</td>
<td>60%</td>
<td>30%</td>
</tr>
<tr>
<td>Students connect conclusions to scientific knowledge/theory- cohorts’ responses to statement</td>
<td>0%</td>
<td>10%</td>
<td>90%</td>
</tr>
<tr>
<td>Students consider a variety of explanations</td>
<td>0%</td>
<td>20%</td>
<td>80%</td>
</tr>
<tr>
<td>Students develop own conclusions</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
</tr>
</tbody>
</table>

The findings above suggest that the students in the PSTs classroom frequently participated in investigations while understanding the importance of collection data and in turn developing their own conclusions through an investigative process. 50% of the PSTs suggested that they rarely conducted the procedure themselves and indeed not only did 60% believe that the students frequently conducted their own procedure but 80% indicate that the students design their own procedure. What is interesting is that the PSTs, coming up to this survey, had placed value on the importance of questioning in an inquiry-based activity, yet none of the PSTs reported to having done this regularly in the classroom. The reason for this is not explored but
one can speculate that the formation of questions is still something that the cohort is not comfortable with in their classroom. The findings will be discussed more thoroughly in the next section through comparison with the other two cohorts however the suggestion from this table is that it appears that partial inquiry featured within their respective classrooms during the 10 week practicum. This is subjective as it is the PSTs’ interpretation of their own practice so what follows is an analysis by the author of the PSTs’ lesson plans and practices in the classroom from participant observation.

7.2.2 Lesson Plans developed during Teaching Practicum

The next section contains a number of tables. Each table is arranged according to the topic and the evidence of inquiry orientations for each of the four PSTs who supplied their lesson plans for analysis. Direct extracts from the lesson plans are included in each table. The first series of lesson plans were developed by Rebecca who was also observed teaching in the classroom. Her lesson plans were very detailed and averaged 16 pages in length which is extreme when compared to the other PSTs lesson plans. She does appear to show evidence of inquiry orientations both in terms of her approaches to lesson planning and in her student activities.

Table 7.2: Lesson plans developed by Rebecca

<table>
<thead>
<tr>
<th>Lesson plan topic</th>
<th>Evidence of Inquiry Orientations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to Elements</td>
<td>Approaching Inquiry in Lesson Planning: Rebecca explains the prescribed features of inquiry in the section related to Rationale for selection of subject matter.</td>
</tr>
<tr>
<td>Compounds and Mixtures</td>
<td></td>
</tr>
<tr>
<td>Part of the Particle Theory CoRe</td>
<td></td>
</tr>
<tr>
<td>Big Idea: Elements, Compounds and Mixtures</td>
<td></td>
</tr>
<tr>
<td>Solutions</td>
<td>Approaching Inquiry in Lesson Planning: Again Rebecca illustrates an awareness of how she will approach the teaching of the topic through the use of inquiry. “I have decided to get students to observe solutions and try and find links between the solutions. Students will not be told that the items are solutions but they have some prior knowledge of what solutes and solvents are”. This awareness is discussed in the section in the lesson plan related to how the previous lesson has informed the planning for this lesson and places virtue on the importance of students developing their own understanding.</td>
</tr>
<tr>
<td>Part of the Chemical Reactions CoRe</td>
<td></td>
</tr>
<tr>
<td>Big Idea: A Chemical Reaction is when 2 or more substances come together and have an effect on one another to produce different products. (See Appendix D)</td>
<td></td>
</tr>
</tbody>
</table>

4.2.2 Lesson Plans developed during Teaching Practicum

The next section contains a number of tables. Each table is arranged according to the topic and the evidence of inquiry orientations for each of the four PSTs who supplied their lesson plans for analysis. Direct extracts from the lesson plans are included in each table. The first series of lesson plans were developed by Rebecca who was also observed teaching in the classroom. Her lesson plans were very detailed and averaged 16 pages in length which is extreme when compared to the other PSTs lesson plans. She does appear to show evidence of inquiry orientations both in terms of her approaches to lesson planning and in her student activities.

Table 7.2: Lesson plans developed by Rebecca

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<td>Big Idea: A Chemical Reaction is when 2 or more substances come together and have an effect on one another to produce different products. (See Appendix D)</td>
<td></td>
</tr>
</tbody>
</table>
for in the lesson which echoed the key features of scientific inquiry.

**Observation and Drawing Conclusions:**
“Students will be shown a selection of solutions (coffee, orange juice, sea water, honey) and will be required to find links between each solution and state what they have in common and why they different. Students will have to note their ideas on an individual whiteboard. Also it should be noted that students will not be told that the items they are observing are solutions, the aim of the activity is for them to figure it out themselves”.

**Designing Investigation:**
“Students will be divided up into groups of two or three. Each group will get materials needed to make up a solution (salt, water, sugar, hot chocolate). Students will not be told how to make up the solution but will have to guess how...”

**Observation, Collecting Data and Drawing Conclusions:**
“Students will observe the teacher’s solution and they will have to note what the solute and solvent is that makes up the solution. The aim of this activity is to get students to discover that the sand did not dissolve in the water”.

**Conducting Investigation, Collecting Data and Drawing Conclusions:**
“Each group will receive a Tic Tack and stopwatch. Half of the groups will have to suck the sweet and see how long it takes to dissolve/ disappear and the second half will have to chew the sweet and note how long it takes to dissolve/ disappear. Each person in the group will have a job, one person will suck/ chew the sweet, one will keep the time and one will note the time taken for the sweet to dissolve. Students will report their results on the conclusion section of the lesson and state the use of doing this activity”.

**Summary of Lesson Plans developed by Rebecca**

With all three lesson plans, Rebecca used similar wording related to the aims of the lesson. One of the aims of the lesson was to develop “students’ skills of observation, analysis, evaluation, communication and problem solving”. Another aim was “to develop students understanding of solutions using inquiry and practical activities”. The extent of inquiry-based activities within the body of the lesson plans varied with the lesson on solutions proving to have the greatest reference to inquiry-based practices. She included the use of group-work in the solutions lesson plan where each student had a role in the process. This suggests awareness of the part social inclusion plays in the practice of scientific inquiry.

Despite the references to scientific inquiry presented, there were also exemplars where Rebecca failed to capture the essence of student-led inquiry. For example Rebecca states her learning outcomes to be as follows:
As learning outcomes, at the end of this lesson, I hope that students will be able to:

- Compare and contrast the terms solute, solvent and solution by carrying out the solution activity.
- Prepare a solution using everyday ingredients by carrying out the solution activity.
- State everyday examples of solutes, solvents and solutions

(Extract from Lesson Plan)

These learning outcomes do not bear any semblance to student-led inquiry. She is focusing on the product as opposed to the process of learning the science content. In other words she does not give attention to how the practices of a scientist are emulated in the work that they are doing. Also while her aims may reflect a desire for students to learn some of the key skills related to scientific inquiry, this is not mirrored in the activities, particularly within the elements, compounds and mixtures lesson plan. It can be argued therefore that Rebecca’s ability to consider the use of scientific inquiry was topic dependent.

The next table illustrates the references to scientific inquiry which were identified in the lesson plans developed by Clara. The lessons were based on the particle theory, specifically the states of matter.

Table 7.3: Lesson plans developed by Clara

<table>
<thead>
<tr>
<th>Lesson plan topic</th>
<th>Evidence of Inquiry Orientations</th>
</tr>
</thead>
</table>
| **States of Matter:**  
| Lesson 1           | Evidence of Clara’s orientations towards inquiry was observed in the student activity part of the lesson plan.  
|                    | **Student Activity:** “Students will design a method which will cause the two balloons to be repelled by each other”  
|                    | **Observation:** “Students are asked to observe the substances before them and classify them as either solids liquids or gases based on the questions on the observation sheet”.  
|                    | **Drawing Conclusions:** “Trying to make connection to the theory and practice”.  
| **Part of the Particle Theory CoRe** |                                |
| **Big Idea:**  
| **Characteristics of the States of Matter** |                                |
| **States of Matter:**  
| Lesson 2           | **Approaching Inquiry in Lesson Planning:**  
<p>|                    | The below vignettes from the lesson plan reveal Clara’s objectives of the lesson to be very much focused on students learning through inquiry. Interestingly, |</p>
<table>
<thead>
<tr>
<th>States of Matter: Lesson 3</th>
<th>Student Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part of the Particle Theory CoRe</td>
<td>Within this lesson plan, there was some evidence of planned inquiry-based activities.</td>
</tr>
<tr>
<td>Big Idea: Changes of States of Matter</td>
<td>Prediction and Evaluation: “Students will be asked to predict the results of experiments and will evaluate the outcomes”.</td>
</tr>
</tbody>
</table>
| | Observation and Drawing Conclusions: “Students think about this question and come to conclusion as they watch ice cube melt in their hand that heat makes the ice turn to water”.
| | Observation and Collecting Data: “Students watch a kettle boil and take note of temperature at given times and note whether or not water vapour is produced”.
| | Approaching inquiry in lesson planning: Clara reflected on her experience of teaching this class to date and noted from these experiences, the enjoyment that students felt from learning science through inquiry. This extract was taken from the section in the lesson plan related to how the previous lesson informed the planning for this lesson. Evidence below shows that past experiences have directed Clara to plan the following lesson with an inquiry-based orientation. “Based on my experience with this class group so far, they seem like a very well-behaved group with a nice interest in science. This makes for enjoyable lessons, which involve a lot of student inquiry and participation, due to the students being so willing to learn”. However the only evidence of scientific inquiry from the activities section of the lesson plan was having students engage in prediction as they learned about the composition of objects. |
| States of Matter: Lesson 5 | Student Activity |
| Part of the Particle Theory CoRe | Again there was some reference to the features of scientific inquiry within the activities section of the lesson plan which included students having to observe and draw conclusions. |
| Big Idea: Elements, Compounds and Mixtures | Observation: “Pupils observe the application, hopefully acknowledging the size of an element relative to them” |
| | Drawing conclusions: “Pupils will share their findings with the teacher and the class; they will also listen to the findings of their peers”.
| States of Matter: | Student Activity |
| Lesson 6 | There was evidence of structured inquiry (students given instructions by the
### Lesson 6

**Part of the Particle Theory CoRe**

**Big Idea:** Changes of States of Matter

**Observation:**
“Pupils listen to the teacher’s instruction and observe the popcorn model”.

**Observation and Drawing Conclusions:**
“...they shall see the solid melting and the particles being free to move about. They should identify this as a liquid”.

**States of Matter:** Lesson 7
No evidence of scientific inquiry

---

<table>
<thead>
<tr>
<th>Lesson 8</th>
<th>States of Matter: Lesson 8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part of the Particle Theory CoRe</strong></td>
<td><strong>Student Activity</strong></td>
</tr>
</tbody>
</table>
| **Big Idea:** Elements, Compounds and Mixtures | There was evidence of confirmation inquiry as the outcome was known in advance, the teacher designed and carried out the investigation.  
**Confirmation Inquiry:**
“Teacher outlines what is expected of them for this lesson and what they should have learned by the end”.  
**Teacher Designs Investigation:**
“She distributes the equipment to each pair and highlights some key points in the procedure”.  
**Teacher Demonstration, Observation and Collecting Data:**
“She then explains that she will demonstrate how to form a compound using the iron filings and sulphur”. They (The students) observe the demonstration carried out by the teacher. And note the changes that occur”.

---

**Summary of Lesson Plans developed by Clara**

Of the eight lessons on the topic of the states of matter, seven of them included reference to scientific inquiry to some degree suggesting partial inquiry as a focus of her lessons. One lesson plan had no reference to inquiry and featured ICT-related activities instead. The lessons which did feature inquiry were, for the most part, structured or confirmatory in nature however for one activity in both lesson plans 1 and 3, students would be asked to predict the results and draw conclusions (both key features of inquiry). Also in lesson plan 1, students would be asked to design an investigation thereby suggesting that this lesson overall focused on open inquiry. Lesson plan 8 however almost centres entirely on the teacher, therefore suggesting again the power relations that potentially exist at times in her classroom.

In one of her lesson plans, the objectives were focused on learning around the inquiry process, for example “Students will be asked to predict the results of experiments and will evaluate the outcomes”. So overall, there appears to be an orientation to inquiry but it was partial inquiry at best.
Table 7.4 outlines Edel’s references to scientific inquiry captured within the lesson plans she developed on the topic of mechanics, specifically pressure, speed, velocity and acceleration and distance.

Table 7.4: Lesson plans developed by Edel

<table>
<thead>
<tr>
<th>Lesson plan topic</th>
<th>Evidence of Inquiry Orientations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pressure</strong></td>
<td><strong>Student Activity</strong></td>
</tr>
<tr>
<td></td>
<td>Connecting Conclusions to Theory- “The students will be asked to develop a theory for what was happening during the experiments”.</td>
</tr>
<tr>
<td>Pressure</td>
<td>No evidence of Inquiry</td>
</tr>
<tr>
<td>Speed, Velocity and Acceleration</td>
<td>There was some evidence of experimentation but the lesson plan is not detailed enough to analyse whether the approach reflected inquiry.</td>
</tr>
<tr>
<td>Speed</td>
<td><strong>Student Activity</strong></td>
</tr>
<tr>
<td>Speed and Distance</td>
<td>Analysing Data: “The students will be given a set of data and will be asked to create a velocity-time graph and asked to calculate acceleration”.</td>
</tr>
<tr>
<td>Speed, Velocity and Acceleration</td>
<td>Same as previous lesson plan</td>
</tr>
<tr>
<td>Speed</td>
<td>No evidence of Inquiry</td>
</tr>
<tr>
<td>Speed, Velocity and Acceleration</td>
<td><strong>Student Activity</strong></td>
</tr>
<tr>
<td>Speed, Velocity and Acceleration</td>
<td>Data Collection and Analysis “The concept of calculating speed and the DTS triangle will be explained and used in various examples. Using a toy car the students will measure the distance and time. They will then determine the speed of the toy vehicle”.</td>
</tr>
</tbody>
</table>
Summary of Lesson Plans developed by Edel

There was a significant amount of detail missing from these lesson plans when compared with some of the other PSTs’ lesson plans. Because of the detail missing, it was difficult to analyse the lesson plans for evidence of the key features of inquiry. The only references to inquiry tended to be structured inquiry in nature. In the first lesson plan, Edel did refer to how she envisaged using experiments to develop a theory which in itself is fundamental to the inquiry approach but this was not emulated in the design of the activities. Interestingly Edel, during the CoRe workshops, detailed her understanding and knowledge of scientific inquiry significantly more than what was observed through analysis of her lesson plans therefore suggesting a certain disconnection between the responses attached to a CoRe dialogue and the design of her lesson plans.

The references to scientific inquiry presented in the lesson plans developed by Kate are outlined below. The lesson plans are based on the topic of the particle theory, specifically the states of matter and also on the topic of respiration.

<table>
<thead>
<tr>
<th>Lesson plan topic</th>
<th>Evidence of Inquiry Orientations</th>
</tr>
</thead>
<tbody>
<tr>
<td>States of Matter</td>
<td></td>
</tr>
<tr>
<td><strong>Part of the Particle Theory CoRe</strong></td>
<td></td>
</tr>
<tr>
<td>Big Idea: Changes of States of Matter</td>
<td>Student Activity</td>
</tr>
<tr>
<td>Observation: “Through the use of video clips, students must observe these and answer questions afterwards “I will show students a number of short clips that show the changes in states of matter. I will show them 3 states of matter, ice, water and steam to help them remember how solids liquids and gases can change into different states”.</td>
<td></td>
</tr>
<tr>
<td>States of Matter</td>
<td>No Evidence of Inquiry</td>
</tr>
<tr>
<td>Respiration</td>
<td>No Evidence of Inquiry</td>
</tr>
<tr>
<td><strong>Part of the Respiration</strong></td>
<td>Student Activity</td>
</tr>
</tbody>
</table>
| Conducting Investigation | “Students will answer questions on experiment, set up experiment and carry it out to the best of their abilities explaining each step to me as we
Summary of Lesson Plans developed by Kate

In the first states of matter lesson plan, there was some reference to inquiry using ICT where students had to observe and answer questions which would be structured inquiry at best. In the second states of matter lesson plan and the first respiration lesson plan, there was no evidence of scientific inquiry. There was also an opportunity for inquiry during the demonstration of the lungs which did not take place. This class was also observed by the author and it can be confirmed that the activity was very much teacher-led thereby suggesting the focus on teacher control and the dynamics of power relations within the classroom. In the follow up interview, Kate was asked if she had considered doing this activity through inquiry and as she reflected on the lesson she felt that she could have included more inquiry in the lesson “I look back on it now and I think ‘oh’! I should have gotten them to describe what they saw” (Kate). This is suggesting her espoused orientations are somewhat more developed than her enacted orientations.

7.2.3 Classroom Observations

The extracts from the observations show less than expected use of scientific inquiry with Sean, Kate and Clara but in particular with Clara as her lesson resembled a very much didactic, teacher-led class. Rebecca’s lesson had a greater focus on the use of scientific inquiry which was also seen in the lesson plans she provided.

Observation of Kate

Topic: Respiration

Big Idea: The Difference between Respiration and Breathing

The final lesson plan in the above section was observed by the author. The episodes of inquiry discussed in the lesson plan were also observed during the lesson.
However the author did note that Kate explained the outcome of the experiment before the experiment began which suggests confirmation inquiry:

Kate clarifies the chemicals that will be used in the experiment. Kate then explains the outcome before the experiment begins... Kate asks the students what is going to happen if you put regular water in it. There is no answer from the class and Kate does not tease this out. Kate circulates as the students are doing the experiment. Kate shows the students an example of limewater with no cloudiness- instead of the students telling her Kate verifies the results of the experiment.

(Extract from Field Notes)

When Kate asked questions at the end of the experiment, students were looking at their books for answers. Therefore Kate’s “withitness” within the class prevented authentic inquiry experiences from taking place. Also because Kate explained the outcome in advance, this would be partial inquiry at best.

When the students were looking at the live structure of the lungs, they were asked to compare with the diagram of the lungs in the book, this observation and comparison allowed for students to engage in inquiry:

Kate starts dissecting the lungs whilst the students observe. Kate describes everything that is being done during the dissection.

(Extract from Field Notes)

However when Kate started dissecting the lungs, she explains everything without giving the students a chance to predict, observe, explore and draw conclusions, again intimating at the teacher control placed over the activities.

The above extracts suggest that Kate did have inclinations towards scientific inquiry practice however classroom management, teacher control and lack of focus in regards to having the students providing the answer led to an absence of authentic inquiry experiences and the result was partial inquiry at best.

Observation of Clara

Topic: Heat
**Big Idea: There are a number of Different Applications of Heat in Everyday Life**

This lesson was very much centred round a didactic style of teaching with the whiteboard and textbook being the only resources used. As stressed previously, these resources could be used to facilitate an inquiry-based approach (pen and paper inquiry) but this did not happen in the particular lesson. Clara requested that they use the definition of heat found in the textbook instead of engaging in the process of the students constructing their own knowledge and developing their own definition/understanding of the concept. Only at the end of the lesson did she use an inquiry approach when she asked the class to look around and observe examples of where they saw energy conversion taking place. This activity only included reference to the students observing phenomenon and did not refer to the other defined features of inquiry. One interesting point from Clara was that she said “you don’t need to know how it works, just know that it happens” (Clara). This comment was interesting as it suggests that the teacher’s orientations towards science teaching were in line with having students engage in surface learning without developing a deep conceptual awareness of the content.

**Observation of Rebecca**

**Topic: States of Matter**

**Big Idea: Elements, Compounds and Mixtures**

There was evidence of inquiry seen in this lesson but it was structured inquiry as students were given an activity sheet to record the necessary data. First of all students had to, in groups, construct models which they felt best represented elements, compounds and mixtures:

*Rebecca introduces the next activity which is a play-dough activity representing elements, compounds and mixtures. Students are given instructions on PowerPoint and are given an activity worksheet to complete individually and then in groups. The activity is timed for 5 minutes. Students in their groups discuss what elements, compounds and mixtures look like.*

(Extract from Field Notes)
After completing this activity they had to observe the models and draw conclusions as to what they thought the properties of elements, compounds and mixtures were. Students recorded their data on an information sheet. This was done in groups therefore allowing communication of findings and discussion of conclusions to take place, indeed it allowed for the social construction of knowledge. Rebecca scaffolded this activity by circulating and asking questions to probe the students thinking.

Rebecca circulates and probes during the activity. Students record the data on their activity sheet. One group demonstrate their model to the class. Rebecca asks if they had anything to contribute to the discussion that wasn’t mentioned already.

(Extract from Field Notes)

This activity contained a number of the defined features of scientific inquiry. For example, students have to observe, collect data and draw conclusions with Rebecca scaffolding the activity throughout but still giving the students control over their learning. However it must be considered that giving 5 minutes to this activity was perhaps not enough time to allow the students to explore and develop their understanding. Next Rebecca asked students to research for homework the link between elements, compounds and mixtures and solids, liquids and gases and to present their findings in the next lesson.

Interestingly Rebecca’s analysed lesson plans contained the greatest reference to scientific inquiry in terms of the consideration for inquiry-based practice in her aims, objectives and overall lesson structure. This consideration for scientific inquiry practices was emulated to some degree in the classroom observation.

Follow up Interview with Rebecca

The responses provided by Rebecca during the follow up interview provide insights into her experiences of engaging students in inquiry practices. She conceded that it took students some time to adapt to this practice and interestingly suggested that they had to learn to interact with the teacher as formerly this interaction was a teacher dominant engagement:
“It took them a good while to get used to it though, it took them a good month to kinda get ok what is she at. I thought they just weren’t interested but they just hadn’t a clue of how to interact with the teacher”

(Rebecca)

She considered that initially engaging in such practices “played havoc with classroom management” and as a result decided to introduce inquiry slowly into the classroom. This decision suggests an awareness of how to adapt to a particular classroom situation.

