Exploring the use of social constructivist methodologies in teacher practice and student engagement in chemistry.

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Sinéad Nugent B.Sc. (Hons)

Supervisor: Dr. Colette Murphy
Declaration

I declare that this thesis has not been submitted as an exercise for a degree at this or any other university and it is entirely my own work.

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Abstract

This thesis comprises a self-study action research inquiry into the practice of a post-primary chemistry teacher in Ireland. The research had a collaborative aspect to it, as a number of students were invited to participate through cognegenerative dialogue. This research was enacted as a methodology to improve chemistry learning and teaching in the class and to address difficulties in engaging students to become active learners. My style of teaching was traditional, mostly didactic, with very little social interaction between the students during lessons. The emphasis was on the importance of the summative Leaving Certificate exam, as is current practice in most Irish schools. I endeavoured to create a more engaging and active form of pedagogy. Methods undertaken in this research included; a critically reflective approach, research and implementation of social constructivist methodologies into teaching and co-generative dialogues with students. This was all enacted through an action research approach, combined with social constructivist values and a deep consideration of ethical and moral implications of the research. The data-collection took place over the academic year 2016-2017 with a 5th year chemistry class. The data collected comprised of; social constructivist designed lesson plans, field notes on lessons, artefacts of student work, a teacher reflective diary and transcripts of co-generative dialogue discussions with the students.

From engagement with the research I gradually reconceptualised my identity as a reflective and critical thinker through critical reflections on my practice and research into social constructivist methodologies. I also began to challenge entrenched cultural norms and enact changes in the purpose of improving practice. This research impacted my teaching practice and developed an engaging pedagogy that resulted in the students becoming active in their own learning. From this study, social constructivist methodologies can develop and support teachers in their understanding of the nature of science, promoting teaching towards more social approaches. Social constructivist methodologies could be developed into a pedagogical approach that could engage students in the subject of chemistry and support them in becoming active learners. There is also potential for the social constructivist methodology to be implemented into curriculum, when supported by on-going professional development for teachers, and acknowledgement of influencing cultural factors, on its implementation in Ireland.
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List of abbreviations

NCCA – National Council for Curriculum and Assessment
PE – Physical Education
CPD – Continuous Professional Development
DES (1997 - 2010) – Department of Education and Science
DES (2010 - present) – Department of Education and Skills
TY – Transition Year
CAO – Central Applications Office
SEC – State Examinations Commission
OECD – Organisation for Economic Co-operation and Development
AFL – Assessment for Learning
PISA – Programme for International Student Assessment
STEM – Science, Technology, Engineering and Mathematics
ISTA – Irish Science Teachers Association
PCK – Pedagogical Content Knowledge
STS – Science Technology and Society
TALIS – Teaching and Learning International Survey
CBA – Classroom Based Assessments
ZPD – Zone of Proximate Development
RSC – Royal Society of Chemistry
AQA – England – Assessment and Qualifications Alliance
OCR – England – Oxford Cambridge and RSA
SQA – Scottish Qualifications Authority
ACARA – Australian Curriculum, Assessment and Reporting Authority
IB – International Baccalaureate
FNBE – Finnish National Board of Education
CIE – England – Cambridge International Education
CCEA, GCE – Northern Ireland – Council for the Curriculum, Examinations and Assessment, General Certificate of Education
WJEC, GCE – Wales – Welsh Joint Education Committee, General Certificate of Education
PEEL – Project for Enhancing Effective Learning
CERI - Centre for Educational Research and Innovation
Chapter 1: Introduction

1.1 Research context

This is my classroom. It consists of four straight benches positioned in the centre of the room with walkways along either side of the benches. The students (all boys) sit on stools behind the benches and there are six students sitting at each bench. There is enough room for one person to walk (carefully!) between the stools and the next bench. On the left side of the class, there are four white-boards that are attached to the wall. At the back of the class, there are storage units for glassware and experiment equipment, and to the right are six window sections that look out to another building in the school. A work bench runs along the window wall as well. With no wall space left, the periodic table was stuck into the roll of a blind. I had considered the ceiling, and am still contemplating this. Most mornings, I fix the periodic table back into the blind, as it often appears that someone tries to use the blind and dislodges it in the process. The top of the room consists of a raised platform, about 2mx3m, with a bench that is about half the size of the students’ benches. This is the teacher’s area. There is a sink, gas taps and a computer permanently on the desk, and at other times, the jumble of notes and resources I might be using for a class. Behind the desk is another white-board, and on the
roof in front of the teacher’s bench is a data projector. Despite the windows, this class is usually dark, due to the blinds being drawn so that the projection on the white board can be seen. The data projector has been in that room for over ten years, and the capacity of the bulb has dimmed somewhat in that time. The stools for the students are arranged in a row behind the benches so that all are facing the raised teacher’s area.

Take a typical Monday and fifth year chemistry was my first class. I would try to arrive at least ten minutes before the class, to set myself up and to say hello to the students as they arrived in. By 8:56am, most of the class were usually in situ, that being their chosen seat in the classroom, and some tended to converse. The bell rang at 9:00am. A few stragglers usually appeared very soon after the bell, so I allowed a settling in period. It was 9:03am, and I was missing three students. One was sick, another’s lift was delayed and the third understood the bell to indicate the perfect time to go to his locker. By the time all attendees for the class were seated, it was 9:06am. I usually asked the students to take out their work from the weekend, and discuss with their partner how they found the work. Other times, I allowed conversation to develop. This initial time allowed me to complete the administration task of marking the attendance list. This required logging onto the school online platform and entering absent beside the names of the students who are absent that morning. Usually, during that initial time, the principal of the school would come over the intercom and deliver the morning announcements, including the habitual one of reminding teachers to take the roll and report any discrepancies to the deputy principal. At that point, the clock in the class could read 9:12am. Time is a precious commodity in schools, although it is not always used most effectively. This outlined the start of a typical day in my practice.

The following details a typical theory class in my practice prior to this study.

My PowerPoint was ready on the computer and I unfroze the data projector. I used to have a pointer for my presentations which enabled me to walk around the class, but that got mislaid; a hazard for small things left in this classroom. With the pointer missing, I spent the majority of class time at or around the teacher area. I worked through the presentation that I had created for the class on the topic. Generally, this induces a higher occurrence of teacher-talk. The students took notes, and I asked questions, again from the teacher’s area. I got into a habit of not nominating students by name. Rather, I asked the question to the whole class, and someone usually responded. Only if there was silence after a question would I call the name of a student. Depending on the topic and if there was a lot of theory, I could stand there explaining for the rest of the class. Alternatively, I would go through a topic and
then get the students to answer a question or complete a quick activity on the topic. I always try to have exam based questions for my students to work on during different topics. During the students’ completion of the activity or questions, I walked around the classroom, thus leaving the teacher area. However, the layout of the class presented difficulties. In the students’ attempts to keep the walkways clear, the areas behind the students were sometimes obstructed by extra stools. My walk therefore consisted of an external perimeter circuit. I could not reach many of the students due to the structure of the classroom. Those sitting on inner stools were difficult to access. During the topic, after a chunk of information was given, I asked the class if there were any questions about what had been explained. If a question arose, I would answer but rarely moved from my presenting position during that time. The bell rang. As happens on occasion, I had not expected it and homework was given hastily over the bell. Otherwise, homework was ordinarily assigned with about three minutes left. After this, the students packed up their things and left the class. As I had noticed many times before, conversation erupted when the bell went.

This vignette is an introduction to the problem setting of my practice (Gade, 2016) and how this room has been generating problems of practice for me for the last ten years. The main research question of this study developed from my experience in practice, and from an increasing awareness of educational theories; “Can social constructivist methodologies affect teacher practice, and/or student engagement in chemistry?”. Three sub-questions were developed from the main research question to organise conceptual themes within the study. The sub-questions are: Which social constructivist methodologies impacted on my practice, and how? How did the social constructivist methodologies and practice affect student engagement? How does the current chemistry curriculum relate to social constructivist methodologies?”. These questions represent the main theoretical aspects of this study, which are; the affect of the methodology on my teaching practice, the resultant impact on student engagement and the influence of the curriculum on both.

For many researchers, the aim of education should be the development of lifelong learners, rather than the memorisation of facts (Kwakman, 2003; Johnston, Conneely, Murchan & Tangney, 2015). Educational curriculum development research acknowledges that economic and social developments
of the twenty-first century have had significant effects on education practice and policies. This effect has resulted in a drive to reform the education system to assist young people in preparation for the diversity they will meet in the 21st century (Johnston et al, 2015). For students entering their chosen path after school, they should be able to work with complex ideas at a conceptual level, work creatively to produce new ideas, products or knowledge, critically evaluate material and information, communicate clearly and problem solve. Students need integrated knowledge and skills rather than de-contextualised facts, and need to take ownership of their ongoing learning (CERI (Centre for Educational Research and Innovation), 2008). When I looked at my students, and my practice, I could not see how I was promoting those skills or the enjoyment of learning in my class. The National Council for Curriculum and Assessment (NCCA) senior cycle document; Towards Learning, outlined the vision of the new senior cycle and that included the development of “active learners” (NCCA, 2009, p.5). They describe active learners as students who;

_pursue excellence in learning to the best of their ability and develop a love of learning by seeking and using knowledge_ (NCCA, 2009, p. 5).

The document goes on to detail the development of critical thinking skills, autonomy and responsibility for learning and goal setting in terms of the students own learning intentions (NCCA, 2009). On critical reflection I did not see active learners, although I saw an active teacher. I concluded that my students were not engaged in their learning, rather they seemed to be quite passive. My experience as a physical education (PE) teacher also influenced my thinking in relation to engagement and activity in classes. Teaching both chemistry and PE, I have experienced two very different classroom environments. In the enactment of PE, I found that social learning was a natural component of those lessons, while in my chemistry classroom, the active social element of learning seemed less evident. During the PE class students were engaged, active and involved in the lessons, and usually cited PE as their favourite class. I began to think how such a level of social engagement could be realised in the chemistry classroom. Student engagement and learning cannot be left to chance and require promotion through effective teaching (Pollard & Tann, 1993, as cited in Murphy, Murphy & Kilfeather, 2011). I recognised this, and recognised that student learning, skill development and conceptual understanding were being hampered by a traditional style of teaching. The students were passive in lessons and there were infrequent
opportunities to engage with the subject or their learning. The issue of the passive student and the over-active teacher was also expressed at a school-wide level. Teachers in the school deliberated about methods that could promote students to become more actively involved in their learning. However, this issue seemed to falter at the deliberation stage, and a lot of teachers resigned themselves to the idea that the students would not change. During those discussions, I decided that instead of changing the students, I would change. I decided that I needed to look at my teaching practice and examine how I could promote active and engaged learners in my classroom. It is acknowledged that students need a different set of skills for learning and working in the 21st century compared to the last one hundred years (Johnston et al, 2015). Those skills involve more than just the memorisation of facts. Therefore, a traditional model of teaching, i.e. the transmission of knowledge, was bound to miss the mark for developing skills and knowledge to further lifelong learning (Kwakman, 2003). A change in learning requires a change in teaching. The learning environment should promote more engaged students by involving them actively in their learning, promote discussion and provide strategies for collaboration and cooperation in learning (Murphy, 2015). As effective teaching was recognised for the promotion of student engagement, it was clear that the change required would be pedagogical in nature and centre around the teacher. Research into attitudes towards science education have found that the teacher is the most influential factor on student attitude to science, not curriculum variables (Osborne, Simon & Collins, 2003). This demonstrates that teachers are an influential factor when considering any curriculum change that advocates a different pedagogical viewpoint.