Also Rebecca conceded that it does take longer to prepare for an inquiry-oriented lesson and suggested that the teacher may have certain attitudinal dispositions around their ability to consider inquiry-oriented classes and their drive to engage in the additional preparatory work:

“It takes longer for you to prepare but you can still get the same covered in the class, you just get it covered better... I think it’s just that it has the wrong attitude like the teachers don’t know how to do it and they won’t put in that extra work in preparing the class”

(Rebecca)

Indeed Rebecca did express that it was “quiet challenging” to complete lesson plans and prepare resources and “still have energy for teaching class”. This response documents the realities of teaching whereby preparation forms a large part of the teaching compass.

**Observation of Sean**

**Topic: Respiration**

**Big Idea: The Difference between Respiration and Breathing**

Students engaged in an investigation to determine whether a person inhales more during exercise. This can be viewed as a structured inquiry activity with Sean providing instruction:

*We’re going to do a little activity first so. Ok so what we are going to do is we are going to time ye ok and you have to count the number of times you have to breathe in... now the next part ok I want everyone to stand up, chairs under your desks ok so*
basically just jog on the spot for 30 seconds. Ok so that’s about 30 seconds so count how many times you breathe in ok, go. Breathe in now not out ok?

(Sean)

Students observed their pulses before and after exercising and were able to draw conclusions from this. This was an inquiry-oriented activity as the students did not know the outcome in advance and through their comparison, they were able to draw a conclusion. However the activity was very much a structured inquiry activity as it lacked features such as having students formulate the research question and design their own investigation. The remainder of the lesson was a PowerPoint presentation.

Follow up Interview with Sean

Reflection on the Use of Inquiry

He acknowledged that he gave students aims at the beginning of the lessons with certain class groups to focus their thinking and with other class groups he let them devise their own experiment but gave them a title to guide them. When Sean was asked if engaging in such investigations had an effect on student outcomes he considered that it “worked very well” and shared how the students retained their new understanding of the content:

The next class after doing the experiment again, the results we kind of went through the write up and most of them were able to remember...like I didn’t have to give them a conclusion, they were able to draw their own... it was something different to them I’d say plus they’re first years and they felt like real scientists”.

(Sean)

He also compared this with the experience he had with another class group, who did not engage in such an activity and he revealed that there was a difference in terms of student learning and engagement:

“Cause then with another class where I didn’t try it that way they were a bit more disruptive... it could be down to not making the connection completely”.

(Sean)
Sean also noted the role of the teacher during these practical investigations as being a facilitator who would “always circulate around and kind of watch them how they are thinking” (Sean). He did acknowledge the difficulty he had with trying not to give the students the answer when they were struggling but did reflect on the importance of students coming up with the answer to a question:

“Sometimes they’d be kind of looking at you, basically just give me the answer and you are just probing them and questioning them to get to the answer themselves cause I think they definitely have to get the answer themselves... they’ll remember it whereas if you tell them the answer, you have to tell them like how many times for it to stay whereas if they discover it themselves, they’ll remember it”. (Sean)

Here Sean is reporting the struggle he encountered with trying not to give students the perceived “correct answer”. Again this reflects the culture of there being only one correct, defined answer to a problem which is very much the antithesis to a guided or open inquiry approach.

Despite the attempts made to refocus the conversation on the observed lesson, Sean tended to discuss past lessons which were not related to the CoRe topics.

7.2.4 Conclusions
In all, the PSTs showed a large variation in terms of their practice in the classroom. Some lessons, such as Clara’s lesson, had limited orientations towards inquiry and mirrored a didactic teacher-led lesson. Interestingly Clara was most vocal during the CoRe construction and considered a number of inquiry-oriented activities but this was not emulated in the observed lesson. The responses given in the survey do compare favourably with the findings from the lesson plans and observations as all three showed structured/partial inquiry were present. However there were some occasions where the PSTs proposed that certain features of inquiry were frequently acted upon in the classroom but this was not seen either from the lesson plans or the observations. For example, all PSTs said that the students frequently had roles during investigations and actively carried out investigations. This was not seen in the analysis of the lesson plans or the classroom observations. It must be remembered
however that the PSTs were speaking of the entire 10 week experience when answering the survey. Therefore it is difficult to compare responses given in the survey with what was seen in both the lesson plans and the observations. Hence the main conclusion that can be drawn is that the PSTs depiction of inquiry resembles partial inquiry at best and while they do portray orientations towards inquiry in their approaches towards lesson planning, this is by and large not repeated in the design and enactment of the student activities. How their action of inquiry compares to other cohorts not involved in the PLC will be considered in the next section.

7.3 RQ4 How does the scientific inquiry practice of these PSTs compare with other teachers (pre-service and in-service) - What factors inhibit its enactment?

7.3.1 Average Action of Inquiry
This section presents the findings from the survey that was given to the three different cohorts described previously. The action of scientific inquiry was analysed by calculating the average score for eighteen of the twenty questions asked in the survey. These questions reveal inquiry action if teachers gave often or almost always as their chosen response. The other two questions reflect teacher-led approaches so were excluded in this calculation as they do not reflect inquiry orientations. Before the analysis began, it was decided to accumulate the five responses into three responses, due to the small numbers within the cells. The responses “seldom” and “almost never” were combined into the response “rarely” and the responses “often” and “almost always” were combined into the response “frequently”. The third response remained as “sometimes” 12. One way ANOVA was carried out to identify significant difference between the averages of the different cohorts. There was found to be a significant difference of 0.002 between the groups. Further tests were carried out (Tukey HSD, Bonferroni etc.) to identify with which group these differences lay. Table 7.6 documents these significant differences.

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12 This decision was made on the basis of advice sought by a statistician.
Table 7.6: Significant differences between cohorts (average action of inquiry)

<table>
<thead>
<tr>
<th>Teacher compared with</th>
<th>Teacher</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) PST not in study (n=29)</td>
<td>PST in study</td>
</tr>
<tr>
<td></td>
<td>In-service teacher</td>
</tr>
<tr>
<td>(2) PST in study (n=12)</td>
<td>PST not in study</td>
</tr>
<tr>
<td></td>
<td>In-service teacher</td>
</tr>
<tr>
<td>(3) In-service teacher (n=94)</td>
<td>PST not in study</td>
</tr>
<tr>
<td></td>
<td>PST in study</td>
</tr>
</tbody>
</table>

It can be suggested from above data that PSTs involved in the study had significantly different responses to both the PSTs not involved in the study (p=0.016) and the cohort of in-service teachers (0.001). As well as this, there was found to be no significant difference between the PSTs who were not involved in the study and the in-service teachers. Figure 7.1 presents a box plot of the average action of inquiry between the different cohorts. The action of inquiry ranges from 1.00 to 3.00 with “rarely” reflecting the figure 1.00, “sometimes” reflecting the figure 2.00 and “frequently” associated with the figure 3.00. The closer the box plot is to the figure 3.00, the greater the average action of scientific inquiry. In the discussion of the results, the PSTs not involved in the study are presented as PST-1, the PSTs involved in the study are presented as PST-2 and the in-service teachers as IST.

Figure 7.1: Average action of scientific inquiry
Finally an independent sample Kruskal Wallis test was used to determine which cohort had the highest average for inquiry practice, the PSTs involved in the study were shown to have the highest average of inquiry practice over the other cohorts involved in the study, as revealed in the above box plot. There were also three ISTs (outliers 68, 121 and 122) whose average action of inquiry was significantly lower than all the other participants with an average action of 0.84, 0.79 and 0.84 respectively. Referral back to the data has verified that one of these teachers chose the response of rarely for the majority of the responses given (7 out of 10). For the remaining questions, they did not supply an answer to the statements. In relation to the other two teachers, they did not answer eleven out of the twenty questions and for those that they did answer, rarely was their most frequently chosen response. The participant with the highest overall average action of inquiry (2.79) was a PST involved in the study.

7.3.2 Responses to the Individual Statements on the Survey

The following section puts forth the responses to the individual questions. For the examples shown in bar chart format, there was a statistically significant difference between the PST-2s and the other two cohorts. The author would like to note that there were other examples where the PSTs involved in the study responded more positively than the other cohorts however the results were not viewed as being statistically different. Such examples are represented in a table at the end of the section. Cross tabulations were carried out for each of the questions and a chi-squared test was done to explore association between the groups.

\[13\] Note: even though there are size differences between the three box plots, the individual percentages were used to work out the average action of inquiry. For example 6 out of 12 represented 50% for the PSTs involved in the study while 47 out of 94 represented 50% of the in-service teachers.
Figure 7.2: Students formulate question- cohorts’ responses to statement

Figure 7.2 represents the three cohorts’ responses to the statement “Students formulate (generate/make) questions which can be answered by investigations, e.g. using prior knowledge”. In all, 48.3% of PST-1s, 40% of PST-2s and 78.7% of ISTs chose the “rarely” response and 51.7% of PST-1s, 60% of PST-2s and 21.3% of ISTs chose the “sometimes” response. Even though no participant identified that this was a frequent action in their classroom, an interesting point to note is the number of in-service teachers who chose “rarely” as their response.
Figure 7.3: Time is devoted to research question- cohorts’ responses to statement

Figure 7.3 reflects the responses which all three cohorts gave to the statement; “Time is devoted to students thinking about and defining their own research question”. Considerably more PSTs involved in the study chose the frequently response (70%) against 17.2% for the PST-1s and 12.8% for the ISTs. Also none of the PST-2 chose “rarely” for this particular question while 44.8% of PST-1s and 52.1% of the ISTs chose this option.
For the statement “Students justify procedure”, 60% of PST-2s believed that they frequently allow students to justify the procedure with 27.6% of PST-1s and 36.2% of ISTs choosing this response. Again with this statement, none of the PSTs involved in the study chose the rarely option while 20.7% of PST-1s and 28.7% of ISTs identified that they rarely involved students in justifying the procedure that they used during an investigation.
Figure 7.5: Students design procedure themselves- cohorts’ responses to statement

80% of PST-2s identified that they frequently involved students in designing their own procedure while only 31% of PST-1s and 12.8% of ISTs chose this response. This is an important feature of both guided and open inquiry and therefore the margin shows that the PSTs in the study had more frequent orientations towards this action of inquiry practice. None of the PST-2s chose the option of “rarely” while 41.4% of PST-1s and 57.4% of ISTs chose this option.
In terms of providing students with a step by step procedure, 79.8% of in-service teachers frequently do this with 40% of PST-2s and 69% of PST-1s choosing this option. 40% of PST-2s identified that they rarely gave students step by step instruction while only 6.9% of PST-1s and 5.3% of ISTs chose this response.
Delegation of roles is an important feature of group investigative practices. The above bar chart reveals that all of the PST-2s frequently assigned roles to their students in an investigation while 62.1% of PST-1s and 81.9% of ISTs gave this response. 10.3% of PST-1s and 7.4% of ISTs believed that the rarely gave students roles during investigations. Indeed there was evidence from some of the lesson plans and observations, particularly with reference to Rebecca, where there was a focus on the social exploration/generation of knowledge.
Figure 7.8 shows the responses from the participants in relation to the statement “Students develop their own conclusions”. This is one of the essential features of scientific inquiry and it is evident from the above graph that all of the PST-2’s involved students in developing their own conclusions while only 62.1% of PST-1s and 52.1% of ISTs chose this option. 13.8% of PST-1s and 14.9% of ISTs chose the “rarely” option for this statement.
Figure 7.9: Students consider a variety of explanations- cohorts’ responses to statement

Students need to consider a variety of explanations in their discussion of the data and Figure 7.9 shows that the PSTs in the study frequently allowed students to consider a variety of explanations (80%), while only 31% of the PST-1s and 30.9% of the ISTs gave this response. Interestingly none of the PST-2s believed that they rarely provided students with this opportunity while conversely, 41.4% of PST-1s and 25.5% of ISTs chose this response.

Table 7.7 represents the responses to the remaining statements; however it must be noted that there was no statistically significant difference between the cohorts when
the data was analysed using chi-square tests. However the reason for this appears to be the tendency for the numerical responses of the PST-1s and the ISTs to be similar.

Table 7.7: Responses from cohorts with no significant differences

<table>
<thead>
<tr>
<th>Statement</th>
<th>Cohort</th>
<th>Rarely</th>
<th>Sometimes</th>
<th>Frequently</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Students research questions are used to determine direction and focus of practical work</strong></td>
<td>PST1</td>
<td>44.8%</td>
<td>31%</td>
<td>24.1%</td>
<td>.150</td>
</tr>
<tr>
<td></td>
<td>PST2</td>
<td>20%</td>
<td>30%</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IST</td>
<td>51.1%</td>
<td>31.9%</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td><strong>Time is devoted to evaluating and adapting procedure</strong></td>
<td>PST1</td>
<td>20.7%</td>
<td>31%</td>
<td>48.3%</td>
<td>.226</td>
</tr>
<tr>
<td></td>
<td>PST2</td>
<td>10%</td>
<td>10%</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IST</td>
<td>35.1%</td>
<td>31.9%</td>
<td>30.8%</td>
<td></td>
</tr>
<tr>
<td><strong>Students conduct own procedure</strong></td>
<td>PST1</td>
<td>27.6%</td>
<td>27.6%</td>
<td>44.8%</td>
<td>.559</td>
</tr>
<tr>
<td></td>
<td>PST2</td>
<td>10%</td>
<td>20%</td>
<td>70%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IST</td>
<td>30.9%</td>
<td>17%</td>
<td>48.9%</td>
<td></td>
</tr>
<tr>
<td><strong>Teacher conducts procedure</strong></td>
<td>PST1</td>
<td>27.6%</td>
<td>44.8%</td>
<td>27.6%</td>
<td>.09</td>
</tr>
<tr>
<td></td>
<td>PST2</td>
<td>50%</td>
<td>20%</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IST</td>
<td>54.3%</td>
<td>30.9%</td>
<td>11.7%</td>
<td></td>
</tr>
<tr>
<td><strong>Students actively participate in investigations</strong></td>
<td>PST1</td>
<td>0%</td>
<td>3.4%</td>
<td>96.6%</td>
<td>.593</td>
</tr>
<tr>
<td></td>
<td>PST2</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IST</td>
<td>4.3%</td>
<td>7.4%</td>
<td>85.1%</td>
<td></td>
</tr>
<tr>
<td><strong>Students determine data for collection</strong></td>
<td>PST1</td>
<td>48.3%</td>
<td>31%</td>
<td>20.7%</td>
<td>.325</td>
</tr>
<tr>
<td></td>
<td>PST2</td>
<td>20%</td>
<td>40%</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IST</td>
<td>28.7%</td>
<td>41.5%</td>
<td>24.5%</td>
<td></td>
</tr>
<tr>
<td><strong>Students take details notes and observe</strong></td>
<td>PST1</td>
<td>24.1%</td>
<td>34.5%</td>
<td>41.4%</td>
<td>.900</td>
</tr>
<tr>
<td></td>
<td>PST2</td>
<td>20%</td>
<td>40%</td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IST</td>
<td>19.1%</td>
<td>29.8%</td>
<td>47.9%</td>
<td></td>
</tr>
<tr>
<td><strong>Students understand the importance of collecting data</strong></td>
<td>PST1</td>
<td>6.9%</td>
<td>34.5%</td>
<td>58.6%</td>
<td>.442</td>
</tr>
<tr>
<td></td>
<td>PST1</td>
<td>PST2</td>
<td>IST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PST2</td>
<td>0%</td>
<td>10%</td>
<td>90%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IST</td>
<td>3.2%</td>
<td>22.3%</td>
<td>71.3%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Students decide what data to collect**

<table>
<thead>
<tr>
<th></th>
<th>PST1</th>
<th>PST2</th>
<th>IST</th>
</tr>
</thead>
<tbody>
<tr>
<td>PST1</td>
<td>48.3%</td>
<td>10%</td>
<td>30%</td>
</tr>
<tr>
<td>PST2</td>
<td>10%</td>
<td>60%</td>
<td>30%</td>
</tr>
<tr>
<td>IST</td>
<td>27.7%</td>
<td>38.3%</td>
<td>29.8%</td>
</tr>
</tbody>
</table>

**Students connect conclusions to scientific knowledge/theory - cohorts’ responses to statement**

<table>
<thead>
<tr>
<th></th>
<th>PST1</th>
<th>PST2</th>
<th>IST</th>
</tr>
</thead>
<tbody>
<tr>
<td>PST1</td>
<td>10.3%</td>
<td>0%</td>
<td>10%</td>
</tr>
<tr>
<td>PST2</td>
<td>0%</td>
<td>10%</td>
<td>90%</td>
</tr>
<tr>
<td>IST</td>
<td>14.9%</td>
<td>25.5%</td>
<td>59.6%</td>
</tr>
</tbody>
</table>

**Students justify conclusions – cohorts’ responses to statement**

<table>
<thead>
<tr>
<th></th>
<th>PST1</th>
<th>PST2</th>
<th>IST</th>
</tr>
</thead>
<tbody>
<tr>
<td>PST1</td>
<td>10.3%</td>
<td>0%</td>
<td>10%</td>
</tr>
<tr>
<td>PST2</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>IST</td>
<td>16%</td>
<td>23.4%</td>
<td>60.6%</td>
</tr>
</tbody>
</table>

The findings above appear to suggest that the features of inquiry are seen more frequently in the classroom of the case study PSTs. However an interesting point to note is that a greater percentage of PSTs involved in the study chose “frequently” in response to “teacher conducts procedure”. Nevertheless taking all the responses into consideration and having calculated the average action of inquiry, it can be deduced that all cohorts display some orientation towards inquiry (partial inquiry) but the case study cohort appear to enact orientations towards inquiry more frequently in the classroom.

### 7.3.3 Barriers to Implementing Scientific Inquiry

In the analysis of the surveys the factors which can prevent the use of inquiry in the classroom were explored. The following section presents the perceived barriers categorised into different themes. The barriers suggested by the in-service teachers and the pre-service teachers not involved in the case study are presented first followed by those given by the case study cohort to see if there are differences between the groups.

**Time constraints**

A number of participants (n=78) revealed that time constraints limited the implementation of scientific inquiry. The issue of time constraints could be broken down into a number of factors related to time. Some participants revealed that
whether the class was a single or double class (n=2) was a factor which influenced teaching through scientific inquiry and also one in-service teacher suggested that timetabling issues resulted in “Not enough classes scheduled” to allow inquiry to take place. Another participant revealed that inquiry activities takes up more class time “Enquiry based learning tends to take up more class time than giving students title & method” (PST) and that “It takes time to adapt to this new system” (IST). This latter comment is interesting as it aligns with the issue of using once off professional development for changing educational practice. This in-service teacher is highlighting that changing practice takes time and sees this as a barrier towards approaching it in the classroom.

One PST gave an interesting insight into the relationship between the use of scientific inquiry and time:

“If I know the way the pupils will discover the answers on their own I will facilitate them discovering it on their own. However if they will go too deep and take too long I would do it the easy way and just tell them how to do it”.

(PST)

The above response suggests that while this PST sees value in allowing students to construct their own understanding, they feel the need to intervene, due to time constraints if the students are learning beyond what was originally envisaged, this intimates at a crowded curriculum. Indeed the time constraints associated with having to complete the syllabus were noted by a number of participants (n=8). The time taken to plan and source resources for inquiry activities was also noted by some teachers (n=5). The rate at which students engage in work was mentioned as a concern by one teacher. Another in-service teacher believed that in first and second year there would be more time to use inquiry, after which the exam pressures dominate the focus of pedagogical choices.

Another in-service teacher revealed that the lack of lab technicians in schools resulted in the teacher having to give more time to preparing investigative activities:
“The lack of lab technicians in the school meant that the time needed to set up the equipment, even getting it out from the stores means that a double class would be needed to even do this”.

(ISI)

A PST gave a similar response suggesting that experiments should not be rushed and they must be adequately prepared for and this was viewed as a time constraint by the participant:

“Time factors: experiments or investigations should not be rushed and must be thoroughly planned and prepared”

(PST)

The length of time that experiments can take to complete was identified as a factor by one PST. She revealed that “Some experiments are too lengthy to perform in groups/individually” (PST). External pressure to complete the required topics was identified by one PST who suggested that their co-operating teacher advised against such strategies as “there were only a certain number of lessons to complete each topic” (PST).

**Personal Constraints**

This category applies to issues which could be viewed as personal to the teacher. In all 7 in-service teachers suggested personal constraints which prevented them from implementing scientific inquiry. The lack of support from colleagues and the level of cooperation amongst colleagues were given as barriers by some teachers (n=3). The lack of success of peers in using inquiry-based learning was seen by one teacher as a potential barrier. The attitude of colleagues was identified by another teacher. Interestingly only one teacher revealed that not knowing how to approach inquiry acted as a barrier. One teacher identified that with the exams coming and that “the fall guy is me”, this could prove to be as a disabling factor towards teaching through inquiry. One PST in particular raised questions in relation to whether inquiry should be part of a classroom experience “Is it worth doing? Is it necessary?” This contribution would suggest an attitudinal orientation which questions the potential impact of inquiry in the construction of new knowledge.
Finally two PSTs suggested that the co-operating teacher in a school influenced their practice of scientific inquiry.

**Student Constraints**

A large number of teachers, both pre-service and in-service teachers, recognised that student ability (n=30) was a limiting factor. One in-service teacher revealed that students do not have the cognitive or reasoning skills; that students are used to rote learning. The latter was also identified by another teacher as students have a “lack of prior exposure to inquiry”. Another in-service teacher acknowledged that students’ ability to work in groups would be viewed as a potential issue. Other teachers (n=2) revealed that students having to work independently would inhibit the use of authentic inquiry experiences. This suggests a certain misunderstanding as inquiry can and indeed should allow for group exploration with each group member assigned certain roles.