1.2 Overview of the project

This study utilised a reflective action research methodology. The cycles of action and research occurred continuously throughout the study, with research impacting planning, planning implemented into action during the lessons, and reflection informing research for the next development of planning. Action research was occurring daily. However, there were also major cycles of action research through the study. These major cycles included the culmination of daily action research practices to be reflected upon as a block of learning. There were
five major cycles of action research in this study and they were determined by the academic terms within a school year in Ireland.

The action research study took place in an Irish post-primary, senior cycle chemistry class context, in which the students were preparing for the Leaving Certificate (summative exam of upper secondary level schooling in Ireland). The school was a large all-boys school in Kildare, Ireland. I have worked in this school as a junior certificate science, senior cycle chemistry and PE teacher for the last eleven years. The data-collection took place with the consent of a 5th year chemistry group. In this class, there were 24 students. The study was focused on the theoretical and instructional development of my teaching practice. The data-collection took place over one academic year (2016-2017) and included reflective planning of social constructivist teaching methodologies with a keen focus on developing social learning within the class. Teaching methodologies were researched and incorporated into lesson plans. I recorded field notes during some classes, including a record of my emotions during the lesson, the level of engagement of the students and student comments and questions. At the end of each lesson a lesson reflection was written. At the end of the week, I engaged in weekly meta-reflections using the lesson reflections from that week. The weekly meta-reflections were framed by reflective questions, e.g. *what went well and what could be improved*, with the overall aim of engaging students in the lessons.

To incorporate the student perspective into the study, representative students volunteered to take part in co-generative dialogue discussions. A co-generative dialogue is a discourse in which teachers and students partake in a collaborative effort to set in motion positive changes in teaching and learning (Martin, 2006). In a co-generated learning space, the attempt is made to bridge an understanding between the context of the teacher and the context of the student. This collaboration could lead to improvements within the classroom, socially, academically and emotionally.
1.3 Outline of the chapters

In chapter two, the wider context of this study is situated within the literature available. The chapter discusses curricula in terms of historical development, current changes and impacts on teaching practice and student engagement. The factors that affect teaching practice are then outlined, including the influence of culture and assessment in Ireland. Following this, student engagement is analysed, including a discussion of research papers and studies on the factors that can impact student engagement within the classroom. Finally, the theoretical framework is presented along with the key concepts of the study and their interaction with literature in the area.

Chapter three details the design, preparation and implementation of the action research approach. It explores the history of action research and the variety of understandings that can exist. The education action research model that is used in this study is then discussed. The focus areas within the teachers practice and the development of cultural tools within the study that generated data are outlined. The method of data analysis is presented and the ethics of the study discussed.

Chapter four presents the first findings chapter which relates to teaching practice. The different social constructivist strategies that were implemented into practice, and the impact on learning, assessment and reflection are discussed.

Chapter five is the second findings chapter and focuses on the impact on student engagement as a result of the social constructivist approach taken in the study.

Chapter six, is an analysis of the occurrence of social constructivist theories within chemistry curricula in Ireland and Europe.

Chapter seven is the general discussion of the study, including the conclusions from the research. This chapter includes an evaluation of the key findings in relation to literature and how these findings can contribute to theory in relation to pedagogical practice, the design of professional learning models for teachers and curriculum development.
Chapter 2: Literature Review

2.1 Introduction

As stated in chapter one, the main research question of this study is; “Can social constructivist methodologies affect teacher practice, and/or student engagement in chemistry”. During this chapter, the literature review will explore and address the main theoretical aspects of the thesis, as outlined by the sub-questions main themes; impacts on teaching practice, student engagement and curriculum. The chapter also presents the theoretical framework for this thesis.

This research was an inductive, practitioner action-research which explored the adoption of a social constructivist position and development of social constructivist methodologies into teaching practice and analysis of the resultant impacts. Figure 2.1 is a diagram of the interactions that occur between teachers’ practice, curriculum and student engagement. It is acknowledged that this diagram is not exhaustive, although it represents major aspects of culture that have impacted education in Ireland, from the experience of the researcher and the literature accessed during the study.

Figure 2.1 Representation of the relationships between curriculum, teachers’ practice and student engagement.
Figure 2.1 represents the complexity of relationships that exist between the main conceptual areas of my research question. The following is an explanation of the diagram and later in the chapter the main concepts are expanded through discussion with educational research literature. The diagram contains three main conceptual areas which are denoted by the green boxes. Around the green boxes are purple boxes. The purple boxes represent cultural and influencing factors that impact the main conceptual areas. Between the green boxes are red arrows of varying widths and direction. The direction of the arrow represents the direction of the main force of influence. For example, teachers’ practice has a big impact on student engagement, so the arrow points from teachers’ practice towards student engagement. The varying widths represent the extent to which the influence from one area effects another, i.e. wider arrow, stronger influence. The final element of the diagram is a black zig-zag line on the arrow from curriculum to teachers’ practice. This illustrates that a disconnect is occurring between intended curriculum aims or change and teachers’ practice. This is also represented by the narrowest red arrow, whose direction of influence is going from curriculum to teachers’ practice. This highlights that curriculum has a weak influence on teachers’ practice.

Curriculum has a thicker red arrow connecting it with student engagement, which represents a stronger relationship. The arrow also has a double-head, which indicates a two-way relationship. Student engagement impacts curriculum as curriculum impacts student engagement. An example of this was the fall in the number of students choosing to study the physical sciences in the late 1980’s. This drop led to the Irish government publishing a policy report call the “Task force on the physical sciences” (DES (Department of Education and Science), 2002). In response to the falling student numbers, curricular developments that were in progress were advanced for introduction into schools the following year, 2003. In that example, decreasing numbers of students prompted curriculum change. Curriculum could then positively or
negatively impact on student engagement. Student-centered approaches to learning have been found to promote engagement (Murphy, 2015), while curricula that have not been changed and are outdated, over-crowded and traditionally taught have impacted negatively on engagement.

Teacher’s practice has the strongest connection (thickest red arrow) with student engagement in this diagram. The practice of the teacher directly impacts on student engagement and consequently the learning of the student. Aspects that have a major impact on teachers’ practice is the culture in which the teacher developed and in which they are teaching. Another aspect that influences and sometimes determines teachers’ practice is assessment. Those aspects could combine in different ways to produce positive or negative student engagement. Those aspects were also interacting with the teacher as a person, their personality and cultural-context, which could all impact on their practice and in turn student engagement. Student engagement linked with both teachers’ practice and curriculum. The strongest connecter (thickest red arrow) between teachers’ practice and student engagement represents the traditional style of teaching where the teacher impacted student engagement by leading the learning and the transmission of knowledge. This influence is moving in one direction.

Engagement for a student in lessons could be impacted by factors including; level of interest, social opportunities and emotional connections. An interesting lesson or task for a student is dependent on what interests that student, so getting to know students is important for their engagement. Acknowledgement of the student and their interests would also promote the emotional factor of engagement. Interest could be developed through real-life examples, challenges, game like situations, etc. The social engagement of the students was another very important factor, and could be achieved through incorporating social elements and discussions into classroom tasks. The opportunity for the student to engage socially and generate an emotional connection with the task and the people around them, could impact positively on engagement. The chapter discusses the three main conceptual areas; curriculum, teachers’ practice and student engagement in more detail, outlining the inter-relationships and their influences. The theoretical framework is presented, describing the relationship between the theory from the literature
review and how that will sit within the main theoretical aspects of this study’s action research approach.

2.2 Curriculum

2.2.1 Introduction

This section contains a discussion on the influencing factors that impact curricula in Ireland. It also details curriculum changes that have been occurring in recent years. The developments and issues within curriculum development are outlined and possible strategies to improve the relationship between curriculum and teachers’ practice are presented.

Beginning with curriculum, influencing factors included methodology and policy. Methodology encompasses which theory of learning, ontological and epistemological position was enacted in the curriculum. Policy includes political directives from the Department of Education and Skills (DES), curriculum design, use of international best practice and learning approaches. In the Irish education system, individualised learning methods appear in curricula, more so than a coherent theory of learning. Examples of individualized learning methods include inquiry-based learning and problem-based learning (DES, 2016b). An implicit social constructivist methodology exists in government policies and reports. Constructivist themes could be identified when rationales for learning included active methods of learning to construct knowledge (DES, 2016b). Despite constructivist themes emerging in curricula, methods of teaching (e.g. inquiry) were not relating to theories of learning (e.g. social constructivism). This is perhaps due to the implicit, rather than explicit, referencing of a constructivist theory of learning.

In Ireland curriculum developments in recent years were attempting to move away from previous curriculum formats that enabled a traditional style of teaching. However, there appeared to be a disconnect between the ideals of curriculum change and its impact on teachers practice. The intended changes did not seem to take root within the practicality of the classroom (NCCA, 2013). One of the factors that could have influenced this disconnect was the continued
use of once-off professional development workshops. Evidence of this disconnect, between intended curriculum changes and teachers practice, was found in a study conducted in the Netherlands by Kwakman (2003). In her exploratory study about factors that affect teachers’ participation in professional learning, she found that strong influencing factors for teachers were the meaningfulness and relevance of an activity or concept to their professional experiences. The study demonstrated that, from the perspective of the teachers that were surveyed, learning that was connected to the teachers’ daily tasks and activities, was a strong predictor in their active engagement in professional learning (Kwakman, 2003). This finding has an implication for effective professional development in Ireland. It suggests that professional development would benefit from linking to teachers everyday experiences and could then have a more meaningful affect on their practice. This is in contrast to the current model of professional learning, which focuses on once-off workshops which have been acknowledged as having little impact on the promotion of effective learning for teachers (Kwakman, 2003). One interpretation from the study and the issue with once-off professional learning models could be that teachers’ experiences are not being taken into account or developed, therefore meaning for the teachers is missing. Professional learning models need to take a greater account of teachers experiences, by developing towards more collaborative relationships with teachers, rather than the current top-down and dissemination model that currently exists.