One teacher felt that inquiry suits stronger students but can leave weaker students floundering. Two teachers recognised that student age was a factor and that “students need to be spoon fed everything” (PST) and that first year students “are not able to think in such a way” (IST). This view was also echoed by a PST who believed that inquiry was more suitable for older age groups:

“I think it is more appropriate for older class groups as in my experience 1st year classes are not able to think in such a way as enquiry based learning is beneficial to them”.

(IST)

Some in-service teachers (n=6) acknowledged that maturity levels could serve as a potential barrier.

Student discipline and classroom management (n=15) was a factor presented by a number of both pre-service and in-service teachers. One PST summed up this perception by saying “class group (is a barrier) - less likely to do inquiry in a class with a discipline issue and will stick to the course”. Interest, motivation and focus were referenced by a number of both pre and in-teachers (n=10). Prior knowledge of
students was also seen to be a barrier by a number of in-service teachers (n=6). One PST suggested that focusing on doing the experiment rather than learning could serve as a potential barrier to enacting inquiry approaches. What is interesting with this comment is that this particular PST is not aligning experimental work with potential learning experiences that can take place concurrently. In other words, this PST does not consider inquiry practices as a vehicle towards learning the scientific concepts. One PST associated the socio-economic status of the school as being a limiting factor:

“One limiting factor is the pupils themselves. Having taught in a disadvantaged school, the amount of autonomy and independence I can give the pupils is limited somewhat”

(PST)

Most of the participants did not believe the use of scientific inquiry was subject dependent however three PSTs did believe it was. For example, one PST suggested that the degree of difficulty of a topic was an important consideration:

“The topic to be investigated is quite important. Whether the topic is hard or whether students will understand what is being done is very important…”

(PST)

**Physical Constraints**

The resources available in schools were a popular response given by both pre-service and in-service teachers with forty three teachers sharing this perception. Within the theme of resources, the lack of equipment and breakage of equipment were identified by a number of in-teachers (n=19). The facilities, the sharing of limited lab space and the timetabling of classes outside the lab were recognised as being disabling factors towards the implementation of inquiry (n=10). The expensive chemicals needed to enact investigations were seen by one pre-service and in-service teacher:

“In chemistry I would be wary of using it as chemicals are expensive meaning if the pupil did not carry out the procedure correctly more chemicals are needed for the repeat”

(PST)
The issue of larger class groups was also recognised by some pre-service teachers (n=4). The issue of safety was given by a small number of pre-service (n=2) and in-service teachers (n=7).

**Constraints given by the PSTs (PST-2) involved in the study (n=12)**

The PST-2s gave similar constraints to those provided by the other two cohorts. The following section provides a description of these constraints.

**Time Constraints**

Three of the case study cohort mentioned how time constraints could be a limiting factor with one suggesting that “it takes time for students to adapt to this new system” with another believing that a double class was not sufficient time to complete an experiment:

“The time constraints of a double to complete an experiment was also an issue. It put pressure on to move quickly through the procedure which hindered student inquiry”

(PST-2)

Another PST-2 found that the co-operating teacher placed pressure on her to complete the course and this pressure would limit the use of scientific inquiry:

“I found that I preferred to teach through inquiry and that the pupils learnt far better but I felt pressure from my co-operating teacher to move on, he felt that I should just get material covered, that there wasn’t time for inquiry”

(PST-2)

**Personal constraints**

The teacher’s lack of prior experience was viewed by one PST-2 as being a disabling factor. Another PST-2 suggested the extensive curricular duties as being a factor in whether inquiry is used. One PST felt that her school were opposed to such a strategy because of the additional time she felt it required:

“I found my school were very against it though, my co-operating teacher because am say like I was doing forces like loads of stuff about forces and they really really, they learned it so well and I went through the chapters slowly because obviously it takes more if you’re doing inquiry”
Another PST implied that other teachers got “very defensive” if she tried to discuss the approaches she used in the classroom. A third PST identified the difficulty within the new school context because:

“You’re planted in there it’s very difficult for you to establish yourself. It would be much easier for us when we have our own classrooms and they know that this is what goes on (inquiry)”

This comment provides insight into the technical struggles which inhibit putting theory learned from professional development endeavours into practice.

**Student constraints**

Two of the cohort believed that if students had prior exposure to inquiry they would find it easier to relate to this approach:

“From TP I found that if the students had some exposure to inquiry prior to a wholly inquiry lesson they found it easier to understand the purpose of the lesson, less of a shock to the system”

Student safety was identified by one PST-2 and student behaviour was viewed by two others with one suggesting “Very poor classroom behaviour can make discovery activities very challenging”. Student ability was given as limiting factors by two members of the group with one PST-2 suggesting that the “ability of group limits the amount of inquiry that can be carried out and how far it can be taken”.

One PST-2 believed students’ language skills was a disabling factor:

“Students language skills I found that students with more limited linguistic skills struggled with the writing even though verbally they responded well to the IBL”
This comment identifies a key association between the practice of scientific inquiry and the ability to communicate science and highlights the need to focus on developing these skills within an inquiry classroom (Brownell et al. 2013). Another PST-2 signalled the level of prior knowledge, focus and interest as being the primary limitations. Willingness to learn was also identified by another PST-2.

**Physical Constraints**

One of the PST-2s identified the lack of resources and technology as being a disabling factor towards the enactment of inquiry while another PST-2 believed that curriculum duties served as a limitation.

Despite the constraints given, one PST-2 did suggest that the benefits of using inquiry in the class far outweighed the difficulties or limitations which come with using this approach:

“The benefits for the incorporation of “Inquiry-based learning” in the classroom outweighs the limitations and difficulties associated with it”

(PST-2)

Another PST-2 believed that it was easier to teach some topics through inquiry more than others. Interestingly, this can be seen with the lesson plans in section 7.2.2 where inquiry activities tended to be used to teach only some topics.

**7.4 Main Themes related to the Action of Scientific Inquiry in the Classroom**

The following points provide a summary of the main themes identified from this chapter and seek to signpost for the reader the main points that will be discussed in the discussion chapter:

- The PSTs do appear to have enacted scientific inquiry to some degree in classroom practice. This can be suggested predominantly by looking at the self-reporting survey and perhaps the lesson plans. The observations however did not provide much evidence of the defined features of scientific inquiry. Clara, for example, presented lesson plans which contained reference to inquiry-oriented activities but the observed lesson was more reflective of a
didactic teacher-led class. Also some of the lesson plans included aims which mentioned scientific inquiry but this was not reflected in either the learning outcomes or the student activities.

- When inquiry was seen within the survey, lesson plans and observations, it was very much at the structured/guided level of inquiry (partial inquiry). It must be remembered that in phase two the PSTs tended towards this level of inquiry. Therefore it can be suggested that their orientations towards scientific inquiry in phase two was mirrored in phase three.

- The barriers towards scientific inquiry are very much in line with those reported in the literature with some additions, namely the influence of a lab technician as to whether or not inquiry can take place in a classroom.

- All cohorts report similar barriers towards enacting inquiry but the case study cohort did appear to have a higher average action of inquiry in the classroom.
Discussion
8.1 Introduction
The framework guiding this study reflects the hypothesis that a PCK tool (the CoRe) can be used to capture and develop inquiry orientations through the social construction of meaning within a PLC. The findings reported previously provide evidence that this is the case and will be discussed in this chapter. It was critical to gain a foundational understanding of the PSTs’ orientations towards inquiry in order to understand whether the interactions within the CoRe PLC could lead to such development. Dialogue analysis suggests that the PSTs in phase two supported each other as they began to construct their own living educational theory (Whitehead 1989) of inquiry. The CoRes were starting to portray the PSTs’ espoused scientific inquiry orientations. However for meaningful change to occur, it was necessary to view professional development from enacted habits of practice through individual narratives (in the form of PaP-eRs) and comparisons with other cohorts.

To that end the following research questions are discussed in light of the findings:

- What are the foundational scientific inquiry orientations of a cohort of pre-service science teachers before, during and after a six week teaching practicum?
- What are the affordances of a PCK lens as a professional development aid, specifically its use in describing and developing inquiry orientations in pre-service science teachers through the social construction of meaning?
- How do the perceived developing inquiry orientations successfully translate into actual classroom practice?
- How does the scientific inquiry practice of these PSTs compare with other teachers (pre-service and in-service): What factors inhibit its enactment?

8.2 RQ1. What are the foundational scientific inquiry orientations of a cohort of pre-service science teachers before, during and after a six week teaching practicum?
The key themes identified at the end of chapter 5 are represented in Figure 8.1
As a reminder this question was addressed in phase one of the study. This phase primarily served two purposes: (1) to introduce the PSTs to the CoRe as a PCK lens and (2) to gain a foundational understanding of the PSTs’ orientations towards scientific inquiry (linked to RQ1.). Essentially phase one served as an opportunity to develop an understanding of their apprenticeship of observation (Lortie 1975) in terms of their orientations towards scientific inquiry and how this manifested itself through their espoused and enacted PCK.

**8.2.1 Pre-Practicum CoRes- Capturing their Past Experiences as Students**

A substantial volume of research highlights that PCK develops with experience (Loughran *et al.* 2006; de Jong and van Driel 2004, Hume and Berry 2011). Before classroom experience is possible it can be suggested that PSTs rely on the PCK of their classroom teachers, an experience referred to as their apprenticeship of observation (Lortie 1975). Haston and Leon-Guerrero (2008) consider that a PST’s apprenticeship of observation is a source of PCK and stress the importance of understanding what influences a PST’s PCK. As an inquiry habitus can be embedded within a teachers’ PCK (Jordan-Spang 2008) it must also be considered that the PSTs’ orientations towards scientific inquiry would have been largely governed by their apprenticeship of observation (Darling-Hammond 2006). Therefore as this
research question is discussed in light of the findings, it is necessary to consider their past experiences as students as they developed the CoRes, particularly the pre-practicum CoRes.

Lortie (1975) considers the unnamed effects which the apprenticeship of observation has on the PSTs’ practice and determines these effects to have a greater influence on their practice than that of their ITE programme. Indeed Bullock (2011) proposes that the culture of teaching and learning is replicated because of the tacit, unexamined effects of the apprenticeship of observation. The assumption of teacher educators is that PSTs should be “told” theory before beginning their teaching practicum so they can put theory into practice however researchers still have little understanding of how PSTs learn to teach (Bullock 2011). Tapping into their PCK and specifically their orientations towards scientific inquiry may offer insight into the PSTs’ apprenticeship of observation which can in turn allow for examination of the effects of their student experiences (Bullock 2011). Therefore it was critical to tap into the PSTs’ orientations towards scientific inquiry before they had classroom teaching experience. Examination of PCK can also allow for the articulation of their understanding of “good teaching” which can then be fostered through group exploration. It sets them on a trajectory for reasoning about the transformation of the content they teach (Mavhunga 2014).

Initially the reference made to their own classroom experience as they developed the pre-practicum CoRes was less than the author had assumed would be the case. It can be suggested that it was an internalised dialogue that facilitated their external discussion. This idea of PSTs engaging in an internal dialogue as a product of their apprenticeship of observation is echoed in the literature according to Knowles (1993) who stresses the need for teacher educators to make explicit this internal dialogue. It is true to say that their student experiences would be the dominant influence on their beginning interpretation of “good” teaching practice yet the gaps in the CoRes, particularly pre-practicum, make visible the progression needed to begin to understand the knowledge needed for effective instruction. In other words, it can allow the PSTs to see the gaps in their knowledge which can make this amenable to change.
It must be considered that this is not something that PSTs are used to in their daily practice. Indeed the findings have shown that the development of the CoRes was a progressive process by viewing their initial interactions within the PLC and their struggles to elaborate on their thinking. Hume and Berry (2010) also found that the PSTs within their study struggled to develop CoRes due in part to their lack of classroom experience and in turn their naïve PCK (Hume and Berry 2011). The exploration of the CoRes developed pre-practicum confirms this. Hume and Berry (2010) suggest that PCK construction through the CoRe tool does provide a good foundation for PCK development and is therefore a worthwhile endeavour for PSTs regardless of their classroom experience. Whilst the PSTs in this current study did struggle when they developed the CoRes prior to their teaching practicum experience, it allowed them the opportunity to recognise their limited knowledge and understanding of the key concepts associated with the topics under discussion, the particle theory and genetics.

PSTs are historically told how to teach and this in turn leads to a problem of enactment where they find it difficult to enact the propositional ideas (theories) they learned during their ITE coursework (Darling-Hammond 2006). It can be suggested that the CoRe allows for connections to be made between the social construction of knowledge and theory. The PSTs deficiencies in PCK are as a consequence of the system and their preparation but can be subject to change through the CoRe by making thinking visible. Indeed this act mirrors a constructivist process where PSTs are not being told the perceived “correct” answer but are exploring their own ideas/understandings through social interactions. Their apprenticeship of observation does not prepare them for understanding the complexities of teaching (Russell 2008, cited in Bullock 2011) however providing a community which explores the complexities of teaching can help PSTs to begin examining their understanding of teaching and learning, in this case their orientations towards scientific inquiry. This can in turn allow for the opportunity to examine considerations around “how do I improve my practice” (Whitehead 1989, p.1), through collaborative exploration where PSTs can begin an inquiry into scientific inquiry.
8.2.2 Initial Orientations towards Scientific Inquiry

The focus in the Particle Theory CoRe discussions pre-practicum tended to lean towards the teacher “showing” as opposed to the student “doing”. This suggests a teacher dominant habitus informing their practice. There was also mention during the design of the Genetics CoRe of the teacher having to “explain” and that it would be “difficult for students to put into their own words”. These responses suggest orientations devoid of student-led construction of knowledge and the focus on prescribed definitions.

There were also several references to authentic science being aligned with real-life applications only. For example, during the development of the Particle Theory CoRe, a PST within cohort A stressed the need to link with real-life. While it can be argued that real-life applications do form part of the scientific practice, together with investigative practices and theory formation (knowledge generation), they are not solely representative of authentic scientific practices (Evagorou 2013). Also authentic scientific inquiry mirrors a scientist’s practices (NRC 2000) yet there was no reference to a scientist’s practices during the construction of both the Particle Theory and Genetics CoRe. It can be argued that in order to help students develop an inquiry-oriented way of thinking they need a reference point in terms of how their practices mirror that of a scientist, yet the PSTs were missing this crucial link in their articulation.

One of the PSTs during the development of the Genetics CoRe, made reference to the importance of engaging in hands-on, practical investigations yet discussed how the absence of mandatory experiments from the Junior Certificate syllabus in genetics prevented such experiences. This comment is interesting as it suggests this PST has had experience of these mandatory experiments only. They view teaching science within the confines of these mandatory experiments not as an explorative, investigative opportunity where creativity and knowledge construction are viewed as pertinent to learning the concepts.

The PSTs also failed to connect their teaching strategies to student learning in terms of providing justification for their instructional decisions. They tended to make
declarations without engaging in meaningful consideration for how these strategies influence student learning. For example, during the development of the Particle Theory CoRe a suggestion was made to include demonstrations but they did not signal why they were important to facilitate student learning. It is clear here that they consider the importance of demonstrations because they mention the need to include “as many as you can” (PST-group A) yet they did not connect with why this was important. In a sense they were not fully articulating the complex nature of teacher knowledge (Loughran et al. 2006), which suggests the naïve understanding of teaching and learning. Indeed it suggests a lack of experience in articulating understanding in this manner. It can be argued that while the CoRe provides a structure to facilitate inquiry into scientific inquiry, the PSTs must first become proficient in a) inquiry through the CoRe and b) making sense of scientific inquiry.

The partial orientations towards scientific inquiry were observed mainly during the discussion of the teaching strategies prompt but analysis of existing CoRes developed by Loughran et al (2006) suggests orientations can be visible throughout the CoRe. This implies the PSTs’ weak PCK in terms of their understanding of how scientific inquiry can be embedded within the varying components of PCK.

8.2.3 Evidence of Scientific Inquiry Practices in the Classroom
The CoRe workshops before teaching practicum allowed for the articulation of espoused PCK and in turn their orientations towards scientific inquiry, if present. The findings showed weak dispositions towards inquiry in the pre-practicum CoRe however in order to get a true representation of their positionality towards inquiry it was necessary to interpret their classroom practice. The observations which the author conducted during the six week teaching practicum experience captured aspects of the PSTs’ individual PCK in action, specifically their orientations towards inquiry. Loughran et al. (2004) coined the term “classroom window” (p.293) as a way of critically examining the diverse ranges of teaching and learning situations which PSTs may encounter. These, according to Bullock (2011), expand on the articulation of PCK from the CoRe workshops and as a reminder are known as PaP-eRs. A teacher’s PCK guides their action when teaching subject matter in the classroom, therefore accounts of classroom practice can give insights into the nature of a teacher’s PCK in action (van Driel and de Jong 2001).
observations confirmed the low level nature of the PSTs’ orientations towards scientific inquiry however it must be remembered that only a small number of PSTs were observed, therefore generalisation of the entire cohort’s action is not possible. It must also be considered that the PSTs were at an early stage of development so this finding is not surprising.

There was a marked difference between the PSTs in terms of the teaching strategies they employed. Brian, for example, focused on an interactive student-led lesson with a variety of instructional strategies being employed. There were issues with the deliverance of these strategies; however the intent was to have the students involved in constructing their own learning. Conversely Jason conducted a lesson which contained limited use of resources apart from the aid of the whiteboard and worksheets. It must be considered that the use of a whiteboard only does not automatically reflect a didactic, traditional lesson. Indeed inquiry-oriented practices can take place simply using the whiteboard which, for example, could contain a data set for students to analyse and draw conclusions from (Bell et al. 2005). The lesson in its totality was effectively an example of a didactic, “jug and mug” approach to teaching. The difference in approach between the two PSTs with the same level of classroom experience revealed two very different habits of mind which it can be argued were products of the experiences they had when they were students in the classroom. These experiences effectively influenced their orientations to science teaching which in turn shaped their knowledge of instructional strategies (Magnusson et al. 1999).

While some of the PSTs did try to enact more student-led activities, the degree to which scientific inquiry approaches were used was lacking in all the classes observed. This suggests that the PSTs’ orientations towards science teaching were not reflective of scientific inquiry and this influenced their neglected use of the approach. Also it is important to note the disparity between what Aishling, in her interview, considered to match student learning. She suggested that engagement in an activity equalled learning and this, according to Nuthall (2005) is a cultural myth which seeps into classroom practice and can distract from authentic learning experiences. Nuthall (2005) argues that engagement in an activity does not
automatically equal learning and it is the cognitive underpinnings of the activity and the level of deep conceptual development of knowledge during an activity which equates to learning. Again, a response such as this highlights the PST’s low level of PCK.

The Place of Questioning within the Lesson

A key feature of an inquiry activity is the role of questioning within the learning process. What was interesting to note from some of the classroom observations was the limited targeted questions asked during the different learning activities to promote student thinking. It can be suggested that some of the PSTs did not view the importance of questioning. Mary, for example, dismissed the questions as “stupid questions” during her lesson on the properties of solids, liquids and gases. One of the students asked Mary "why are the gas particles so much smaller"? This question would provide an opportunity to discuss the micro level of particle composition yet Mary did not use this opportunity to explore this concept. Such responses do not invoke the question driven process which is scientific inquiry (NRC 1996). Mary’s response also puts into question what learning she sees as “valid” or “right”. It can be implied from her response that Mary considers prescribed content that she wants students to learn as being “valid” or “right”. This again is counter to the philosophical underpinnings of scientific inquiry.

In the interview, Aishling considered that she practiced scientific inquiry through her questioning however the observation of the lesson showed limited use of questioning within the class. This is interesting as it suggests that either Aishling’s reflections of the lesson were somewhat inaccurate or her conception of inquiry differs from the literature. Aishling also proposed that inquiry, through questioning, is useful if it is done with the “right” class. While she did not elaborate on this point, it suggests that she considers inquiry to only be suitable with certain students. The literature would argue that inquiry can be used for differentiated learning (Petty 2009), thereby suggesting that inquiry can be effective for students with different motivations, abilities etc. So the fact that Aishling perceives inquiry to only be suitable with certain students suggests a weak PCK in regards her understanding of how students learn.
The Power Relations in the Classroom

The power relations (Donnelly et al. 2014) between the PSTs and the students was an interesting observation as examples of the teacher controlling the activities and the arrival at the “correct” answer was seen in many of the observed classes. These power relations can, according to Donnelly et al. (2014), diminish the opportunity for authentic inquiry if the power is given solely to the teacher. A balance needs to be maintained in inquiry activities where both the student and the (pre-service) teacher exist in a social relationship where dominant views can be interrogated and challenged (Donnelly et al. 2014). For such opportunities to exist the teacher needs to have orientations towards science teaching reflective of this practice. There were also a number of occasions during the observation of both the particle theory and genetics classes where the PSTs gave away the perceived “correct” answer. For example, Brian did try to include some student-led thinking however proceeded to answer his own questions, thereby eliminating opportunity for students to construct their own knowledge. This, according to Strauss (2015), is a struggle for all teachers and must be recognised in professional development endeavours.