Murchan (2018) carried out a case study in Ireland which investigated the changes in assessment in lower secondary school in Ireland and the reactions of the main stakeholders. The educational change culture in Ireland traditionally employs a top-down didactic style, and is accompanied by centralised professional development training, little in-school support and lack of time afforded to the possibility of embedding the change in a genuine manner in the teacher’s practice (Murchan, 2018). Kwakman stated that one of the strongest predictors for teachers engagement in professional learning was learning that was connected to their daily experiences and practice (2003). This disconnect, between theoretical change and the classroom, is also compounded by the lack of a coherent and explicit methodology within the curriculum. A potential issue is that the ideals of curricular change seem to be at odds with the teachers strongly held beliefs and their own methodology of learning. In Ireland, there remains an absence of statement regarding any
methodology within the chemistry curriculum. The absence of a methodology can lead to the absence of a coherent rationale. In figure 2.1, the red arrow between *curriculum and teacher’s practice* is the narrowest, as I felt that the weakest connection lay between those two aspects. This study hopes to provide evidence for strategies that could address this situation.

### 2.2.2 Overview of Irish education system

In Irish schools, the age a student enters the post-primary system is between twelve and thirteen years. In the post-primary system, the junior certificate (now referred to as the junior cycle) begins in first year (12-13yrs) and the summative examinations occur in third year (15-16yrs). In the majority of schools in Ireland there is an optional transition year (TY) and then students enter the senior cycle (upper secondary school). Senior cycle in Ireland encompasses two years, 5th and 6th year and students sit their Leaving Certificate, the final summative exam, typically aged between eighteen and nineteen. Therefore, senior cycle students range in age from 15/16 years up to 18/19 years. After the leaving certificate, students receive a pre-determined amount of points in relation to the grade they achieved in their leaving certificate from the Central Applications Office (CAO). Their accumulated points from their top six subjects (out of seven usually sat) will grant them access, if successful to their chosen college course.

Education in Ireland is currently experiencing a seismic shift in terms of both curriculum and pedagogical changes. Curricular design and implementation is being changed, teachers’ practices are being questioned, and schools are engaged in school-based self-evaluation programmes, as directed by government policy. Every junior certificate subject in Ireland is being revised on a phased basis under the roll-out of the new junior cycle programme (DES, 2015). This has been a lot of change in a relatively short period of time in Irish classrooms. Amidst all this change is the fact that the syllabus for chemistry, at senior cycle, has not been revised since its publication in 1999. Chemistry is not unique with a curriculum dating back to 1999, as many other subjects at senior cycle are awaiting updated curricula. It was mentioned in Irish educational research that post-primary science curricula were obsolete, overcrowded and that they assessed mainly factual knowledge rather than deeper conceptual learning (Murphy, 2015). The same research connected the not-fit-
for-purpose curriculum, along with other school and cultural factors, with student disengagement from science lessons. The traditional approach to teaching was also mentioned and that it was fostered through textbooks and other resources (Murphy, 2015). The current change at junior cycle is trying to address some of those concerns. However, that change has not yet reached senior cycle. In senior cycle the curriculum remains focused on subject content and the continued importance placed on the summative exam. This has generated a teaching for coverage rather than teaching for learning approach in Ireland (Dadds, 2001). The teaching generated from this type of curriculum, over an extended period, has become embedded in the culture of pedagogy in Ireland, and the challenge in changing this must not be underestimated.

An extended investigation into curriculum in Ireland, including development and current changes follows. Identification of factors that could be contributing to the disconnect between curriculum and teachers’ practice is presented, along with possible solutions. Curriculum design and development is important for chemistry as the next major educational change in Ireland is the revision of the senior cycle, and that revision is modelled off the key skills approach enacted through the current junior cycle. Issues raised in this study could aid senior cycle curricular development, which could in turn have a positive impact on the teaching practice of chemistry teachers.

2.2.3 Curriculum development in Ireland

Curricula in Ireland are developed centrally by the National Council for Curriculum and Assessment (NCCA). This is a statutory agency that advises the minister for education and skills on all matters of curriculum at all levels of schooling. The assessment for the developed curricula are produced by the State Examinations Commission (SEC), another statutory agency which is responsible for the running and correcting of the national summative state examinations at mainly secondary level (Murchan, 2018). Both the NCCA and the SEC report to the DES. Curricula are reflective of the values of the society in which they are set, but choices regarding content and learning experiences are required. Those choices are reflective of the values within the culture which in turn are represented through the curriculum ideology (McCormack & Gleeson, 2012). The selection of curriculum that is representative of culture in
any country is intertwined with political interests. This interaction between
curriculum and culture has resulted in tensions between invested parties (DES, 
SEC, NCCA) and, to some extent, contested ownership (McCormack & 
Gleeson, 2012). The curriculum represents, among other things, a political view 
of education. Irish curriculum culture was heavily influenced by a Catholic 
tradition which included a Classical Humanist tradition and an emphasis on 
“transmission of subject knowledge and skills rather than student-centered 
holistic education” (McCormack & Gleeson, 2012, p. 400). This tradition has 
had a lasting imprint on curriculum understanding and decisions. Ireland was 
reluctant to change from the Classical position, as it was an established culture 
within schools (Gleeson, 2010). Critical debate surrounding curriculum 
development was also impeded due to a technical focus on education rather 
than critical questions regarding the broader idea that education could be more 
than schooling (McCormack & Gleeson, 2012). An ideological battle historically 
ocurred during the broader debate on the relationship between education and 
culture. There appeared to be two main sides to the debate, one focused on an 
economic orientation and the other, a socio-educational position (McCormack 
& Gleeson, 2012). The tension between an economic focus and educative focus 
can be seen clearly in curricula in Ireland. In curricula and policies, statements 
of holistic, societal and educative aims were mentioned alongside statements 
expressing the need to develop future graduates for economic purposes (DES, 
2016b; NCCA, 1999). This demonstrates the tension between ideologies and 
the existence of a contested partnership. Due to the “representational 
partnership” model that engaged compromise and consensus, the curriculum 
lacked direction and therefore a positional outlook (McCormack & Gleeson, 
2012, p.401). The curricular compromise on ideology resulted in a lack of clarity. 
This lack of clarity became an issue when new curricula were introduced into 
the educational system. Teachers were told what the change would entail and 
how it was to be initiated, but the why of the change was a mixed message 
between economic and holistic. The educative rationale was being linked to 
learning approaches, rather than an overall understanding of how education 
was viewed in Ireland. A key criterion of success for reform at a local level, 
involves the message of change being clear and accurately communicated to 
those who must implement the reform and that the change was being 
interpreted in the way intended by policymakers (Murchan, 2018). For many 
reasons, an issue of contention in Ireland has been the lack of a clear and 
accurate communication of change.
Curriculum reform in Ireland, as in most countries throughout the world, can be traced to initiatives borrowed from other countries, i.e. “policy borrowing” (Murchan, 2018, p. 100). The policies that were borrowed, were adapted from international best practice, at the time. This international practice included information from international organisations, pan-European programmes like the Bologna Process and international studies such as PISA (Murchan, 2018). The incorporation of a key skills and learning outcomes based curriculum was informed by competencies work by the Organisation for Economic Co-operation and Development (OECD) and the European Commission through the Bologna Process (O’Brien & Brancaleone, 2011; Murchan, 2018). Most recent evidence of this borrowing can be seen in the junior cycle policy, which included borrowed themes like; increased focus on assessment for learning (AfL) (OECD, 2005), reframing of curricula around transferrable skills (Johnston et al, 2015; O’Brien & Brancaleone, 2011), the influence of PISA results and the development of school based assessment (for example: The Scottish Government, 2011). Ambiguity in relation to the stated methodology of curricula could be attributed to the lack of consensus on ideology and the practice of policy borrowing to generate curricula. Granted, the policies were emergent from best practice internationally, at that time. There remained the issue of inserting decontextualised policy, (policy generated within another society, and often at another time), into curriculum which was understood to be a contextualised social process (McCormack & Gleeson, 2012).

The disconnect that exists between curriculum and teachers practice (figure 2.1) can be attributed to ambiguity in relation to methodology. Clear and accurate communication of rationale of change, seemed to be lost in translation between curriculum change and the teachers’ practice. On the one hand was the theoretical curriculum that the policymakers and political interest groups devised and disseminated, and on the other hand was the practically enacted curriculum that occurred in the classrooms of Ireland. Further issues, identified in America, associated with miscommunication between intended curriculum and teachers’ practice included; ambiguity in relation to methodology, overly ambitious instructional concepts, school and teacher capacity for this change, push-back (Coburn, Hill & Spillane, 2016) and teachers’ own beliefs about what was important for the teaching and learning of their students (Datnow & Hubbard, 2016). These issues are likely contributors to the disconnect between curriculum and teachers’ practice.
2.2.4 Enactments of methods in the absence of methodology

The methodology utilised in this study was social constructivism. In an Irish context, learning approaches, with constructivist themes appear in curriculums. However, the terms constructivist and social constructivism are neither stated nor explained. The methods of learning that displayed constructivist themes included; active learning, engagement in discussions, problem-solving and using data to generate new information (conclusions) (NCCA, 2003; DES 2016b). In the new junior cycle framework for science (DES, 2015) and draft senior cycle chemistry syllabus (NCCA, 2011a), a definite learning approach was advocated for; namely, inquiry-based learning. Inquiry learning was promoted as an approach that would encourage students to engage with material and concepts in science (DES, 2016b). Promotion of inquiry was a European directive and was evident in The Rocard Report (Rocard, et. al., 2007). It was with good reason that those reports and policies, on a European-wide level, promoted inquiry-based learning. Within Irish educational research literature on teachers’ practices, it was found that inquiry-based learning facilitated students in developing deeper conceptual understandings of scientific processes (Murphy, Varley & Veale, 2012). The approach also had a positive impact on student attainment, particularly for students with lower levels of self-confidence and from disadvantaged backgrounds (Roccard et. al., 2007). There seemed to be a consensus on the benefits of the adoption of inquiry-based methods. However, the practical employment of more inductive and inquiry orientated approaches to science were not evident in classrooms (Murphy, Varley & Veale, 2012). This finding was evidenced on a large scale in Ireland, when it was acknowledged that the aim of promoting inquiry methods in the revised junior certificate science curriculum (NCCA, 2003), did not manifest in the classroom (Kennedy, 2013). In this case, a disconnect was evident between the intended aims of curriculum and enacted actions of practice.