Effect of Classroom Management on Student Learning

Classroom management affected the successful implementation of different instructional strategies in a number of lessons. For example, Mary asked the students in pairs to think about what they believed were the properties of solids, liquids and gases in order to establish prior knowledge. Mary’s lack of “withitness” (Kyriacou 1998) meant that a large number of students copied answers directly from their textbook without Mary seeing this take place. This meant that the task was not as effective as it could have been. The author would argue that a teacher’s knowledge of classroom management should be an embedded feature of a teacher’s professional knowledge. Grossman (1990) placed knowledge of classroom management into a different teacher knowledge base, which is general pedagogical knowledge. However this author would suggest that for the delivery of scientific inquiry practices to be effective, the PCK of a teacher needs to have general pedagogical knowledge within its description. Indeed others have also included pedagogical knowledge (more specifically classroom management) within the description of PCK (Magnusson et al. 1999).
Time management was an issue in Aishling’s class in particular. She rushed through an activity on diffusion which likely resulted in surface learning. Harris and Rooks (2010) would consider appropriate time management as critical to a successful inquiry-based learning experience. Teachers can often adopt superficial features of an inquiry-based approach and do not give the time to explore students’ prior knowledge and construction of new knowledge (Harris and Rooks 2010). Therefore the rushed nature of Aishling’s diffusion activity indicates that while she had espoused ideas about teaching through inquiry, her enacted practice resulted in a superficial approach to inquiry.

**Concluding Remarks on the PSTs’ Classroom Experiences**

It must be noted that despite the opportunity to observe some classes and conduct an interview, the PSTs did not contribute to the design of the PaP-eRs as much as the author would have hoped. Despite a number of attempts made to ask the cohort to develop reflections and provide lesson plans etc. this was not achieved. Bertram and Loughran (2014) also noted that the PSTs in their study did not embrace the development of PaP-eRs and this perhaps suggests the PSTs negative appraisal of enactment and reflection of practice.

To give closure to this section it must be noted that the espoused responses given in the CoRe workshops were often not emulated in classroom practice. An example of this was the use of teaching strategies in Jason’s classroom which did not reflect the strategies considered in the CoRe. Indeed reference back to the data suggests that Jason was a vocal contributor in the design of the CoRe. It can be suggested that Jason’s espoused ideas of how to teach the particular Big Idea were not mirrored in the classroom practice, thereby highlighting the separation between the PST’s decision-making and how they acted in the classroom. It also identifies the disparity between what the PSTs considered to be good teaching practice and what unfolded when they entered a real classroom context.
8.2.4 Orientations towards Inquiry Post-practicum

Insufficient PCK can lead to PSTs resorting to didactic methods of teaching (Geddis *et al.* 1993). Mavhunga (2014) in her study with PSTs noted the significant improvement of a cohort’s PCK after they had developed CoRes. Therefore could the PSTs’ orientations towards scientific inquiry, embedded within their PCK, develop after initial CoRe construction and classroom experience? The findings from phase one suggest that despite some progress after the 6 week practicum, the PSTs still had limited orientations towards the use of scientific inquiry in the classroom and where activities were considered, they were very much confirmation inquiry.

The PSTs’ weak inquiry-oriented PCK can also be seen when examining the interplay between two components of PCK from the Magnusson *et al.* (1999) model, i.e. knowledge of students understanding of science and knowledge of instructional strategies. The PSTs considered the importance of visual representations as a way of developing students understanding of science, yet they failed to connect with instructional strategies which could allow for visual interpretation of the construct. They therefore failed to connect the different components of PCK as they developed the CoRes. As mentioned previously, this was also the case pre-practicum. Also, similar to pre-practicum, they tended to put forth instructional strategies, inquiry-based or otherwise, without due consideration for why these strategies could be used to engage students with the particular ideas. This again shows weak PCK as the PSTs are not connecting with the complexities and the reasoning behind using particular classroom practices to enhance student learning.

Not only did they show weak dispositions towards scientific inquiry, they also had misunderstanding in terms of how it can be practiced in the classroom. They considered that scientific inquiry can only be done through investigations, however the research argues for the use of “paper and pencil” inquiry (Nowak *et al.* 2013; Bell *et al.* 2005). Here students are still drawing conclusions and constructing new knowledge from data presented on paper without engaging in investigations to collect that data. Indeed this practice is mirrored in the outside laboratory where scientists often work with existing data to draw new conclusions (Schwartz *et al.* 2004). It was also interesting to note that, similar to before teaching practicum, the
PSTs consistently referred to having students relate to their own lives as being reflective of authentic science.

The PSTs did express concern about the level of detail/content covered in a class on a number of occasions during the development of the post-practicum Genetics CoRe. With the Particle Theory CoRe, they also considered questions beyond the scope of the syllabus as a potential difficulty. The same cohort of PSTs expressed concern about keeping classroom control and maintaining appropriately low noise levels. Interestingly the pre-practicum CoRes did not contain this level of detail in regards the potential difficulties/limitations which suggest that the PSTs are reflecting on their experiences in the classroom and are using these to inform their decision-making. Indeed largely speaking, when developing the CoRes after their classroom experience, they used vignettes from their experiences as acting teachers to help develop their respective CoRe. In a sense their apprenticeship of observation was less of an influence on their choices as they gained experience in the classroom (Borg 2004). This view is conferred by Kennedy (1999) who suggests that PSTs are initially influenced by their experiences as students, then by the subject matter they learn in their ITE programme and finally they develop their own techniques and styles through their classroom teaching experience. In all, the concerns mentioned above can potentially mitigate the practice of scientific inquiry, particularly for PSTs who already have underdeveloped PCK exacerbated by limited classroom experience. The CoRe can make visible these concerns to be discussed within a supportive PLC.

Comparison between the Particle Theory CoRe and the Genetics CoRe post-practicum also shows contrasting evidence of scientific inquiry with the Genetics CoRe, while still limited, showing greater reference. Veal and McKinster (1999) propose that orientations towards scientific inquiry can best be viewed within the context of general PCK. However this author would suggest that scientific inquiry can be viewed within topic-specific PCK as not every topic lends itself naturally to the practice of scientific inquiry (Darling-Hammond 2008).
Forming the Direction for Phase Two of the Study

Grossman (1990) considered the use of targeted workshops during teacher education as a source of PCK development. It was therefore important to expose the PSTs to the CoRe before their initial teaching practicum experience as developing a sense of “community” could provide a framework to serve these novice teachers not only during their initial training but throughout their career (Sim 2006). It was clear from phase one that orientations towards inquiry were missing from the past experiences of the PSTs. However the collaboration between PSTs within the PLC even at this early stage served the purpose of providing a supportive working atmosphere which Kind (2009) stresses is a contributory factor to the growth of PCK and indeed the enhancement of inquiry-oriented thinking (Crippen et al. 2010). Indeed the construction of the CoRe pre and post-practicum also provided an opportunity for the PSTs to view their progress and understand their positionality in terms of their understanding of scientific inquiry. It could allow for a portrayal of the PSTs gap in knowledge which then informs the potential for their enactment of instructions which mirror scientific inquiry practices. This is in itself a constructivist practice as the PSTs are constructing their own understanding of their foundational knowledge regarding scientific inquiry. The CoRe workshop creates a structure where concrete knowledge not assumptions is portrayed. It can allow for PSTs concerns about enacting inquiry to be made visible which is amenable to a change process.

Overall while there was some development in terms of their recognition of how inquiry could be embedded within the classroom, the analysis of the post-practicum CoRes suggests that after the 6 weeks experience, the PSTs portray a weak foundational awareness of scientific inquiry. Therefore it can be argued that while the CoRe does offer an opportunity to articulate one’s PCK and indeed their orientations towards scientific inquiry, development towards the latter may not be possible without an intervention.

This realisation led to the adaption of the CoRe to include an inquiry focus and directed the next phase of the study which was focused on using the adapted CoRe tool within a PLC to socially construct the PSTs awareness and practice of scientific inquiry.
8.3 RQ2. What are the affordances of a PCK lens as a professional development aid, specifically its use in describing and developing inquiry orientations in pre-service science teachers through the social construction of meaning?

The main aim of this chapter was to openly examine how knowledge of scientific inquiry was socially constructed. As a reminder the key themes are presented in Figure 8.2

Figure 8.2: Key themes from findings part B which addresses RQ 2

The CoRe tool since its inception by Loughran et al. (2006) has been adapted to suit the research purposes of those interested in the academic construct of PCK and its use to facilitate the professional formation of PSTs has gained momentum in recent years. The adaptation of the CoRe scaffold to have an inquiry focus has only been reported in one other study. As mentioned previously, Espinosa et al. (2011) adapted the CoRe significantly to use it as a tool to discuss the implications of engaging in inquiry in the classroom. In all, the adaptations made to the CoRe scaffold by different researchers suggest its flexibility (Lehane and Bertram 2015) therefore changing the CoRe in phase two was not unusual as it has been done by others with different research foci.
In the discussion of this research question it is important to reflect on the worldview held by the author which ultimately focused the conceptual framework of the study. As a reminder social constructionism embodied this study and is underpinned by the philosophy that knowledge can be constructed through social interaction. With this in mind, a key focus of this study was to engage PSTs in a learning community focused on enhancing their orientations towards scientific inquiry using a PCK lens. The use of a PCK lens for the articulation of scientific inquiry is a rationale choice when one considers the association between PCK and scientific inquiry. The construct of PCK is an amalgamated not fragmented notion whereby knowledge is viewable as a symbiosis between the different knowledge components. Knowledge that is fragmented does not help the teacher with crafting instruction which best represents science as inquiry (Roehrig and Luft 2004). Therefore having an experience for teachers whereby they portray their PCK and more specifically their scientific inquiry orientations embodies three agendas (1) through articulation their PCK can develop (Loughran et al. 2006) and (2) through the capture and sharing of scientific inquiry orientations within a community learning experience, enhanced awareness is possible and finally (3) through CoRe construction, the teacher de-fragments their knowledge to create a learning symbiosis.

The analysis of phase one revealed limited orientations to the defined features of scientific inquiry however they did at times show awareness of the importance of student-led engagement. The author made the conscious decision to adapt the CoRe slightly in phase two to have a greater inquiry focus. She believed doing this could draw out examples of scientific inquiry if it was within the PCK of the PSTs. It would also in a sense “force” the PSTs to engage in dialogue reflecting inquiry-oriented decisions within their teaching repertoire.

8.3.1 Examining the use of the CoRe to promote understanding of Scientific Inquiry within a PLC

It is the belief of some researchers that inquiry-based instruction develops through classroom experience (Gejda and LaRocca 2006). However the CoRes developed after the teaching practicum experience did not substantiate these claims. Indeed the findings suggest that it was only through adaptation of the CoRe and the sharing of
ideas within the group, did inquiry-oriented thinking begin to develop. Discussing the pedagogical prompts ensures an environment which promotes learner autonomy and constructivism, indeed it promotes inquiry orientations. This can readily be observed through the social interactions between the PSTs. In reality Clare related the nature of CoRe workshops to the action of inquiry when she referred to how they were inquiring into their own practice and viewed this as a positive professional development opportunity. This is echoed in the literature with Darling-Hammond (2008) intimating that teachers need the opportunity to engage in their own inquiry during professional development opportunities as “training in inquiry also helps teachers look at the world from multiple perspectives” (p.8). Indeed having the PSTs experience the uncertainties and frustrations during the CoRe construction mirrors the feelings experienced by students during the practice of scientific inquiry. This can therefore allow the PSTs to develop a degree of empathy and awareness of learning in such a constructivist environment. This assertion compliments the practical paradigm atypical in the Irish education system where students and indeed teachers are not perceived as receivers of transmitted knowledge but as learning subjects and makers of meaning (Gleeson 2012). The CoRe workshops have allowed for the control to be shifted towards the PSTs becoming the makers of meaning and it can be argued that this in turn has embedded a shift in the way these PSTs think about the what, the how and the why of teaching. This is fundamentally reflective of their PCK and can be evidenced through responses such as that made by Edel during the interview where she suggested that involvement in the PLC made her think more creatively.

The National Research Centre (2012) recognised the importance of having an appropriate framework in place to support PSTs in preparing to use inquiry in the class. The discursive and interactive nature of the CoRe workshops led to developmental opportunities as the PSTs began to consider the suggestions of other PSTs within the scaffolded PLC. Previous attempts to develop PLCs have focused on typecasting early career teachers as “passive consumers of pre-packaged knowledge” (Lieberman and Woods 2002, p.316) instead of being active agents in the development of their knowledge base for teaching. The latter requires participants within the PLC to be actively involved in constructing their knowledge
without being told the perceived “correct” answer, similar to the position of students within an inquiry classroom. It can be argued that changing practice/orientations is something which cannot be achieved within a single workshop. It is something which takes time to examine and adapt in light of years of being immersed within the technical paradigm (Gleeson 2012). This current study suggests that a more interactive setting with careful scaffolding can accelerate the genuine learning of PSTs as they inquire into their own practice.

It must be considered here that the degree to which the PSTs developed their understanding of inquiry varied amongst the cohorts. Cohorts B and C appeared to show enhanced understanding of inquiry both in terms of their own theorisations of inquiry and the practical applications of inquiry in the classroom. It can be suggested that since knowledge and experience are initially individual repertoires when working in PLCs, the social construction of knowledge is very much dependent on what this knowledge and experience looks like in reality. Therefore different PSTs within different learning communities will construct their own knowledge, which is reflective of the experience and knowledge of others within the PLC.

**Engaging in Professional Collaboration**

Price and Lee (2013) found that the attitude towards science increased positively when persons were engaged in social situations which promoted participant communication. Fullan (2007) asserts that change occurs when teachers engage in meaningful work. The responses from the PSTs, when they discuss the influence of this study on their practice, suggests that they see their involvement within the PLC as meaningful. Indeed the working collaboration which is indicative of the CoRe workshops reflects much of what Fullan (2007) argues in his contributions to research on educational change. He reports that because of physical isolation and lack of discussions amongst teachers they fail to develop a share technical culture, a coherent knowledge base of teaching (Fullan 2007). This physical isolation is due to the existing norm in place where teachers do not collectively engage in opportunities to share and discuss one another’s work (Fullan 2007). He extends this idea further by reflecting on the fact that educational change is a collective endeavour. This current study purports to provide an avenue for teachers to not only share ideas and
experiences but places itself within the ideology of collective collaboration through the interactive nature of the CoRe workshops. St Clair (2008) impresses upon this collective collaboration as a community of practice between teachers in which he identifies these communities of practice experiences as avenues to think about learning and teaching particular actions in the classroom.

The findings from the OECD TALIS Report developed by Shiels et al. (2009) suggest that in Ireland the existence of professional collaboration amongst teachers is lacking in comparison to the other surveyed countries. Therefore this study is uniquely positioned within the Irish context as it has provided opportunity for PSTs to engage in collaboration with each other within their respective PLCs. According to Lieberman and Woods (2002), well developed PLCs are crucial for enhancing both the content and pedagogical knowledge of early career teachers. PLCs provide a shift towards a community-based practice and appreciation for people in collaboration (Snow-Gerona 2005). As teachers engage in professional development within these learning communities they can face uncertainties in a collaborative, supportive environment where uncertainty is valued and supported (Snow-Gerona 2005). It is important for teachers to recognise that with any change process, it is acceptable for teachers to feel uncomfortable as they embark on the change but feeling uncomfortable in isolation may act as a barrier to the successful implementation of the change process. Initially the PSTs in this current study struggled to think of inquiry-related activities but once one member of the cohort expressed an idea, this oriented the PSTs to think of additional teaching strategies which had an inquiry focus. This struggle was not surprising as PSTs often think of teaching in terms of transmission of knowledge (Loughran et al. 2008) as opposed to the constructivist approach to teaching where students build on their previous knowledge through their own discovery. Therefore having a supportive, collegial environment allowed the PSTs to work together and construct their understanding as a community.

This support can also be seen when the dialogue exchange (section 6.3) between the PSTs is examined. The PSTs worked together to help each other both at times when a PST was struggling and at times where they were just automatically feeding off
each other’s responses to construct a particular teaching strategy. The PSTs as social actors were constructing knowledge and developing their own versions of reality (their living educational theory) through their verbal interactions (Burr 2003). Fullan (2007) recognises that when teachers do get help, the most effectively source of this required help tends to come from fellow teachers. This help essentially lends itself to professional development opportunities for these teachers who emancipate against teacher isolation and embrace collegiality since the degree of change is strongly related to the extent to which teachers work with each other (Fullan 2007). Kind (2009) also identifies with the importance of this but more specifically from the perspective of collegiality being a common factor which appears to contribute to the growth of PCK in novice teachers.

8.3.2 Evidence of Scientific Inquiry within the different Components of PCK
As per phase one, the phase two findings showed that it was in the description of the teaching procedures pedagogical prompt (prompt 7) in the CoRe that the PSTs made the greatest reference to scientific inquiry. Previous to the analysis of the data, the author believed it could be captured in other areas of the CoRe as suggested by Nargund-Joshi and Liu (2013), since it can be embodied within different components of PCK. Orientations to inquiry were also observed as PSTs discussed specific ways of ascertaining students understanding around a particular Big Idea and when they considered knowledge of students thinking which would influence the teaching of a particular Big Idea. However these exemplars were minimal in comparison to the volume of inquiry orientations suggested in line with the teaching procedures pedagogical prompt. It is necessary to note here that even though the teaching procedures question was adapted, the three cohorts were advised after the adaption was made that inquiry orientations are not restricted to the teaching procedures prompt. Indeed they were shown exemplars from Loughran et al.’s published CoRe on alternative places within the CoRe in which inquiry orientations can be observed. Yet the fact that the PSTs consistently referred to it within one component of PCK again shows a novice understanding of the interplay between the different components which make up a teacher’s PCK. Discussion of the previous research question highlighted this in relation to phase one but interestingly even at the completion of the CoRe workshops in phase two the PSTs were still failing to
integrate the components. It is still necessary to have integration when describing PCK as literature would conceptualise PCK as having integrative components (Park and Oliver 2008a).

The reader may question why the author did not just engage the PSTs in discussions around this single prompt, seeing as it is the prompt most closely associated with the verbalisation of a teacher’s orientations towards inquiry. The author believed that in order to help foster the PSTs’ professional formation it was necessary to focus on all aspects of a teacher’s PCK. This was done with the intention to prevent the PSTs developing value systems focused entirely on the importance of innovative instructional strategies to the enhancement of student learning. This in turn would place emphasis on the integrative nature of PCK and how one component of PCK can influence another. So far the limited reference to inquiry other than in the teaching procedures prompt would suggest that the PSTs do not have that integration within their own PCK.

8.3.3 Engaging in Reflective Practice- Revisiting developed CoRes and PaP-eRs
Merit was placed on having the PSTs revisit a developed CoRe in the study to examine any changes they would make upon reflection. Other studies also involved PSTs in revisiting already developed CoRes as a self-assessment activity to gain insight into their attitudes related to their developing knowledge for teaching science (Nilsson and Loughran 2012). In this current study, evidence of advancing awareness of inquiry was the focus of this reflection and was most recognisable when the cohort reflected on the Particle Theory CoRe at the end of phase two. They were able to acknowledge the progress they had made and articulate areas within the CoRe that they would change. This provides evidential support that a CoRe is very much a “living” framework that can be revisited and adapted. It can be used to make visible their understanding of “good” teaching practice.

The PSTs were also shown CoRes and PaP-eRs published by Loughran et al. (2006) and asked to highlight orientations towards scientific inquiry within the artefacts. Williams and Lockley (2012) identify the need to have exemplar samples of the PCK of expert teachers. Showing the PSTs published concrete exemplars of PCK allowed
them to understand what the PCK of expert teachers looked like (see Loughran et al. 2006) whilst at the same time searching for evidence of orientations towards scientific inquiry. The author was conscious about not introducing the experienced teachers’ CoRes too early on in the process as she considers the importance of having the PSTs engage in the initial struggles while developing a CoRe. Also the CoRe documents the PCK of a particular group of teachers therefore opportunities for replication cannot be condoned. As was documented in chapter six, the PSTs struggled to identify orientations towards scientific inquiry, particularly from the Particle Theory CoRe which they were shown. This suggests that the PSTs are at a stage where they are able to articulate but not recognise scientific inquiry practices. It also evidences the added value they place on the CoRes they developed themselves as the PSTs appeared to engage more with reviewing their own CoRes. This implies the ownership they have taken over their documented PCK as opposed to the PCK of other teachers.

8.3.4 Developing a Living Educational Theory of Inquiry

Previous literature has suggested that if PSTs were to enact inquiry in the classroom setting they needed to have an experience of authentic inquiry practice in their undergraduate programme (Windschitl 2004). The PSTs in this study did not engage in practical applications of inquiry in the laboratory setting however through the more formal discursive setting they inquired into their own practice to develop their own living educational theory (Whitehead 1989) of inquiry. Each PST described their own unique definition of scientific inquiry both at the beginning and end of phase two. As addressed in the findings section, examples of the former were lacking the distinct features of scientific inquiry within their description. The examples provided by the PSTs at the end of phase two showed true representations of scientific inquiry. Anderson (2002) suggests that inquiry can be a contested construct because of the confusion about what inquiry is. This author would therefore suggest the importance of teachers constructing their own living educational theory (Whitehead 1989) of what they believe inquiry would represent in their own classroom setting.
Evidence of Antithetical Scientific Inquiry Orientations

It is important to note here that while the orientations towards scientific inquiry were certainly recognisable in phase two, section 6.9 did report on evidence antithetical to the practice of scientific inquiry. The CoRe workshops gave the PSTs an opportunity to explore their existing beliefs about inquiry-based practices some of which may have been not favourable to using such strategies. Indeed the CoRe allows for insight into their personal contestations around inquiry. Emphasis on learning concrete definitions and perceiving inquiry to be “fun” without the focus on how it can facilitate learning were both evidenced in the discussions with the PSTs. Also the PSTs still do not appear to recognise paper and pencil inquiry as being a valid inquiry practice. They also neglect to mention how the practice of scientific inquiry mirrors the actions of a scientist engaged in authentic inquiry experiences and tend to view inquiry as a pedagogical approach solely. Also Sam believed that sometimes inquiry was not an option as it could lead to confusion amongst the students and the focus should be on definitions because that was ultimately what they would be asked to answer in examination situations. These all suggest certain attitudinal dispositions (Crawford 2007) that the PSTs possess some of which have not been addressed through the involvement in the PLC. In a sense the PSTs decision-making is influenced by contextual factors such as curricular constraints etc. which need to be recognised in order to allow for changing educational practices. Interestingly Sam later verbalised her frustrations at having to develop her own ideas without being told what the perceived “correct” answer was thereby identifying the frustrations she had initially with having to construct her own understanding.