Shulman (American) (1986) stated that methods or practices were better understood if they were organised in a coherent fashion within a theoretical framework, i.e. a methodology. As an example, he noted that studies about teaching effectiveness that included research-based practices presented in lengthy lists, without the provision of a conceptual framework or rationale were difficult to remember of gain clarity on (Shulman, 1986). The lack of an
overarching rationale or methodology impacted on practitioners’ ability to recall the lists of practices (Shulman, 1986). The lack of a methodology or framework could lead to methods or teaching procedures being carried out without the teacher being able to explain why they are engaged in that action. Methodology provides a framework in which the development of methods is guided by an overall rationale. Methods developed with a rationale could then be implemented with purpose into practice. Methods (e.g. inquiry-based learning) when enacted in the absence of an overarching methodology could appear as separate entities. Those methods could end up being added to teaching practices to break up a normalised routine rather choosing them for a certain pedagogic reason (Loughran, Berry & Mulhall, 2012). The ability to reason pedagogic change from a methodological position could lead to a transformation of teaching practice.

2.2.5 Curriculum change in Ireland

This section details the curricular changes that have occurred and are currently occurring in Ireland. Specifically, the introduction of the revised junior certificate science curriculum (NCCA, 2003) and the development of the junior cycle reform and introduction of a new science specification (DES, 2015). A comparison of the curriculums rationales and initial support structures for teachers are outlined, as well as barriers to implementation. Possible strategies to overcome barriers to curricular change are proposed, with the aim to improve how curriculum developments can impact teachers’ practice.

The promotion and development of Science, Engineering, Technology and Mathematics (STEM) education in Ireland is a key governmental strategic focus since the beginning of the twenty-first century. The Irish government’s formation of the Task Force on the Physical Sciences took place in 2002. This task force was set up in response to a serious decline in the numbers of school and university students selecting to study physical sciences since 1987. The Task Force was assigned the role of tackling the issue of the decline in the sciences and to put in place an action strategy (Kennedy, 2013). One of the main aims, and the reason the Task Force was formed, was to increase the number and quality of future graduates, to attract overseas investment (DES, 2002). The task force hoped to achieve this aim, through increased access to resources, training, implementation of research-based practice into teaching
and learning at all levels of education, and promotion of science through the media (D.E.S., 2002b). Recommended within the Task Force report for education was the increased use of practical, laboratory activity in science for the promotion of engagement in scientific inquiry. It also included the advanced introduction of curriculum changes, with the introduction of the revised syllabus for junior certificate science and the revised physical science syllabus at leaving certificate level, to be ready for implementation in schools for 2003 (D.E.S., 2002). This advanced introduction of curriculum changes occurred, and was introduced into post-primary schools in 2003. However, the implementation of curriculum reform did not seem to take root within classrooms. It was stated by the NCCA, in relation to the revised science syllabus of 2003 that:

*a perceived divergence has emerged between the intended curriculum and the enacted curriculum* (NCCA, 2013, p.1).

This observation from the NCCA correlated with Kennedy’s work (2013). In Kennedy’s (2013) paper, he looked at the response of science teachers in Ireland to the introduction and continued practice of the revised junior certificate science and mandatory practical work. He found, that one of the intended curriculum aims; the promotion of inquiry practices, had not manifested in the classroom (Kennedy, 2013). Teachers experienced difficulties achieving the aims of the intended curriculum.

The revised junior certificate science course consisted of 24 mandatory investigations and the written completion of those investigations was worth 10% of the total marks awarded. The investigations were intended to be open-ended but there was evidence that in practice the students followed text-book instructions (DES, 2016b). The publishing companies of science text-books in Ireland catered for the instruction method by publishing books and experiment books that laid out the investigation in a recipe like format (DES, 2016b). In the absence of other resources, teachers turned to and used the text-books that were produced. Coursework B, an extended investigation, was the second part of the practical assessment worth 25% of the total marks. The method of implementation of Coursework B was of keen interest, as one of the initial aims for the investigative model was for the promotion of an inquiry-based approach to teaching. Kennedy concluded, from the responses to an Irish Science Teachers Association (ISTA) questionnaire on the science course, that there
were considerable issues in trying to implement inquiry-based approaches through the medium of Coursework B. Some of the issues included: lack of resources, insufficient time in labs and lack of inservice training to help teachers implement the theorised approach (Kennedy, 2013). He inferred that the introduction of investigations did not automatically mean that inquiry approaches were adopted or that the interest levels of students for science increased (Kennedy, 2013). Here was evidence of the disconnect between intended curriculum and enacted curriculum. Also, Coursework B was assessed through a written report booklet that was pre-designed with certain headings and restricted writing space. Assessment in this case was narrowed to report writing rather than practical demonstration of inquiry skills, e.g. manipulation of equipment, gathering of data, recording, problem solving and the synthesis of results. 35% of the total marks for this course went to practical work, the first time in the State’s history (Kennedy, 2013). However, no practical work was assessed with everything being written and indirect. It was acknowledged that “activities that are not rewarded by the assessment are unlikely to take place” (DES, 2016b, p. 36). This positioned assessment as a strong influential factor for teachers in their practice, sometimes to the detriment of the intended curricular and pedagogical change.