These antithetical examples lend themselves to the authentic learning experience that the PSTs are engaged in as they make their spontaneous automatic decisions, referred to as their gestalts (Korthagen 2010). In recognising this, it must be remembered that change is a journey, not a blueprint (Fullan 1996). It is unrealistic to assume that the PSTs’ attitudes, beliefs and understanding could make such a monumental shift from being involved in a PLC for a relatively short space of time. This is also recognisable in the fact that the PSTs’ orientations towards scientific inquiry largely reflect inquiry at the structured or guided level. An organic learning experience such as the one they were involved in meant that altering their existing
schemas cannot be done automatically without reasonable classroom experience and chance for reflection of practice (Korthagen 2010). However the experience of being involved in the CoRe workshops, plants the seed (Bertram and Loughran 2014) for the PSTs to develop further as they gain classroom experiences.

8.3.5 Exploring the Additional Professional Learning Experiences

Aside from engaging in this learning community, there is limited opportunity in ITE to explore, discuss and reflect on PSTs developing PCK (Sim 2006). The findings suggest that the PSTs placed association between their progressive professional development and their involvement in the study. Grossman (1990) identified the need to have a framework to shape PSTs learning from their experiences and the CoRe tool can offer such a framework. Previous studies have identified the use of the CoRe as a professional development tool (Loughran et al. 2001). However the extent to which the tool has supported PSTs as they transition through their ITE programme has not been well reported in the literature. For example Hume and Berry (2013) examined the influence of the CoRe on PSTs as a supportive framework during their teaching practicum, but there is a lack of reference to how the CoRe influenced the professional development of PSTs throughout their ITE training.

While the experiences of the PSTs who remained on in the study are valuable, the reflexive researcher needs to firstly consider why the other PSTs dropped out of the study.

While the dropouts were disappointing, having 12 participants remain on in a longitudinal study that required a large investment of time could actually be viewed as a positive retention rate. The reason for this is that the study was a voluntary addition to the PSTs already heavy workload. Therefore the dropout rate overall would be considered moderate when taking the time and work commitments into account. Indeed the dropout rate is higher in other studies reported in the literature (e.g. Colby et al. 1983; Gustavson 2012). The author is aware of other studies with lower dropout rates (e.g Coady 2010) but given the commitments needed from the participants within the current study, the dropout rates are not overly perturbing but are important to note in the overall presentation of the study.
Unfortunately, the author did not follow up with these PSTs and so the reasoning is purely speculative. However it is the contention of the author that there are a number of possible reasons for why the PSTs withdrew. Looking at the initial perceptions of others, time constraints has been identified by some teachers (Hume and Berry 2011; Bertram 2010) and because of this it would be difficult to carry out a CoRe for every topic (Bertram 2010). Also having come from a similar ITE programme the author can suggest that the contact hours and required coursework could potentially prevent the PSTs from engaging in a voluntary professional development experience. PSTs in the study carried out by Bertram and Loughran (2014) noted similar constraints but did consider that the CoRe could act directly as a more formal lesson plan with some modifications so that it could link in with the ITE requirements on teaching practicum.

The second possible reason for the dropout rate is that the PSTs did not see value in engaging in the CoRe workshops. The author acknowledges that PCK examination takes time and exploration into the complexities of teaching is not something that can be readily done. It needs to be carefully scaffolded (Hume and Berry 2011) and possibly because the CoRe experience was new to the author also, she did not provide the required scaffolding needed for some of the PSTs. It can also be argued that such a new experience, where participants are inquiring into their own practice and not being fed the information, can at first prove to be a negative experience. It can also be considered that the PSTs did not have the requisite knowledge to complete the CoRe and hence were frustrated with the experience. However this only heightens the argument for having PSTs engage in such practices to make visible their existing knowledge which can make it amenable to change.

Having discussed possible reasons for the PSTs attrition, it is important to understand why participants remained on in such an intense longitudinal study. Boys et al. (2003) suggests that researchers with a similar background to the participants influence the nature of the relationship between the two, meaning that participants feel more comfortable with a researcher who shares similar experiences. The author in the current study completed the same ITE programme as the PSTs meaning that they likely trusted her and felt comfortable (Boys et al. 2003) during the CoRe
workshops. Perhaps some of the PSTs who dropped out after phase one had yet to develop this comfortable relationship with the author.

Booker et al. (2011) noted from their review of the literature that retention rates can be maintained through the use of face to face qualitative interviews rather than alternative modes of data collection, such as the use of pre and post-tests. The reason for this is that a certain rapport can be built with the participants which in turn makes the experience more personalised for them and also gives them a chance to ask any questions or raise concerns about the study (Boys et al. 2003). The author believes that the PSTs who remained on in the study committed as best they could within the academic constraints of completing their ITE programme at the same time. It can be argued that those who remained on found personal benefit (Booker et al. 2011) from being involved in the study, given the time and work commitments involved in the study. These personal benefits will now be explored.

A comparison with benefits outlined in another study conducted by Bertram and Loughran (2012) is firstly made. These benefits come under three categories (1) professional practice (2) student learning and (3) content (Bertram and Loughran 2012) and are shown in Table 8.1:

Table 8.1 Benefits of developing a CoRe (Bertram and Loughran 2012)

<table>
<thead>
<tr>
<th>Aspect of PCK</th>
<th>Helped teachers:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Professional Practice</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Re-think how they could improve their teaching</td>
</tr>
<tr>
<td></td>
<td>• To reflect on their current practice</td>
</tr>
<tr>
<td></td>
<td>• “Forced” teachers to explicitly think and connect with their intuitive and tacit knowledge about teaching and learning</td>
</tr>
<tr>
<td></td>
<td>• Offered benefits to inexperienced teachers as well as experienced teachers</td>
</tr>
<tr>
<td><strong>Student Learning</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• To think specifically about the importance of knowing their students</td>
</tr>
<tr>
<td></td>
<td>• To think about how they recognised and evaluated student learning</td>
</tr>
<tr>
<td></td>
<td>• To be aware of, and think about how to, approach drawing out and responding to students’ alternative conceptions/misconceptions</td>
</tr>
</tbody>
</table>
Content

Helped teachers:

- To recognise the range of teaching strategies they had expertise in and using these for the teaching of particular content
- To think specifically about the depth and breadth of content
- To think about how to approach and plan for new and unfamiliar content

These benefits were provided by in-service teachers and so it is an interesting comparison to make with the benefits provided by the PSTs in this current study. The benefits which the PSTs identified from being involved in this study can be categorised as follows (1) professional practice (2) lesson preparation (3) content and (4) idea generation and are shown in Table 8.2:

Table 8.2 Benefits of developing a CoRe: PSTs from current study

<table>
<thead>
<tr>
<th>Aspect of PCK</th>
<th>Helped teachers:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Practice</td>
<td>Helped teachers:</td>
</tr>
<tr>
<td></td>
<td>- To reflect on their practice and think about their own learning</td>
</tr>
<tr>
<td></td>
<td>- Become more aware of the complexities of teaching</td>
</tr>
<tr>
<td></td>
<td>- Gain confidence in their own teaching ability</td>
</tr>
<tr>
<td>Lesson Preparation</td>
<td>Helped teachers:</td>
</tr>
<tr>
<td></td>
<td>- To scaffold their thinking as they engaged in lesson planning</td>
</tr>
<tr>
<td></td>
<td>- Think about what could go wrong in the classroom before it did</td>
</tr>
<tr>
<td>Content</td>
<td>Helped teachers:</td>
</tr>
<tr>
<td></td>
<td>- Recognise the range of teaching strategies they had and use these for teaching of particular content</td>
</tr>
<tr>
<td></td>
<td>- Extend their learning beyond their prescribed training</td>
</tr>
<tr>
<td></td>
<td>- Improved their content knowledge</td>
</tr>
<tr>
<td>Idea generation</td>
<td>Helped teachers:</td>
</tr>
<tr>
<td></td>
<td>- Share ideas of how they would approach the teaching of particular content</td>
</tr>
</tbody>
</table>

There were some similarities provided by both the pre-service and in-service teachers in terms of their reported attribution to the involvement in the CoRe design. Both felt that the CoRe experience allowed them to recognise their range of teaching strategies but the PSTs also believed that the involvement provided an avenue to share ideas. They both noted that involvement allowed them to reflect on their
current practice and in a sense offer a documentation of progress of their developing knowledge.

**Self-Efficacy as an affective Affiliate of PCK**

The literature on PCK and PLCs describes the importance of a teacher’s self-efficacy in shaping their classroom practice. The findings have suggested that the PSTs, in general, have developed an emerging confidence to engage in scientific inquiry practices which it can be argued resulted from their involvement in the PLC (Wong 2010). Having a belief about how successful a teacher can enact their PCK in the classroom is key to classroom practice and both the interactions within the PLC and the benefits reported by the PSTs show a developing self-efficacy. As previously described, a teacher’s self-efficacy is intimately linked with their PCK, therefore part of PCK development is developing more positive self-efficacy. This needs to be considered in the discussion since a tool used to develop PCK, i.e the CoRe, has invariably facilitated the PSTs in developing more positive beliefs about their own ability. It can be implied that working with the PLC supported this development.

Despite their initial reticence, their emerging confidence (efficacy) was obvious as they gained a greater awareness and a better understanding of how scientific inquiry can be represented in classroom practice. The developing self-efficacy can firstly be viewed from the interview findings where the PSTs shared that they had a greater confidence in their own ability (see Table 8.2). Developing their self-efficacy is critical if PSTs are to have a belief in their ability to deal with different challenges (Yasar-Kazu and Erten 2014). Because of the open nature of scientific inquiry, it is conceivable to think that the teacher may encounter challenges in the classroom. Therefore developing their self-efficacy is critical to helping PSTs consider and enact inquiry practices.

Not only was there evidence that PSTs gained more confidence to teach through scientific inquiry, there was also evidence that some PSTs developed confidence related to life skills. This growing confidence was highlighted by Rebecca who believed that she learned to communicate within a group setting, something which she was uncomfortable with previously. It can be suggested that one of the goals of
teaching and learning is to develop life skills, something which is fundamental to the new Junior Cycle Framework (NCCA 2012). So what is interesting here is that Rebecca developed a necessary life skill from being involved in study. Similar to the practice of scientific inquiry, the goal should be on the process skills learned as well as the content knowledge gained and Rebecca is expressing an additional skill beyond developing awareness of scientific inquiry.

Sean also showed evidence of a positive self-efficacy by suggesting that he did not believe he would be as efficient as a teacher if it were not for his involvement in the study. This is interesting as it provides evidence that PSTs can develop a positive self-efficacy, even with limited classroom experience, by involving themselves in a scaffolded PLC. While this response by Sean is promising, it must be met with some hesitation as a teacher’s self-efficacy needs to translate into classroom practice too through their enacted PCK (Park and Oliver 2008a). The question remains whether Sean’s perceived confidence is observable in a real classroom context.

The cohort’s emerging confidence can also be seen when looking at the evidence of PSTs disagreeing with each other in phase two. This suggests that not only were they confident in their own ideas but they felt comfortable to express their viewpoint within the PLC. Pirtle and Tobia (2014) consider this to be key to implementing an effective PLC. Analysis of the interactions in phase two also showed that as the PSTs continued to work together, a more automatic and natural dialogue exchange began to take place. PSTs readily disagreed with each other and expressed contrasting views at times. This suggests a developing belief in their own knowledge. The contributions within phase one demonstrated hesitation and low voice projections, both of which would be considered identifiable communicator variables in evidencing a teacher’s low self-efficacy (Oettingen 1995).

A PLC can help foster a teacher’s self-efficacy through providing an affective support system between community members. There was some evidence where the PSTs acted as an affective support for each other, namely in an exchange between Edel and Sean and Kate and Rebecca. It can be suggested that by giving each other emotional support enhanced the PSTs confidence in communicating their idea of an
IBSE activity. This emotional support within a PLC is identified in the literature as being one of the defining advantages to constructing knowledge within a community (McLaughlin and Davidson 1994). So by socially constructing their PCK, the PSTs invariably increased their self-efficacy towards successful classroom practices.

While the development of scientific inquiry orientations was the overarching intention of this research study, understanding how a PLC facilitated these developments was key. Socially constructing their knowledge of inquiry was presented previously but the consideration is now given to additional factors with are interpreted from the above benefits. They can be identified as a tool to document progress and a lesson planning tool. For example, lesson planning is key to creating awareness and enactment of scientific inquiry in the classroom (Schwartz 2009) and therefore having a tool which can be used as a lesson planning aid can invariably facilitate developing scientific inquiry orientations. The cohort identified the usefulness of the CoRe scaffold as they developed lesson plans whilst on their teaching practicum experience. Grace believed that it was “embedded in you” and awareness of the CoRe scaffold made the PSTs, in their own eyes, plan for every eventuality. The cohort revealed that they used the CoRe scaffold in their planning for every lesson, not just confined to those in which they developed CoRes on. Bertram and Loughran (2012) also identified the use of a CoRe to help plan the content and think more concretely about the depth to which one would cover the content. Crawford (2007) recognised the difficulty that novice teachers face when trying to integrate aspects of teaching science as inquiry within their planning and instruction. However the PSTs in this study have suggested that the CoRe can also be considered as a lesson planning tool which provides a platform for PSTs to approach their instruction of a lesson through inquiry.

All PSTs considered that involvement in the CoRe workshops provided a documentary analysis of their progress, more specifically their progress related to developing inquiry orientations. Indeed when the cohort were exposed to the Particle Theory CoRe in phase two they continued to suggest alterations to the original CoRe, this evidencing their developing knowledge of inquiry. In a sense the CoRe
can be used as a feedback tool (Petty 2009) which allows PSTs to formatively assess their growing understanding of inquiry and identify their gaps in knowledge.

8.3.6 The Place of the CoRe in ITE

All of the PSTs who remained in the study for phase two and phase three believed that the CoRe and the use of a learning community should be included in their ITE, more specifically into their subject pedagogics modules. Coady (2010) in her study on PSTs’ experiences in the University of Limerick identified subject pedagogics as an aspect of the ITE programme which needed greater emphasis placed on it. The PSTs in this current study believed that including the CoRe in the subject pedagogics module could facilitate their growing competencies as a teacher.

This is counter to the experience had by Bertram and Loughran (2012) where only two of their PSTs believed it should be integrated into their ITE. The PSTs in that study assumed it would be unsustainable to include CoRe development into their regular practice due to time constraints (Bertram and Loughran 2012). While time constraints have been negatively associated with CoRe development in other studies (Rohann et al. 2009), the same authors did reflect on the literature to conclude that the design of the CoRe is best suited as a professional development tool in teacher education. The PSTs believed that, with the exception of their involvement in this current study, PCK was only referred to by one teacher educator over their four years of training with this teacher educator dedicating a short discussion on PCK within a lecture experience. They also articulated the segregation that existed between the education and science components of the ITE programme. Clearly if the principle objective of an ITE programme was to train PSTs to the highest standard, then the PSTs’ PCK should be central to the knowledge base development promoted in ITE. Even if the context disables the education and science modules from aligning more coherently, then having the CoRe as an integral part of the ITE could serve to readjust this alignment.

The findings from this study substantiate the importance of PCK awareness to the professional formation of PSTs. Also this study proposes that focusing on a particular pedagogical approach, within the PCK framework, through a
collaborative, supportive environment can lead to an emergent professional identity. Indeed Edel considered that if she was taught through inquiry in her ITE, it would be easier to implement in the classroom setting. It can be argued that the experience of socially constructing her understandings of scientific inquiry through the CoRe scaffold made her realise this. There is a need to develop PSTs’ automatic engagement with the most basic and general of science practices (Roth et al. 1998), in essence to engage PSTs in the practices of inquiry within their ITE. If the reader reflects on the quote in chapter one proclaimed by Confucius 551-476 BC

“I hear and I forget
I see and I remember
I do and I understand”

Not only should this be indicative of the approaches students engage in in their learning of science, it should be an integral focus of the training of teachers to follow such constructivist approaches. But what exactly does one mean when they say “I do and I understand”? Is it to replicate what has been done in the past in line with Lortie’s thinking on the apprenticeship of observation? The literature would suggest no and that there is a reflective need to interrogate past practice (Fullan 2007) to facilitate the development of a PST’s conceptual and pedagogical awareness. This view is echoed by Wilcox et al. (1991) who suggest that if we are to challenge prospective teachers’ beliefs we must create the situation in which meaningful discussion can occur where these beliefs are faced and reconsidered.

The question remains, if PSTs are not exposed to inquiry in their ITE, how are they able to place inquiry orientations within their own teaching? Is it from their experiences as a student in their post-primary education? Roychoudhury and Rice (2013) suggest that PSTs past experiences are marred in the transmission style teaching approaches and that there is a need to move away from such past experiences. It is crucial that teacher educators are aware of the typical past experiences of PSTs and focus on educating PSTs in best practice. The CoRe provides a rich description of PSTs’ past experiences and how these experiences shape their knowledge base. The CoRe can also, with a minute adaptation, help
frame the PSTs thinking towards the use of scientific inquiry. This framing of understanding can be achieved through the process of the PSTs’ inquiring into their own practice by “doing and understanding”.

8.3.6.1 Implications for the Concurrent and the Consecutive Models of Teacher Education

Previously a description of the concurrent and consecutive models of ITE was provided. As outlined, this study focused on a cohort experiencing their training through the concurrent model of teacher education. It was hypothesised that because this cohort were facilitated in developing their pedagogical and content knowledge concurrently over the four year degree programme, the opportunity would prevail for alignment between these knowledge components. In other words, a concurrent model of teacher education could provide an opportunity to focus on PCK as the unique knowledge base of teachers because of the emphasis placed on both within the degree programme (Musset 2010). The cohort reported that PCK was not emphasised in their training despite the potential alignment. Gleeson (2004) suggests the teacher education has been diluted and there is a lack of integration within the context of the University of Limerick. Indeed he suggests that there are “turf wars” taking place because of the various departments involved in training teachers through the concurrent model. The PSTs in this current study did reflect on the fragmentation they experienced during their ITE programme. Interestingly Musset (2010) believes fragmentation to be negatively associated with the consecutive model. Musset (2010) suggests that the concurrent model offers the potential for an integrated learning experience since pedagogical and content knowledge training take place at the same time. The findings suggest that this integration is lacking in the University of Limerick.

The consecutive model of teacher education is the dominant choice for aspiring teachers (Stuart and Tattoo 2000) yet before this study the author would have suggested that this model fails to focus on the PCK of the training teachers. The experiences of the participants appear to suggest that unless PCK is at the forefront of teacher educators’ attentions, it will not be part of the repertoire of PSTs’ understandings of effective teaching and learning. This is regardless of the model of ITE.
The key question that remains however is whether or not the findings from the study are generalizable. This will be discussed in the next section.

**8.3.6.2 Discussing the Generalisability/Transferability of the CoRe Experiences**

It is necessary to consider in this discussion whether the overall CoRe experience could be easily transferrable to PSTs within different national contexts. The volume of existing research with PSTs in the international context (e.g. Hume and Berry 2013; Nilsson and Loughran 2012) would provide evidence for the transferable nature of the CoRe scaffold across different education systems and ITE experiences. Therefore it is reasonable to assume that the CoRe scaffold could be used as a tool with PSTs in other national contexts. Also this study provides evidence for the flexible nature of the CoRe, thereby suggesting the CoRe could be transferrable in an adapted form to suit the needs within the specific context.

In relation to generalisability, this study is reporting on one case study cohort’s responses to engaging in a PLC scaffolded through a PCK lens. Yin (2009) describes the concept of analytical generalization whereby a previously developed theory is used as a template to compare the empirical results of a case study. The conceptual framework outlines how a PCK tool could be used to capture scientific inquiry orientations by describing associated literature. The author worked off an existing theory i.e. how inquiry orientations can be captured within a teacher’s PCK and from this used a PCK template as the guiding research tool. Thereby the author sought to “generalize a particular set of results to some broader theory” (Yin 2009, p. 43) and not to understand the experiences of a larger population. Nonetheless, it must be reflected on whether or not similar experiences could be had by other PSTs in the Irish context.

It can be considered that PCK as an academic construct could be seen as a vehicle to deliver best practice for all PSTs in the Irish context, due to similar apprenticeships of observation. PSTs, in general, in the Republic of Ireland come from similar apprenticeships of observations (Conway *et al.* 2009) therefore their foundational understandings of scientific inquiry may be comparable to the cohort described within this study. This can be implied from the results of the national survey (see
section 8.5 for further discussion) distributed in this study which shows scientific inquiry to be missing from practices within certain Irish classrooms. While the findings are not representative of a national sample size, it does give some indication towards the place of scientific inquiry in Ireland.

It can be intimated that if other PSTs were to construct CoRes on similar topic areas, the specific content of the CoRes would be different for all cohorts as PCK is an individual (or group) construct. However it can be suggested that the overarching orientations of the CoRe would be similar for other PSTs.

It must also be noted that there was no selective sampling in terms of the initial recruitment of the PSTs in the current study (e.g. it was not just the higher achievers that were chosen). This cohort represented a typical sample of PSTs therefore it can be implied that the experiences had by the PSTs in terms of how they valued the group construction of knowledge may potentially be appreciated by other cohorts of PSTs.

To conclude PCK as an academic construct could be seen as a vehicle to deliver best practice for all PSTs in the Irish context. It must be remembered that PCK is unique to individual teachers therefore each CoRe and indeed PaP-eR will be different in terms of content. However it can be implied that PSTs in Ireland, generally, will have similar baseline understandings of the complexities of teaching. In other words they will have comparable understandings about the what, how and why of teaching due to similar apprenticeships of observation (Conway et al. 2009).

8.3.7 The Importance of engaging in a Professional Development Culture

It is necessary to establish a culture of professional development with PSTs so that it is embedded in them as they are inducted into their in-service career. “For a teacher to grow professionally and become a better teacher of science, a special, continuous effort is required” (Showalter 1984, p. 21). Therefore having a focus on this in ITE may propel this action and awareness of the need for continuous professional development as they embark on the realities of the classroom setting. The orality (Dannels 2002) or the role of communication in the development of a professional
culture is emphasised in the literature. This communication needs to be nurtured from early in one’s career so it can continue as they become immersed in classroom practice.

There is also a need to develop the ability of PSTs to engage in inductive inquiry into how they can facilitate their own professional growth. Instead of being the recipients of pre-packaged information it is important to have the initiative and experience to engage in research into best practices, particularly as they become embedded into the classroom as practicing teachers. By having the PSTs developing and articulating their understanding of scientific inquiry and in turn constructing their own living educational theory (Whitehead 1989) of inquiry is a starting point for this cohort to continue initiating their own professional development throughout their career.

8.3.8 Does the CoRe capture all aspects of a Teacher’s PCK?
The CoRe has been a useful tool in science education research for more than 10 years but in the meantime, more modern interpretations of PCK have been presented in the literature (e.g. Park and Oliver 2008a). Therefore the question remains; does the CoRe capture all aspects of a teacher’s PCK when considering modern conceptualisations of the construct? Reflecting on the hexagon model presented by Park and Oliver (2008a), they consider curricular saliency and the horizontal and vertical curriculum as part of the PCK component, knowledge of science curriculum. The model also extends the component, knowledge of assessment of science learning, to include dimensions of science learning (Park and Oliver 2008a). The CoRe in its current form does not allow for explicit consideration of these features of teachers’ knowledge. Also the hexagon model explores the beliefs about Nature of Science within the description of a teacher’s orientations towards science teaching (Park and Oliver 2008a); however this is not explicitly observed in the current CoRe format.

Hagevik et al. (2010) would consider knowledge of the context as being a composite element of PCK however it can be argued that the CoRe does not explicitly allow for discussion of the context within its completion. This can also be evidenced from the
CoRes completed in the current study where reference to individual school contexts and school cultures were not articulated in the CoRe. Hauk et al. (2015) propose that knowledge of discourse is a critical component of PCK. They view the knowledge of how to construct dialogic interactions within the classroom as important for students learning. For example, they propose that the dialogue during inquiry activities is key to successful student understanding. Again it can be suggested that knowledge of discourse is not explicitly considered within the CoRe. Related to this Andrew (2001) suggested that the teacher’s language awareness is a component of PCK. Again this is not explicitly considered in the CoRe scaffold.

The CoRe captures topic-specific PCK only as the Big Ideas generated and the pedagogical prompts which expand the Big Ideas are related to specific topics. Therefore the CoRe tool does not explicitly capture other types of PCK, such as general PCK and domain-specific PCK (Veal and MaKinster 1999). Also, as noted previously, the CoRe only reflects espoused topic-specific PCK, therefore thorough representations of a teacher’s PCK need to include study into classroom practice. Finally, Lee and Luft (2008) discuss two types of PCK, integrative and transformative PCK. Does the CoRe explicitly allow for the symbiosis that is transformative PCK to be expressed? Or does the structure naturally result in content being viewed as separate to pedagogy (integrative PCK)? The author would argue that both types of PCK can be represented through the CoRe as the content of the CoRe captures whether the teachers in question articulate their knowledge in a symbiotic way. When reviewing the CoRes developed by expert teachers (Loughran et al. 2006) versus the CoRes developed by the PSTs in the current study, it can be argued that the former very much reflects transformative PCK. The CoRes developed by the PSTs in the current study reflect incoherence between the different knowledge components, thereby assuming an integrative PCK. Indeed the literature suggests that expert teachers have transformative PCK while novice (pre-service) teachers would hold integrative PCK (Lee and Luft 2008). So, it can be implied that the CoRe captures both types of PCK and this in itself is an important feature of the CoRe as it can evidence a teacher’s level of PCK. Transformative PCK would reflect higher level PCK while integrative PCK would reflect lower level PCK (Lee and Luft 2008).
8.3.9 Responding to the Contentions around PCK

The author believes it necessary to revisit the work of Settlage (2013) who has posted his contention that PCK as a construct “skulks about as a strangely persistent yet unfulfilled notion” (Settlage 2013, p. 1). Indeed he considers that PCK has failed to deliver the desired impact on student learning (Settlage 2013). Having seen the impact that articulation of their knowledge can have on the professional formation of novice teachers the author believes that focusing on PCK as the theoretical basis can provide fulfilled notions. Indeed it is her contention that the CoRes and PaP-eRs can represent and make visible what actually happens in the classroom. The findings also suggest that an educational construct, such as PCK, can make visible teachers’ conceptualisations of IBSE. It is the author’s assertion that this addresses the concern raised by Settlage (2013) of how PCK can deliver.

He also considers the notion that PCK “lurks as an intellectual dead-end for those who might contemplate it as the foundations for a research agenda”, (Settlage 2013, p.1). He also considers that it is only useful in science methods courses to explain how neither a strong grasp of subject matter nor the mastery of management skills is sufficient for successful classroom practice (Settlage 2013). Furthermore he believes it to be an antiquated endeavour and researchers should focus on newer avenues with less travelled paths which offer fresh possibilities to advance science education research and the preparation of novice teachers (Settlage 2013). This author would argue that having a construct which has remained as an accepted entity in science education research for the best part of twenty five years shows it to be a worthwhile endeavour to pursue. The idea of inquiry has been around since the time of Dewey and if researchers were to associate inquiry as being an antiquated entity then advances in understanding students’ learning of science would not be as progressive as it is now. This author would suggest that for PCK to be seen as a modern construct one needs to focus their research on using the power of PCK to facilitate current issues. One such issue is the preparation of pre-service science teachers and their disconnection between educational theory and practice, specifically towards the enactment of scientific inquiry. This current study has shown that PCK can be a modern construct if it facilitates current PSTs’ professional formation and if the true
semblance of PCK remains in that it is the knowledge of how to make new material comprehensible to students, there is nothing antiquated about that.

8.3.10 Considering alternative Professional Lenses in light of the Findings

While teachers’ PCK was the professional lens used in this study to capture the PSTs’ professional knowledge regarding their orientations towards scientific inquiry, it must be noted that alternative professional lenses also influence teachers’ practice within the classroom. The following section will explore how pedagogical knowledge, content knowledge, personal learning history and identity and teacher attitude influence classroom practices. It will firstly look at how a teacher’s professional vision is key to expressing these features in the classroom.

All of these features are influenced by the professional vision of the teacher, which in turn impacts on their classroom practices. The term professional vision reflects the many nuanced ways in which a professional sees (Fai-Ho and Tan 2012). In other words, the same phenomenon may be viewed from alternative perspectives by different people (Fai-Ho and Tan 2012). While it can be implied that professional vision is an important feature of a researcher’s capacities, teachers should develop a professional vision too to gain perspective of their own classroom practices (Fai-Ho and Tan 2012). A teacher’s professional vision influences how they see the activity of teaching through scientific inquiry (McDonald 2008) as well as other classroom practices. Indeed it can be argued that a teacher’s professional vision is individual and therefore represents autonomous understandings of how scientific inquiry can be expressed in classroom practice. It can be implied that having a teacher consider their own living educational theory (Whitehead 1989) of scientific inquiry leads naturally to them articulating their own vision of scientific inquiry in classroom practice.

The pentagonal framework (Fai-Ho and Tan 2012) highlights the number of features which should be studied when viewing classroom events through professional vision. Features include the concepts (content knowledge), skills and processes (pedagogical knowledge) and attitudes which characterise a teacher’s practices (Fai-Ho and Tan 2012).
With specific reference to the practice of scientific inquiry, a teacher’s general pedagogical knowledge is an important feature of a teacher’s capacities to enact scientific inquiry (Grangeat et al. 2015). More specifically, science inquiry pedagogical knowledge is necessary to understand the practice and how it can be implemented successfully in the classroom (Chowdhary et al. 2013). The latter reflects the teacher’s knowledge of appropriate questioning, design and enactment of experimentation, learning cycles and the use of models and analogies (Chowdhary et al. 2013). All of these can impact on the students’ experience of authentic scientific inquiry.

Additionally a teacher’s content knowledge is seen to influence a teacher’s practice in the classroom in general (Nicholson 1996) and their practice of scientific inquiry more specifically (Breslyn 2009). Indeed Breslyn (2009) considers that advancing content knowledge enables changes in teaching practice towards scientific inquiry. Section 8.3.5 explored advancing content knowledge as one of the professional learning experiences reported by the PSTs. It can be implied therefore that the developing content knowledge allowed the PSTs to consider classroom practices rich in scientific inquiry. The reason for this is that appropriate content knowledge can help give teachers the confidence to allow the open-ended exploration that takes place in an inquiry classroom (Lee and Butler-Songer 2003).

In all, it can be argued also that a teacher’s attitudes influence their classroom practices (Wilkins 2008). The outcome of a teacher’s attitudes is the tendency to react either favourably or unfavourably towards a particular situation, therefore teacher action is shaped by their attitude (Munck 2007). If a teacher has an unfavourable attitude towards scientific inquiry, then this will result in actions devoid of such classroom practices. It must be considered however that a number of factors influence a teacher’s attitude, namely their confidence about the subject matter and their commitment to student learning (de Souza-Barros and Elia 1997). A teacher’s interest, appreciation and perseverance also relate to their attitudes towards science teaching (Fai-Ho and Tan 2012). It can be implied that all these factors are linked to the PCK of the teacher and therefore provide evidence for how a teacher’s PCK leads to certain attitudes towards classroom practice (Lombaard 2015). While teacher attitude is an importance consideration in current classroom practice, it can
also be suggested that attitude influences a teacher’s willingness to engage in professional development towards student-led constructivist classroom practices (de Souza-Barros & Elia 1997). Therefore tapping into a teacher’s attitudes is critical in discussions focused on changing classroom practices.

A PST’s personal learning history and in turn their role identity is seen to influence their practice in the classroom (Eick and Reed 2001). Individuals with a strong role identity are seen to have strong beliefs about teaching and learning and in turn are able to enact better their chosen role as a teacher (Eick and Reed 2001). Therefore if a PST professes to have a strong inquiry-oriented image, their practice of scientific inquiry may be possible even with contextual barriers in place (Eick and Reed 2001).

While the author is positioning herself mainly from the point of view of practice related to scientific inquiry, it can be argued that all of the professional lenses considered within this section affect classroom practice in general. The argument remains that while all are important, a teacher’s PCK is still viewed to be the most important in terms of positive outcomes for student learning (Gess-Newsome and Lederman 1999).

Within this discussion it is important to consider alternative tools that can be used to capture teachers’ PCK and in turn their potential scientific inquiry orientations. As mentioned in section 3.2.3.2 a number of tools have been used to capture PCK in the classroom. For example, lesson studies have been shown to be a useful approach for understanding teachers’ enacted PCK. Lesson studies document a teacher’s insights into their own practice through planning, conducting, observing and reflecting on a particular lesson (Ní Shúilleabháin 2015). A lesson study, similar to a PaP-eR, provides a narrative understanding of teachers’ enacted PCK. It has been shown to potentially develop teachers’ PCK (Lewis et al. 2006) by allowing the opportunity for teachers to investigate their own practices (Ní Shúilleabháin 2015). Similar to the CoRe and PaP-eR, it allows for the measurement of a small scale presentation of teachers’ PCK (Ní Shúilleabháin 2015).

The discussion so far has been on tools used to capture PCK however other tools exist which can measure PCK. Gess-Newsome et al. (2012) note a number of issues with measuring PCK. Firstly, an agreed understanding of how PCK should be
defined and measured needs to be considered (Gess-Newsome et al. 2012). How to measure would also be viewed as an issue. For example, would it be through a direct measure such as a paper and pencil test or questionnaire or through an indirect measure such as providing inferences about what teachers do and what they say or believe (Gess-Newsome et al. 2012). Thirdly, a consensus would need to be reached in regards identifying characteristics of “quality” PCK (Gess-Newsome et al. 2012). Finally, PCK is highly specific to the topic, context and person which makes measurement of PCK a particular challenge (Loughran et al. 2006) All of these considerations lead to potential problems in regards accurate measurement of PCK (Gess-Newsome et al. 2012). Tools focused on capturing PCK, do not hold such potential issues. Nevertheless, Park and Oliver (2008a) developed two tools which looked to alleviate these potential issues. They developed a PCK rubric (observations and interviews) and a PCK survey (pre and post-test) to help make visible the tacit nature of PCK. They do believe however that further validation of this instrument is needed before it can be viewed as a useful tool for PCK measurement (Park and Oliver 2008a).

The focus in the literature has been on capturing and measuring enacted PCK, however both Loughran et al. (2006) and Park and Oliver (2008a) would consider the importance of understanding teachers’ espoused PCK. While other tools do exist (e.g. the pre-test developed by Park et al. 2011), the CoRe is viewed to be the tool which not only captures espoused PCK but develops it through collaborative articulation. A teacher’s PCK is complex and so deeply rooted within their intrinsic practice that it is often inaccessible (Baxter and Lederman 1999). A scaffolded framework is needed to allow teachers to articulate their intrinsic knowledge of practice, thus making it amenable to change. The CoRe, as a scaffolded framework, is viewed as the dominant choice amongst PCK researchers (e.g. Bertram 2010; Hume and Berry 2013; Padilla and Garritz 2010). Therefore while the author does acknowledge the other tools present in the research realm, when considering a PCK tool that offers professional learning opportunities, the CoRe appears to have the dominant appeal over others (Loughran et al. 2006).

8.4 RQ3 How do the perceived developing inquiry orientations successfully translate into actual classroom practice?
This research question focused on the PSTs’ enacted orientations towards scientific inquiry during a ten week teaching practicum experience.

As a reminder the key theme related to this research question are presented in Figure 8.3

Figure 8.3: Key themes from findings part C which addresses RQ 3

Research suggests that professional development endeavours are often lost when teachers enter the classroom environment (Goldschmidt and Phelps 2010). It has been shown in the research that the relationship between orientations and practice is complex, and for various reasons teachers do not always translate their orientation for teaching science exactly into their classroom practice (Friedrichsen and Dana 2003; Volkman and Zgagacz 2004). This complexity makes sense however when considering that a science teacher’s practices are influenced by a number of factors, including the social and policy context in which they teach (Little 2003), subject matter knowledge (Abell 2007; Gess-Newsome 1999), their beliefs about teaching (Jones and Carter, 2007; Pajares, 1992; Crawford 2007), and their pedagogical content knowledge (Abell, 2007; Davis et al. 2006 cited in Friedrichsen et al. 2011, p. 359). Indeed Gallagher (1989, cited in Roehrig and Luft 2004) suggests that inquiry-based instruction is challenging to even the most experienced science teachers. Therefore from this perspective, it is possible to understand the PSTs’ partial practice of inquiry.

8.4.1 Exploring the Evidence of Inquiry-based Instruction

Caution needs to be maintained when PSTs embark on teaching experiences as they can often discount the practices they learning during their ITE programme in as little as two weeks into their practicum (Richardson-Koehler 1998). The lesson plans, observations and survey have revealed that the developing inquiry orientations have to some degree translated into actual classroom practice. While the observations revealed only partial inquiry, it must be considered that these observations were
carried out in one class and did not accurately reflect the PSTs’ actions over the 10 week teaching practicum.

The results of the survey appear to suggest that the cohort does have an enhanced inclination towards scientific inquiry practice however there were some interesting responses given by the PSTs. For example, 60% of the PSTs reported to giving the students step-by-step procedures either sometimes or on a more frequent basis. This would suggest inquiry at the structured or confirmatory level (Herron 1971). To some extent the response to that statement contradict the responses given to another statement (students design their own procedure) with 80% of the PSTs claiming they did this on a frequent basis. So while the latter response is promising, it must be met with some caution because of the contradiction. Another interesting finding from the survey was how seldom students formulate their own research question and decide what data to collect, again these features would be related to more open-ended inquiry (Herron 1971). This indicates that open-ended inquiry and to a lesser extent guided inquiry were not frequent practices in the PSTs’ classrooms. To that end it can be suggested that structured inquiry was a dominant feature. Structured inquiry does not provide for autonomous learning (Zion and Mendelovici 2012) and should therefore provide the stepping stone (Bell et al. 2005) to the students engaging in more guided or open-ended inquiry as they gain experience in doing such activities. This implies the PSTs had some awareness of how students should experience science.

Espoused versus Enacted PCK
The research suggests that a teacher’s espoused PCK, as captured in this study through the CoRe, does not necessarily mean it will be enacted in the classroom (Aydeniz and Demet Kirbulut 2011). In all, the PSTs’ espoused PCK does not mirror their enacted PCK. For example, Clara was a vocal contributor in the discussion of inquiry-oriented lessons, yet both her lesson plans and classroom observations lacked such orientation. In other words, her schema (Korthagen 2010) reflects acts directed towards teacher-centred control. Even though the lesson was scheduled within a regular classroom setting, the author is of the belief that inquiry can take place in any classroom. Inquiry can occur in even a theory-based classroom learning
environment (Krajcik et al. 1998). If teachers have such an understanding then it is possible to enhance the sustainability of inquiry-based practices in the classroom. It can be suggested from this study that the PSTs consider authentic inquiry to be grounded in investigative processes within a laboratory setting. So in a sense their involvement in the CoRe workshops did not tap into these assumptions.

The Role of Additional Pedagogies

It is necessary to consider that inquiry should not be used in isolation but should be part of a repertoire of teaching approaches embedded within the teacher. In fact the author does not believe that inquiry has to take place in every lesson as not every worthwhile activity is inquiry-based (Bell et al. 2005). It is more successful when combined with the necessary instruction that is typical in a classroom setting (Barron and Darling-Hammond 2008). Indeed engaging students in the full inquiry process within each lesson is not only resource dependant but could add to the existing lay theories that teachers hold in reference to the time constraints which act as a disabling factor to using inquiry-based practice. Alternatively the author would argue that every lesson should contain some degree of inquiry where students are drawing their own conclusions, in other words engaging in discovery learning using a constructivist approach.

8.4.2 Lesson Planning in Inquiry-based Instruction

Firstly, Rebecca considered that planning for inquiry-based instruction takes more time and requires more work. This view is echoed in the literature with Llewellyn (2007) highlighting this as a concern of teachers. It can be considered that adapting practice does require more input in terms of planning for the teacher as they grapple with the uncertainties of putting theory into practice. Inquiry means different things to different people (Anderson 2002) and practical understandings are often lost in the quest to find the “correct” definition of inquiry. Providing a set definition of inquiry is the antithesis of what the inquiry process should be trying to promote, the use of independent learning in the construction of new knowledge as opposed to arriving at the “correct” answer in an expedited manner. Rebecca would have developed her own living educational theory (Whitehead 1989) of inquiry but as the research
suggests, this transition from theory into practice can be difficult (Mansour 2007). Therefore this struggle needs to be highlighted in light of the findings.

While lesson plans can offer some insight into PSTs’ inquiry orientations, it must be considered that even for lesson plans which appear teacher-led it does not automatically mean that the lesson was purely teacher-directed; the use of dialogue in the classroom can reflect an inquiry-oriented environment (Chappell 2014). However lesson plans are an important support in scaffolding development towards pedagogies that are more attuned with IBSE practice, therefore planning is crucial (Roehrig and Luft 2004a). The PSTs here in general have shown difficulty in doing this which suggests that planning for inquiry-based instruction is challenging (Roehrig and Luft 2004a). Indeed Roehrig and Luft (2004a) identify this challenge is present even after professional development experiences. Macalalag (2012) would argue that PSTs need careful scaffolding in planning and designing an inquiry-based lesson and the failure of the PSTs in this study to articulate IBSE within their lesson plans suggests the need for such scaffolding. Specifically, PSTs need scaffolding when designing (a) objectives that incorporate the “big ideas” in science, (b) performance-oriented goals, (c) driving questions to elicit students’ pre-conceptions and (d) multiple assessment strategies which monitor student progress (Macalalag 2012). Needing to consider inquiry from such diverse angles extends the argument for more careful scaffolding of lesson planning in ITE (Macalalag 2012).

8.4.3 Students’ Attitudes towards Inquiry-based Practices

One factor in achieving a sustainable approach to inquiry is to understand students’ beliefs about how the process facilitates their learning. Rebecca suggested that the students did not understand how to interact with the teacher during an inquiry lesson. This response is interesting as it suggests the struggle students had with the changing dynamic between them and the teacher in the classroom. This challenge is also identified in the research where the teacher dominates the dialogue in a traditional lesson (Rains 1970). Therefore, creating an experience where students are the dominant voice in the dialogue exchange can be a struggle for both the teacher and the students alike.
Sean suggested that the students enjoyed engaging in inquiry but for some, the changing practice did take some adjusting to. Indeed he presented his struggles in trying not to give the students the perceived “correct” answer. This was also seen during the classroom observation. This experience was noted in other studies (Crawford 2007) however Sean recognised that changing habits do take time and this idea of educational change reflects the contributions of Fullan (1996) when he suggests that change takes time. The PSTs have begun to alter their orientations towards scientific inquiry but for change to be successful and sustainable, they need to recognise that “problems are our friends” (Fullan 1996, p.3) and students’ orientations towards scientific inquiry need to be recognised in the process.

8.4.4 Summary of the PSTs’ Enacted Inquiry Instruction

It must be acknowledged that PSTs often feel pressurised when they enter an alien school environment as they may feel the need to conform to the practices in that particular school context. They often feel the need to adopt the practices of their co-operating teachers so they can gain a sense of acceptance in their school environment (Rikard and Knight 1997). It is necessary to consider this in light of the findings as it identifies the realities of PSTs entering into the real classroom environment. A tension can exist between their espoused beliefs about science teaching and those of the key personnel within the existing school context. PSTs also struggle to contend with the beliefs of their teaching practicum tutor who may express an ideology about teaching far removed from that of the PST. Recognising these potential conflicts provides some insight into why the PSTs espoused orientations towards scientific inquiry were not entirely represented in classroom practice. However it can be suggested that engagement in the CoRe workshops has planted the seed (Bertram and Loughran 2014) for when the PSTs finish their ITE program and can begin to enact their espoused orientations towards scientific inquiry.

8.5 RQ4 How does the scientific inquiry practice of these PSTs compare with other teachers (pre-service and in-service) - What factors inhibit its enactment?

This section will primarily discuss the findings which compared the action of scientific inquiry between the case study cohort of PSTs, the non-case study cohort
of PSTs and the in-service science teachers. It will also present discussion with reference to literature on the perceived barriers impeding scientific inquiry practices in the classroom.

The key themes associated with this research question are presented in Figure 8.4

8.5.1 Comparing the Practice of Scientific Inquiry

Having a comparison with the cohort of pre-service science teachers who were not involved in the study allowed the author to determine whether the suggestion was accurate that involvement in the CoRe workshops can serve as a professional development opportunity towards the practice of scientific inquiry. The assertion from the findings was that the CoRe challenged the PSTs to make sense of IBSE in ways others did not have access to. The comparison with the non-case study cohort intimates that it was the case study cohort’s involvement in articulating their knowledge of scientific inquiry through their PCK description that led to the enhanced action of inquiry in the classroom. In other words, it was not as a direct result of their transition through their ITE programme. However as mentioned in section 8.4.1 the action of inquiry models partial inquiry practice.
Overall the findings suggest that the lack of inquiry practice appears to be a norm within the Irish education system, findings which are in line with international data on the action of scientific inquiry in the classroom (Campbell et al. 2010; Roth 1995; Capps and Crawford 2013). However such claims need to be further examined as the sample sizes for both pre-service and in-service teachers do not mirror a baseline representation. It must be remembered that the PSTs observed were from one ITE institution that practiced the concurrent model of ITE as it was never the intention to get a national representation of PSTs or indeed to get a comparison of action between PSTs who have transited through the two models of ITE. When the author refers to the typical pre-service science teacher, she speaks of a particular cohort of final year pre-service science teachers within the University of Limerick, not nationally. Therefore while the findings are telling, they do not provide a generalised understanding of all PSTs’ practice of scientific inquiry in Ireland. Indeed the data from the in-service teachers does not provide a generalised representative sample either, but serves as a pilot representation for a larger study. However, regardless of the population sizes, the findings, though not generalizable, do provide some insight into practice in the Irish context.

To reflect on the study carried out by Coady (2010) on the experiences of pre-service science teachers in the University of Limerick, the findings from the current study add to this and suggest that the PSTs are not being adequately prepared to teach through inquiry. Coady (2010) looked at all active learning methodologies more from the point of view of the PSTs’ opinions rather than their actions. The responses from PSTs in this study ranged from being positive with one PST suggesting that they had learned a lot of strategies with another PST wishing that more practical advice was given in education modules (Coady 2010). A third PST suggested that little is done to prepare them for practical activities (Coady 2010). Another PST considered that four weeks of subject pedagogics before beginning a teaching practicum experience is not an adequate amount of time to develop pedagogical knowledge (Coady 2010). The PSTs in this current study echoed this view point and perhaps when one compares the action of scientific inquiry between the two cohorts, it can be hypothesised that not enough time is given to develop an awareness of pedagogical strategies which mirror constructivist orientations.
It can be suggested that PSTs experience with scientific inquiry can also come from their laboratory experience within their content modules. A study currently being carried out in the University of Limerick is looking at the ability of lab demonstrators to teach using inquiry-based instruction (Flaherty et al. 2015). The results to date indicate a limited understanding of scientific inquiry and a disparity between what the PSTs believe the role of the lab demonstrators to be and vice versa. These lab experiences are a crucial component of their ITE, therefore PSTs need to be provided with some inquiry experiences that they could then mirror in the classroom.

It must be considered that PSTs often enter their ITE programme without having conducted a single inquiry as students (Windschitl 2000). Therefore the essence of ITE is to free PSTs from past learning experiences, many of which result in beliefs about teaching which are problematic. Indeed it is unreasonable to assume that PSTs will spontaneously embrace the idea of using inquiry with their own students (Windschitl 2004) if they have not encountered it previously thereby suggesting the importance of getting an insight into in-service teachers’ practices of scientific inquiry. The primary justification therefore for getting an insight into the practice of scientific inquiry within Irish post-primary schools and how this is relevant to a study involving pre-service science teachers can be answered when one reflects on the afore mentioned apprenticeship of observation (Lortie 1975). The findings reveal that scientific inquiry is very much a seldom enacted pedagogical strategy in Irish post-primary schools. This suggests that PSTs, in their experiences as students, may not have been a learner involved in the scientific inquiry process. This can also be suggested when one reflects on the CoRes developed in phase one of the study as the verbalisation of inquiry orientations were not presented. The implication for this in relation to ITE is that if inquiry-based practices are not emphasised in teacher training, then PSTs will not have encountered inquiry neither as a student nor novice teacher. To that end, there is a need to engage in professional development both at the initial and in-career stages of the continuum of teacher education.
8.5.2 Factors disabling the Practice of Scientific Inquiry

The barriers towards the practice of scientific inquiry gave an interesting insight into potential reasons for its limited use in the Irish education system. Indeed the disabling factors are to a large degree echoed in the relevant literature and will be discussed in the following section.

Time Constraints

Time constraints were a decisive factor in whether or not the action of inquiry was within the teachers’ repository of classroom practices. This issue of time constraints related to the pressure which teachers are under to complete a mandatory curriculum which in itself is crowded with content. This has been the view of many pre-service and in-service teachers in this current study as well as serving as an issue in the literature such as that presented by Asay and Orgill (2010). Asay and Orgill (2010) presented their findings with reference to the experiences of in-service teachers however Fazio et al. (2010) also found the issue of time constraints to be a disabling factor for PSTs’ engagement with inquiry practices. Indeed a study reported by Higgins (2009) looked in part at the attitudes of Irish in-service science teachers towards coursework B. As a reminder coursework B is a part of the Junior Certificate Science syllabus that works off the premise of students engaging in inquiry investigations. In this study, 31 out of the 310 teachers in response to a question related to the early distribution of titles for coursework B believed that it was never a good time to start coursework B as “some teachers found it a waste of valuable time that students could be using for revision purposes” (Higgins 2009, p.19). This focus on time as opposed to authentic learning opportunities offers an insight into the common attitudes of Irish in-service science teachers. The pressure which in-service teachers are under to complete the mandatory curriculum is unfortunately the prevailing focus of teachers as evident from this current study and Higgins (2009). The PSTs involved in the CoRe development held alternative beliefs to the popular opinion that inquiry cannot take place in a classroom setting because of time constraints. While they did concede that it does take longer initially, they believed that students would gain a more advanced conceptual awareness of the material by engaging in inquiry-oriented activities and therefore less time would be needed for revision of the material at a later date.
A systematic change needs to take place to allow for more open, inquiry oriented, authentic learning opportunities where the focus is on the quality of learning and not the quantity of learning. The present curriculum is disabling teachers from focusing on the quality of learning as outlined by the results of the survey.

**Lack of Collegiality**

Another disabling factor which was viewed as a personal constraint by some of the teachers was that of the support of colleagues, attitudes of colleagues and indeed the level of cooperation amongst colleagues. This lack of cooperation contradicts the findings of the OECD TALIS Report developed by Shiels et al. (2009) which reports that cooperation amongst teachers was higher in Ireland than other surveyed countries in terms of cooperation related to the exchange of teaching materials and discussion of learning developments of individual students. The question remains, why is there is a difference in Irish classrooms in terms of the level of cooperation between teachers in Ireland towards enacting scientific inquiry in the classroom? The author would argue that the habitus of the teacher can unconsciously influence their attitudes towards the enactment of inquiry in the classroom and therefore can have a congruent effect on whether or not they support and collaborate with peers. If a culture dictates a system of rote learning within a constricted curriculum, then this culture can permeate into the teachers’ behaviour. This in turn can disable a teacher’s use of scientific inquiry while concurrently prevent cooperation between teachers in a school setting.

Both the non-case study and the case study cohort reported the lack of support from their co-operating teacher as being a challenge. In the study carried out by Rees et al. (2013) they had co-operating teachers facilitating the PSTs using a scientific inquiry framework. This again suggests the importance of the co-operating teacher in guiding the PSTs’ experiences. The author would like to consider the role of the co-operating teacher in the facilitation of PSTs’ inquiry actions in the classroom. Windschitl (2001) concedes that the co-operating teacher does have a role to play but their action towards using inquiry does not necessary lead to a cascading effect resulting in the PSTs’ enactment of the practice. What influences the actions of the PSTs more is the beliefs and attitudes of the co-operating teacher towards using
inquiry-based practices (Rozelle and Wilson 2012). Despite the sometimes conflicting beliefs between the PSTs and their co-operating teachers in the current study, the case study cohort did appear to engage in inquiry practices.

Blanchard et al. (2010) believes that professional development experiences do not readily translate into classroom practices, therefore in response to this, Rees et al. (2013) suggests the importance of cooperation between co-operating teachers and PSTs using an inquiry framework. Openness and willingness to engage in professional development and try alternative approaches in the classroom is directly related to a teacher’s attitude in relation to scientific inquiry but also in relation to their willingness to change. These attitudinal factors need to be the focus of a change process. Rodriguez (1998) successfully altered the attitudes of two PSTs by using a sociotransformative constructivist orientation as a vehicle to facilitate their ability to teach for diversity and understanding while simultaneously preventing resistance to pedagogical change.

**Students as a Constraint**

The students themselves were seen as a disabling factor by a large number of participants (n=30) with issues such as the ability of the students serving as an obstacle towards using inquiry approaches. Indeed one teacher believed that learning through inquiry would only suit the students of perceived greater ability and would leave the weaker students floundering. Crawford (1999) revealed that teachers within her study do not believe that students are capable of carrying out an inquiry activity. While there is some literature to support this belief (Ruebush et al. 2009) there is contradictory research which indicates that using inquiry as an instructional strategy enhances the learning of all students and that inquiry is not just for the seemingly bright students (Colburn 2000b). For all students to benefit from inquiry instruction, Colburn (2000b) recommends the teacher:

- Using orientating activities towards concrete, observable concepts
- Centres activities around questions that students can answer directly via investigation
- Emphasises activities using resources which students are familiar with
• Chooses activities which reflect students’ skill level and knowledge

This would suggest the use of guided inquiry for students of mixed ability. It is important to note here that every class is different and the variation in approach that a teacher makes is directly related to their knowledge of how to teach the content to make it comprehensible to all, in other words their PCK.

Student motivation was also identified in the surveys as a potential challenge to enacting scientific inquiry. This challenge has also been presented in the literature with Edelson et al. (1999) suggesting that for students to engage in inquiry there needs to be a higher level of motivation. A way of dealing with this challenge is to approach the inquiry process around a meaningful problem (Edelson et al. 1999) which is a problem from which the implications matter to students, i.e. it relates to interests in their own lives.

One constraint identified by Rodriguez (1998) involved learning how to manage the students’ resistance to change. This was noted by Rebecca who believed that it took time for students to become comfortable with this new approach and that it required a number of attempts before students were able to interact with her in ways they had not experienced before. Most students have previous education experiences where they are the recipients of information and do not actively involve themselves in their own learning. Engaging in inquiry is counter to this approach and the exam driven, product not process culture reflects students resisting this approach where they just wish the teacher would tell them the “correct” answer. It must be recognised that when students engage in inquiry practices they may experience frustrations, experimental error and missing data (Damnjanovic 1999) and this can mean a delay in them being content recipients. Therefore key to enacting inquiry in the classroom is to create a culture where the learning process supersedes content to be learned. This, the author would admit, is a difficult task in which further research in warranted.

Lack of Resources

Another factor which was reported by a number of in-service teachers was the limited resources available that would promote an inquiry approach. Indeed the
literature does account for resources as a disabling factor with Goodnough and Hung (2009) stressing that teachers feel ill-equipped in the classroom and therefore cannot use inquiry approaches. One additional resource which was unique in this current study was the presence or lack of lab technicians. A number of in-service teachers believed that the lack of lab technicians in a school was a disabling factor. Lab technicians whilst not a compulsory assignment in schools can be found in a number of schools across Ireland with Higgins (2009) reporting that 11% of teachers in her study had access to lab technicians within their school. Their role, amongst others, is to organise and offer advice on the apparatus required for experimental investigations. Stating the lack of lab technicians as a disabling factor leads the author to assume that perhaps teachers are under such severe time constraints that they cannot find the time to organise apparatus for an upcoming investigation. This view was vindicated by Higgins (2009) who reported that teachers believed that preparation and clean up took a substantial amount of time. Another possible reason may relate to the teachers’ confidence where they are not confident in their own ability to set up an experiment or select apparatus which is removed from the cookbook experiments found in the textbook. Again, these are only speculative and further research is warranted.

Another disabling factor was the limited availability of the laboratory classroom and the belief that practical investigations could not take place in a regular classroom setting. Higgins (2009) reported that teachers in Ireland often have four or more third year science groups within a school with 75% of teachers revealing that their school has three or less laboratories in which to engage in practical investigations. The result therefore is a lack of laboratory availability. This effectively means that not all third year groups have equal access to laboratory facilities with only 39% of third year science groups having all their science classes in a laboratory setting (Higgins 2009). While having the students engage in hands on practical investigations does have its purpose, a study by Donnelly et al. (2011) found that the use of a virtual chemistry laboratory (VCL) served as a vehicle to promote inquiry instructions. There are currently plans being negotiated to develop a VCL package which in turn would be disseminated into Irish schools.
The author would argue that there are alternatives but there is a need to educate teachers on the alternatives such as the use of ICT in promoting inquiry instruction. However as Donnelly et al. (2011) suggest, integrating an ICT based resource is a complex process and one needs to bear consideration for the persons at the heart of the change process, the teacher. Professional development towards the integration of ICT would be underpinned by four teacher categorisations which are the contented traditionalist, the selective adopter, the inadvertent user and the creative adapter (Donnelly et al. 2011). The latter category, the creative adapter would have a strong focus on student-centred approaches which allow for meaningful learning while the contented traditionalist would have a strong focus on assessment with limited methodological variation (Donnelly et al. 2011). If a contented traditionalist was to become a creative adapter, they would not be able to make this transition without first becoming a selective adopter and then an inadvertent user (Donnelly et al. 2011). These categorisations reflect the teachers’ habitus, their belief about how science should be taught. A contented traditionalist would have low level PCK while a creative adapter would have a wide scoping and rich level of PCK (Donnelly et al. 2011). So this author would argue that successful transition is underpinned by a teacher’s developing PCK.

Further on from the unavailability of laboratory space, the author would argue that inquiry can take place in the regular classroom setting as evident from a current Framework Seven funded project, Chain Reaction- A Sustainable Approach to Inquiry-based Science Education (IBSE). While within this project, inquiry activities specific to a laboratory setting are collated, the project does place some emphasis on activities that can be completed in the traditional classroom setting while still promoting the essential features of inquiry (Lehane et al. 2015). The author believes that informing teachers that inquiry does not necessarily have to include expensive chemicals and a laboratory setting will help alleviate some of the physical constraints that were referred to in this current study. A greater awareness that inquiry can stretch beyond the laboratory setting to the traditional classroom can in turn promote life-long learning in students and verbalise the message that science is all around us and does not have to be restricted to the laboratory setting. As mentioned in section 8.4.2, Bell et al. (2005) propose that a strategy can be inquiry-oriented if students are
presented with a data set and the experience of analysing the data to draw their own conclusions is an inquiry process. Therefore students could be presented with data in a regular classroom setting. Inquiry in this classroom setting would be indicative of inductive inquiry in which the teacher presents the students with a set of data results (which could be fictional in nature) and asks the students to infer a conclusion or generalisation from the results (Orlich *et al.* 2010).

Another disabling factor, though not directly reported in this current study, is that of class size. Higgins (2009) revealed that 20.6% of teachers who responded to a survey on the Junior Certificate Science syllabus had greater than twenty four students in their class groups. For health and safety reasons, it is necessary to have class groups with less than twenty four students (Higgins 2009). Within the current study, teachers did report safety concerns impeded on the use of scientific inquiry in the classroom. While a direct correlation between the lack of inquiry in the classroom and increased classroom sizes was unreported, the author believes that increased class numbers could deter teachers from using inquiry from both a safety and a management viewpoint. This is in line with the observations proposed by Songer *et al.* (2002).

**Fiscal Constraints**

The literature identifies fiscal constraints (Ketelhut and Nelson 2010) as a disabling factor and in this current study one in-service teacher proposed that the pressure on teachers to teach for the examination acted as a constraint. This teacher considered them to be the target of blame if students did not achieve highly in the state examinations. Indeed Higgins (2009) reported that some teachers felt that having investigative elements to the syllabus, like that with coursework B, was essentially a test of the teacher and not of the student. It is necessary to have accountability as part of being a professional but the author would suggest that some teachers’ beliefs about the purpose of assessment being solely to account for teachers’ actions needs to be acknowledged and addressed. The presence of summative assessments has been identified as impacting the quality of the teaching because of the presence of high stake examinations (Saka *et al.* 2009, Falk and Drayton 2004) and its impact on student and teacher alike.
Lack of awareness of how to approach Inquiry

Only one of the participants, an in-service teacher, revealed that he did not know how to approach inquiry. Whilst the unfamiliarity with how to approach inquiry was referred to in the literature (Crawford 2000), the author feels it necessary to note how only one teacher presented this as a disabling factor. The lack of awareness of how to approach inquiry can be linked to the varying definitions of inquiry presented in the literature (Anderson 2002). The author would argue that for inquiry to be successfully enacted in the classroom, a teacher needs to develop their own personal definition of inquiry which still reflects the key features of inquiry, the already discussed living educational theory (Whitehead 1989) of scientific inquiry. This may help alleviate the issue of educational jargon and the distance between educational theory and practice that is reported by teachers in the relevant literature. Gore and Gitlin (2004) investigated teachers’ attitudes towards educational research and reported that teachers dismissed educational research because they did not find that it was practically applicable in the classroom setting. Coupled with this, the teachers believed that educational researchers lacked the credentials to discuss research related to education as they were separated from the real classroom setting (Gore and Gitlin 2004). The author would argue that developing their own theory of inquiry would help to lessen the gap between theory and practice.

8.5.3 Reflecting on the Findings from the Survey

Many of the constraining factors revealed were similar for all three cohorts. Despite the fact that the case study PSTs did share a number of disabling factors, their responses to the survey and indeed the observations and lesson plans suggests that having an awareness of the potential constraints does not necessarily result in inquiry becoming an unpractised act.

The question that remains is whether a sustainable approach to IBSE is possible within the current Irish education system. Already the promotion of a sustainable approach is the focus of the already outlined Chain Reaction project which commits to a sustainable approach to disseminating inquiry-based practice (Chain Reaction Booklet 2013). The premise of this project in Ireland is to engage teachers in PLCs as they adapt inquiry-focused lessons to their own classroom context. The
anticipated sustainable impact that this project will have is hypothesised by the teachers becoming their own makers of meaning as they create inquiry focused lessons while concurrently reflecting on their own living educational theory (Whitehead 1989) as to what inquiry resembles in actual classroom practice (Lehane et al. 2015). Some researchers would argue that it is problematic having teachers form individual conceptions of inquiry which are removed from the conceptions of researchers (Crawford 1999). However this author believes in the importance of teachers forming their own constructed understanding of inquiry if they are to believe in the practice of inquiry in the classroom.

8.5.3.1 Reflecting on the need for Change
It is necessary to divert the blame solely from the teacher to other factors that promote the indigenous practice of “teaching to the test” and the overreliance on the textbook. It is important to reflect on the position of a teacher as a facilitator of learning and the author would argue that teachers are carers whose vocation is towards student learning. However external factors, more prominently the education system, create somewhat of a resistance to using innovative approaches, such as the use of inquiry. With the introduction of coursework B in the current Junior Certificate syllabus science teachers (94%) reported their dissatisfaction with the increased workload (Higgins 2009). However it is important to emphasise that this negative association with the increased workload can in part be related to the overall saturated product-focused syllabus which must be completed. Teachers within the Higgins study believed that investigative approaches, such as that is coursework B, can only be successful if the syllabus is to be reduced. It is only then can we get a true representation of teachers’ attitudes towards inquiry when the constraints of the existing syllabus are reduced.

The new Junior Cycle Framework which is currently being developed by the NCCA seeks to promote key skills in the learning process and the focus is very much on the development of students’ critical thinking, inquiry and observational skills (Towards a Framework for Junior Cycle, Innovation and Identity 2012). However previous science syllabi have emphasised the promotion of inquiry practice in the classroom but as the results of the quantitative findings in this current study suggests, the action
of inquiry is lacking in the classroom context. The author would argue the need to reflect on the barriers to scientific inquiry such as those expressed by both in-service and PSTs in this study and work in parallel with these disabling factors. Central to a successful renewal of practice in the Irish education system is the need to develop an understanding of what inquiry actually is and how it can be represented in the classroom. Even though unilateral agreement of what can be defined as inquiry is still not developed (Capps and Crawford 2012), this study has suggested the importance of developing personal theories on inquiry specific to classroom experiences and contexts.

8.6 Chapter Summary
Reflecting back on the framework guiding this study, the author has emphasised that if scientific inquiry is wrapped up within the PCK of teachers, it can be captured and perhaps developed through the CoRe tool. The findings suggest that the CoRe tool can be used as a professional development aid to enhance the practice of scientific inquiry due to the PLC in which a CoRe can be developed in. A one stop workshop initiative does not influence teachers’ practice in the classroom (Coenders et al. 2010). Therefore it was important that the PSTs’ experiences in developing their inquiry orientations were more than a one stop workshop, it was a continued professional development endeavour throughout their ITE programme.

Speck (1996) argues that sustained educational change is possible through best practice in professional development opportunities. He argues that best practice resembles professional development as being an ongoing, diverse process where student learning is the goal and educator involvement is essential (Speck 1996). Within the current study this were considered and integrated to facilitate the opportunity for sustainable educational change. The findings in their totality appear to suggest the value that the PSTs placed on the use of the CoRe tool both in terms of the opinions they vocalised and the developing appearance of inquiry orientations as the PSTs continued to involve themselves within the scaffolded PLC. Comparison with another cohort of pre-service science teachers and in-service science teachers reveal two things (1) that the average action of scientific inquiry was significantly more with the case study cohort and (2) the data indicates that scientific inquiry
orientations do not develop naturally with classroom experience therefore professional intervention is needed both at the initial and in-career stages of the continuum of teacher education.

The new knowledge that has been generated from this study can be surmised as the following: The PSTs initially had a weak foundational understanding of scientific inquiry. This is understandable when comparisons are made with the literature. It can be suggested from this study that engagement in a targeted learning community allowed the PSTs to begin articulating their understanding of scientific inquiry practices. In a sense it created a dialogue focused on discussions around the practice of scientific inquiry in a bid to facilitate the social construction of their reality. It can also be suggested that they found additional professional learning experiences which could facilitate their developing inquiry orientations. Their developing orientations did not necessarily translate in their practicum experience when looking at the findings as a whole. Therefore it can be suggested that there is a need to scaffold and facilitate the enacted practice of scientific inquiry, particularly with PSTs who are faced with technical, political and personal barriers as they engage in practicum experiences.
Conclusion

9.1 Contributions to the Field of Science Education
This study has shown the progression from Loughran et al.’s (2006) originally intended use of the CoRe to the successful adaptation made in this study and therefore it can be suggested that this adaptation to the theoretical framework contributes to the field of science education. Previous studies have adapted the CoRe scaffold to suit the development of different components of teachers’ professional knowledge (Espinosa-Bueno et al. 2011; Aydin et al. 2013). This study has shown that adapting one pedagogical prompt within the CoRe scaffold has created an opportunity to develop both the espoused and enacted orientations towards scientific inquiry using the supportive environment which defines a PLC as a place for professional dialogue to take place.

Within the Irish context, the process of engaging PSTs in professional collaboration through the use of a PCK lens is unique in itself. In the international context, the CoRe has never been used to explore the orientations of either pre-service or in-service teachers towards the practice of scientific inquiry. There was an attempt made by Espinosa-Bueno et al. (2011) to relate the CoRe with inquiry however this I-CoRe did not seek to capture and develop inquiry orientations within the PCK of its participants but was used to generate discussions on the implications of including the features of inquiry as a teaching approach. This I-CoRe bore minute resemblance to that developed by Loughran et al. (2006) as three of the pedagogical prompts were removed and the Big Ideas were predetermined by the researcher and focused on the features of scientific inquiry.

Developing Pap-eRs focused on orientations towards scientific inquiry is also novel and allows one to understand the variation between espoused and enacted PCK. The classroom windows provided opportunity to explore the transition between theory and practice and therefore showed the variation between the PSTs group construction of knowledge within a PLC and their individual enactment of that knowledge.

The PSTs have used the experience as a support structure as they transitioned through their ITE and the benefits of being involved in the study have shown that the CoRe has been a valuable aid to PSTs in their professional development towards the
practice of scientific inquiry. Added to this, they engaged in discussions as to the “what” and the “why” of teaching within a PLC and that is unique within the Irish context. Also there are no reports in the literature of Irish PSTs engaging in PLCs removed from didactic, pre-packaged delivery of information; the pre-service teachers in this study were heavily involved in fostering their professional formation through an inquiry into their own practice. This study therefore has opened up the discussion on the successful use of PLCs within the Irish post-primary education system and how through involvement in their own creation of meaning, teachers can develop a sustainable change in practice. This study has presented a response to Settlage’s contention that PCK, as an educational construct, has failed to deliver. The findings have provided evidence of how the PCK construct has facilitated in developing PSTs conceptualisations of IBSE and therefore serves a place within ITE. They have also developed their own living educational theory of scientific inquiry and they believe it is something they will take with them as they transition from being a novice to an experienced teacher. The author would consider that it is at the initial stage of a teacher’s professional development that change is most possible and this study intimates that changing a PST’s apprenticeship of observation is possible when done through a scaffolded, supported and on-going learning experience.

Even though the ultimate goal of disseminating the action of inquiry survey was to compare the case study PSTs with the other two cohorts, the findings did provide some interesting insight into the latter groups’ orientations towards inquiry. Additionally the disabling factors towards the action of scientific inquiry in the Irish context have not been explored previously both from the perspective of pre and in-service science teachers in Ireland and the results of the survey in this study begins to offer windows into the perceived barriers within the Irish context. This is relevant in the context of a changing syllabus focused on scientific inquiry as a means of constructing new knowledge in the classroom (NCCA 2014a).

9.2 Future Work
In light of the findings, a number of possible areas for future research are considered by the author. The author is keen to engage in research directed towards both case and action research studies, the latter of which would have some focus on the
professional development of the researcher. Both, she believes, are the most common research designs used for studies on the CoRe tool (e.g Hume and Berry 2011; 2013) and therefore future work will mirror these designs.

**Research with co-operating Teachers**

Firstly, there were suggestions from the findings that the PSTs lacked support from their co-operating teachers. The role of the co-operating teacher is echoed in the study by Coady (2010) who recommends that a stronger mentor system needs to be in place in schools as part of the model of school/teacher education partnership. Therefore possible research into the use of the adapted CoRe to facilitate the collaboration between PSTs and their co-operating teachers on practicum experience is warranted. Engaging in such collaboration using the original CoRe scaffold served as a professional development experience for PSTs in New Zealand (Hume and Berry 2013). Therefore could the adapted CoRe allow for PSTs and their co-operating teachers to begin to inquire into their own practice of scientific inquiry? Could the CoRe make visible a co-operating teacher’s beliefs about scientific inquiry? It must be considered that the co-operating teacher can often have orientations towards science teaching which are not inquiry-oriented (Binns and Popp 2013) so it is important to engage in collective professional development if the practice of scientific inquiry is to be part of a novice teacher’s professional practice.

**Research with Practicum Tutors**

Additionally could the CoRe serve as a tool for practicum tutors? It is often the case that tutors come from a variety of experiences, each with their own personal orientations towards science teaching. To that end, could the CoRe scaffold serve as a professional development tool for practicum tutors to understand what PSTs should be considering to enhance student learning? Also could the CoRe serve as a tool for PSTs and practicum tutors to engage in professional dialogue over same? The author is already using the CoRe as a scaffold to engage in discussions with her PSTs on practicum placement and the response from PSTs has been positive. However if this is to become a more formal addition to the practicum experience, more research is needed on how the CoRe influences both the practicum tutors and their PSTs’ orientations towards science teaching before, during and after classroom experience.
Research with the PSTs involved in the Current Study

The author would also suggest following up with the pre-service teachers as they transition from novice pre-service teachers to qualified in-service teachers. Have they brought some of the experiences from their involvement in the PLC into their practice? Are they adopting inquiry-oriented activities in their classroom? Do they endeavour to involve themselves in professional collaboration with other teachers? Do they still consider the importance of PCK as a lens that promotes effective teaching and learning? Do they consider additional constraints towards scientific inquiry having gained more experience in the classroom? These are all critical questions which, if answered, would give credence to the assumption that they have made sustainable change to their practice.

Research with PSTs in Science and other Disciplines

Could the CoRe be brought formally into ITE to develop PSTs’ understanding of scientific inquiry, perhaps within the pedagogics module? This could help alleviate the concern regarding the time constraints attached with developing a CoRe as it is viewed as part of the learning experience for PSTs. Could the CoRe have a place in requiring the PSTs to develop their own living educational theory (Whitehead 1989) of inquiry over their four years of study? In all, bringing the CoRe experience into PSTs’ ITE experience could equip them with the ability to verbalise their understandings of teaching and learning, in essence to challenge them to make sense of IBSE. This is something which can then be brought forward through their professional careers.

Also involvement in CoRe design could also help bridge the segregation that currently exists between the education and science components of their programme, indeed it could allow for the blending of the two which could facilitate the development of their PCK as a whole. ITE programmes in other countries also show weak reference to PCK but Mavhunga (2014) stresses the need to focus on a teacher’s PCK as the defining knowledge orientation. Currently issues of subject versus education identity are huge where PSTs are not able to position themselves in terms of their teaching as or by a discipline. Do they see subject knowledge as more crucial than knowledge regarding pedagogy, educational theory etc.? Developing a
CoRe could facilitate PSTs in considering the complexities around teaching, that it is more than subject versus education knowledge, it is the symbiosis that is PCK.

The author would also suggest the collection of a controlled repository of CoRes and PaP-eRs, similar to that developed by Loughran et al. (2012) where the contents have been generated by PSTs for PSTs. This repository would be controlled in the sense that the information contained in the CoRe/PaP-eR comes from the PST(s) but contains factually correct information. Teacher educators could facilitate in ensuring the accuracy therefore involving them in generating an awareness of the importance in articulating PCK in one’s developing practice (Hume and Berry 2011). Indeed the opportunity is there to form a PLC between teacher educators from the various disciplines to begin to create a synergy in terms of the content they teach and the way in which they deliver this content. If context does not normally permit this to be a natural synergy then perhaps the CoRe can serve as a tool to promote this dialogic exchange. The author is keen to look at this in the University of Limerick, particularly at a time when a School of Education is being formed. This School of Education will involve the amalgamation of the different departments, each with their own belief system and experiences. Therefore the CoRe could act as a tool to make visible their orientations and knowledge towards science teaching.

Another focus of future work could serve to look at the experiences of PSTs in both the concurrent and consecutive models of ITE. Would PSTs who engage in two very distinct models of ITE gain similar appreciation for the CoRe as a tool to socially construct their knowledge of teaching science? Also PSTs in the consecutive model can often come from very different backgrounds in terms of their content knowledge. Therefore could the CoRe make visible their existing content knowledge and perhaps develop this, and their PCK in general, through the social construction of meaning.

Also the author proposes that the CoRe design is flexible to the extent that it could be used by PSTs in a number of disciplines. Already the author has given lectures to three cohorts of PSTs not familiar with the CoRe and the feedback from these lectures has been very positive. Results from Coady (2010) suggest the disconnection between what PSTs in all disciplines within the University of
Limerick consider to be effective teaching and learning practices. Therefore the CoRe scaffold offers an opportunity to showcase what PSTs need to understand in terms of the what, the why and the how of teaching. Williams and Lockley (2012) already used the CoRe with technology PSTs; therefore it would be interesting to understand the attitudes of technology PSTs in the Irish context towards the CoRe. The CoRe could also be adapted to suit particular skills and practices within the different discipline areas. For example, in technology education, design-based learning would be viewed as an important practice in the classroom, so could the CoRe be successfully adapted to develop PSTs understanding of this?

**Research with PSTs in other Contexts**

The author also sees value in using the CoRe as a tool to capture PSTs’ PCK in both Northern Ireland and the Republic of Ireland. This would be done to understand how two different education systems influence PSTs’ PCK, having come from different apprenticeships of observation (Lortie 1975). Would there be a variation in terms of the PSTs’ orientations towards science teaching? This could serve as an interesting insight into how different education systems within the one island influence teachers’ beliefs systems and in turn their knowledge.

Would the adapted CoRe work in different contexts/countries? The fact that the CoRe has been used internationally suggests the value that researchers place on the CoRe as a professional tool, therefore could they see value in its use in developing inquiry orientations? Could the adapted CoRe be used as a tool to compare the baseline orientations of PSTs within different contexts? Future work is already being considered between PSTs in Ireland and Australia to understand the similarities between the professional knowledge of two very different contexts.

Also, it would be interesting to gauge the experiences of different ITE students within the Republic of Ireland by constructing CoRes at different stages of their training. This may help to develop a national comparison between PSTs learning in different ITE centres. Presently no such comparison exists and it must be mentioned that using a tool such as the CoRe, which captures the complexities of teacher knowledge, could allow for a deep understanding of PSTs’ experiences nationally.
Research reflective of the new Junior Cycle Science Specification

In a time of changing curricular focus in Ireland, the author would suggest that the CoRe and the professional dialogue that can take place in CoRe design could allow for teachers, both pre and in-service to consider their practice in light of the new Junior Cycle Framework. The CoRe has been used previously with a curriculum focus (Moore and Woolnough 2012) and therefore it can be suggested that the CoRe offers a scaffold to discuss teachers’ espoused understandings of the key skills and principles of learning which embody the new framework (NCCA 2012). As mentioned previously Irish in-service teachers do not typically engage in professional collaboration (Shiels et al. 2009), therefore could the CoRe serve as a tool to begin conversations around best practice, particularly in light of the changing syllabus? The new framework encourages teamwork, critical thinking and communication between students (NCCA 2012). Therefore, can the CoRe offer the potential for teachers to engage in such practices which mirror those advocated for students to develop?

Research on gaining a National Representation of Inquiry Practice

In relation to the survey, the results from the in-service teachers in the current study served as a pilot for a national survey from a larger population. This is again critical at a time of changing syllabus focus towards scientific inquiry. The key question is: what are teachers’ baseline understandings of scientific inquiry? This could potentially inform the direction of professional development initiatives for teachers as the new specification is introduced into schools.

A student survey was also developed by Campbell et al. (2010) and this author would suggest that future work could have a longitudinal focus looking at students’ experiences of scientific inquiry before and after the new science syllabus has commenced in September 2016. The key question here is whether or not the explicit focus of scientific inquiry in the new specification has meant that it has become part of classroom practices. It is also important in such research to understand what students’ attitudes are towards inquiry practices. The students’ voice is critical in any discussion as they are the recipients of knowledge and therefore their experiences and belief systems need to be better understood in any change endeavour.
9.3 Incorporating the CoRe within ITE

While the focus in the previous section was on potential research opportunities, this section will concentrate on how the CoRe tool could be used as a vehicle to enhance PSTs learning in their ITE training. Firstly, it could potentially serve as a vehicle to promote their professional learning by applying this learning in concrete ways. The fact that the CoRe may be viewed as a flexible tool suggests that it could be adapted to facilitate PSTs’ understanding of the Nature of Science, which is a key unifying strand within the new Junior Cycle Science specification. The CoRe could be used to make visible PSTs’ initial understanding of the Nature of Science and an adapted version of the CoRe could be used to advance their understanding, again within a PLC by the social construction of knowledge. The author would contend that a focus of ITE programmes nationally should be on the new specification, but finding ways of developing PSTs’ knowledge of the Nature of Science may prove difficult. The adapted CoRe would offer a dialogic scaffold to begin conversations around the Nature of Science.

The new Junior Cycle Framework also gives attention to the development of short courses within schools (NCCA 2012). These short courses are required to link to the statements of learning presented as part of the new framework, however the design of the short courses are seen to be flexible and open to whoever is constructing them (NCCA 2012). It is important that PSTs gain experience in developing short courses within their ITE experience and the argument could be made for having the CoRe as a scaffold to design the short course. As has been mentioned previously, the CoRe has been used in curricular design (Moore and Woolnough 2012), therefore its use to design a short course is justified. Designing a short course in ITE will also make visible the PSTs’ understanding of the new framework and whether or not they have predispositions towards constructivist practices since the short course should involve student-focused learning (NCCA 2012).

A number of institutions in Ireland use a micro-teach experience to help PSTs to consider their planning and delivery of a micro-lesson. This is an important part of their training as it allows for peer and self-assessment of practice. The suggestion is that the CoRe could be used firstly as a template for the PSTs planning and secondly as a prompting tool for PSTs dialogue when they reflect on their and their peers’
micro-lesson. This is similar to how Nilsson (2009) used the CoRe with her PSTs as a self-assessment scaffold. In effect the PSTs would engage in a lesson study, using the CoRe as a preparation tool and then use the CoRe again as a prompting tool for formative assessment.

The inquiry focused CoRe, as presented in this current study, could also be used as a vehicle to document PSTs’ progression in terms of their learning at the beginning and at the end of a subject pedagogics module. For example, a number of groups within a class could focus on their own respective CoRes, choosing topics which they would find difficult to teach. They would develop a CoRe at the beginning of the semester and then at the end of the semester to make visible their learning within the module. The initial CoRe could potentially act as a motivation to engage more deeply with the upcoming modular content to make them consider the complexities of what they need to know to become a facilitator of students learning. The CoRes could be compared with those developed by expert teachers (e.g. Loughran et al. 2006) to show both the common features but also the gaps in the PSTs’ knowledge. The CoRe could also serve as an assessment tool at the end of a module to capture the PSTs’ understanding of the key learning outcomes from the modular content.

If a teacher educator wished to use the CoRe as a learning tool within their module but was concerned about spending excessive time on their PSTs constructing a CoRe, alternative options are available. For example the class could agree on a particular topic and the respective Big Ideas and then each group would be assigned a Big Idea from which they would tease out the pedagogical prompts Whole class discussion could follow this with open dialogue between the PSTs on what they would include or remove from each other’s contributions.

Engaging in individual CoRe construction (similar to Bertram and Loughran 2012) throughout a PST’s ITE experience could lead to the development of a professional portfolio which makes visible their understanding of what they have learned during the course of their training. These CoRes could be adapted after a teaching practicum experience to show progression of learning. Also it is suggested that PSTs should be encouraged to engage in PaP-eR development during their practicum to capture their
understanding of their enacted PCK. In a sense a PaP-eR could serve as a post lesson appraisal which helps the PST develop their professional competencies.

Finally the CoRe, within the concurrent model of ITE, could serve as a vehicle to bring together PSTs’ key learning from different ITE modules in order to offer some coherence between the different aspects of a teacher’s PCK. Within the consecutive model of ITE it could potentially serve as a tool to capture the PSTs’ knowledge of content within their PCK and then build upon their knowledge of the other components of PCK as they transition through their ITE.

All of these scenarios are focused on facilitating PSTs to develop best practice in science teaching and learning. The author would propose that for the CoRe to be used constructively there is a need to include it as an organic feature of their training, be it within their subject pedagogics, teaching practicum or education modules. The author would admit that this is a difficult task but this study provides a foundation for others to understand the importance of focusing on the complexities of teacher knowledge, in whatever guise, within PSTs’ ITE experience.

9.4 The Author’s Personal Reflection of the CoRe as a Professional Development and Research Tool

The author’s experiences of the CoRe as a professional development tool were mainly positive. However the dominant issue that the author had with using the CoRe was in maintaining the PSTs’ attention throughout the workshop sessions. Due to the fact that the development of a CoRe is a lengthy process there were occasions where the cohort lost situational interest, this was despite the value they reported in engaging in the CoRe experiences. Perhaps, on reflection, shorter sessions where one Big Idea each time is developed could help maintain situational interest. Or perhaps having different groups teasing out different Big Ideas would help to alleviate the issue.

There were also times where the author felt the need to tell the PSTs what to include in the CoRe in a sense, what the “correct” answer was. Even though the author avoided doing this, she still found it difficult, particularly when the PSTs were struggling. It makes the author reflect on the fact that essentially the PSTs were engaging in inquiry and similar to a teacher in the classroom, the author found it
difficult to give the power over to the PSTs. The author did struggle to give the PSTs’ ownership over their articulation. To that end, not only was involvement in the CoRe design a new experience for the PSTs, the author also had to establish her role within the context of the study. It was therefore a professional learning experience for the author as well as the PSTs.

In terms of the CoRe as a research tool, the detail provided within the content of the CoRe gave a deep insight into the PSTs’ understanding of the complexities of teaching. The author did however find the analysis of the CoRe content difficult in the beginning, having been presented with a large amount of data to analyse. However this was less of an issue as the author gained experience in analysing the CoRes. It is important to recognise that this could potentially be an issue for other researchers who are inexperienced with the CoRe as a research tool.

Despite these issues, the author would admit that she was able to see the power of using the CoRe as a vehicle to socially construct the PSTs’ knowledge of scientific inquiry and therefore is keen to use it in future research and learning opportunities like those described previously.

**9.5 Final Comment**
This study has documented the potential for PSTs to engage in professional development within a structured learning community to develop orientations towards practices which mirror the social construction of learning. While the author does recognise that this is a case study and is therefore difficult to generalise, the purpose was not to generalise the findings but to report on an experience which could give insight into how a PLC worked successfully within an Irish ITE context. The findings suggest that by socially constructing one’s knowledge, teachers can begin to construct their own living educational theory (Whitehead 1989) of inquiry. The author does recognise that while the findings are promising, there is a need to alter the focus of learning within the Irish education system from prescribed, summative examinations to more learner-focused assessment for learning. The new Junior Cycle Framework shows promise for this to happen but has been met with resistance from teachers. It can be suggested that there is a need to focus on altering the beliefs system of the teacher and potentially a structured PLC can allow for a changing habit
of mind. The CoRe can offer an environment where beliefs, understandings and indeed progression of knowledge, are made visible.
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