Another Irish study that surveyed teachers after the implementation of the new junior science syllabus, it was found that an uncommon teaching approach, was to allow students pose their own scientific questions and design an experiment to investigate. The authors of the report found that nearly half of the responding teachers indicated that this practice hardly ever, or never happened in their classrooms (Eivers, Shiel & Cheevers, 2006). Another aspect that could have affected teachers practice during the educational change was the lack of curriculum material or resources that could promote teacher learning. It was observed that in the absence of other sources of material, a teacher relied on a text-book for rationale as well as content (DES, 2016b). Text-books by their nature can over-emphasise factual knowledge and present simplistic models, rather than focus on student understanding in science (DES, 2016b). The revised curriculum of junior certificate science stayed in place in Ireland until the roll-out of the new junior cycle, with the initial implementation of a new science course introduced in September 2016.
2.2.6 Current curriculum change

More recent curriculum change in Ireland included the introduction of a new specification for junior cycle science. This new science course included the explicit addition of *nature of science* in the syllabus and more open investigative approaches to science. There was also the publication of more recent reports into STEM; “STEM education in the Irish school system” (DES, 2016b) and “STEM Education, policy statement 2017-2018” (DES, 2017), with the DES making strides to address issues that occurred, and were occurring, in science education in Ireland, i.e. focus on cognitive aims, narrow assessment methods, no contextual link from a holistic aim to subject outcomes and transmission methods in relaying the target knowledge (DES, 2016b). This redressing of science education included the promotion of active student engagement, creativity and contextual learning within the syllabus, and the statement of those aims within the new rationale for science, which was previously absent. A clear explanation as to *what* was being changed in science education was given, and an improved *why*, i.e. skills other than rote learning are needed for our students to become lifelong learners in a 21st century environment. Despite a continuation of an unstated methodological approach to learning, this newest curriculum reform contained a more coherent rationale and better explanations and information in general. However, an aspect of curriculum change that should not be underestimated is the difficulty associated with changing teachers’ pedagogy on a conceptual level. Teacher’s practice requires more than just information and content to experience practical change.

In “Ireland’s National Strategy 2025” report, it stated that an inquiry-based approach to science would be promoted in the new junior cycle. The report states that this approach provides learning opportunities that would be a balance between subject-specific knowledge and the development of skills (DES, 2016a). Inquiry-based learning emphasises curiosity and observation, which can lead to experimentation and problem-solving. Students would then use critical thinking and reflection to generate meaning from their gathered evidence and link this with the natural world (DES, 2016b). Although these are commendable skills to be able to carry out and achieve, the previous junior certificate science curriculum (NCCA, 2003) was also inquiry-based and advocated for extremely similar aims and skills. However, through a combination of different factors these aims were not evident in the classroom.
Developments for the new junior cycle included the focus for knowledge being of and about science rather than the previous syllabus which was based on knowledge (NCCA, 2013). This shift in focus for knowledge could move teachers away from traditional didactic modes of teaching, towards more open and student-centered opportunities. The explicit addressing of how knowledge is construed in the new junior cycle is an important rationale for the course. Despite the lack of a stated methodology, the curriculum addressed how knowledge was viewed, and this was an advancement from the previous reform attempt. This development could aid pedagogical change, along with the introduction of the nature of science. The complete restructuring of the junior cycle approach and introduction of a completely overhauled science subject was a very positive step for science education in Ireland, but the NCCA acknowledged the challenge, as the curriculum changed from one based on knowledge and content to one in which knowledge of and about science were interlinked. That change in how knowledge is constructed will require a major development in teaching culture in Ireland and that must be supported (NCCA, 2013, p. 19).

Despite these changes at a junior cycle level, the curriculum for senior cycle chemistry has not changed since 1999. Consequently, there is a disparity between the aims of the recent STEM reports and the stated aims of the senior cycle curriculum. However, curriculum changes are occurring at a junior cycle level first. The introduction of the new course in science in 2016 and the key skills associated with that programme, are being developed into a revised senior cycle programme, aligning it more with the aims of the newest reports and junior cycle programme. The recent STEM report also showed that there was a small increase in the number of students taking chemistry at senior cycle level, and it is currently at a 17% uptake rate (increase of 3.6% from 2012 to 2017) (DES, 2017, p. 11). A possible factor for this increase could be the impact of curricular change and the promotion of STEM in Ireland. This development within the sciences is a positive step forward for Ireland and is a move towards a more engaged form of learning and away from traditional structures. However, there are issues with the implementation of any change, as discussed.
2.2.7 Issues associated with curricular change

Absence of methodology

Issues with curricular change that could impact teachers practice include; lack of a rationale due to unstated methodology, inadequate or inefficient professional development, lack of clear and accurate communication, lack of curriculum support resources and Irelands focus on assessment. In maths education reform research in Australia, it was stated that social constructivist perspectives on learning could provide a theoretical rationale for curricular change (Goos, 2004). Debates around the consideration of constructivist perspectives in the classroom could move discussions towards overall aims for the learning process, rather than a technical focus on content. However, educational debates about the overall purpose of education were notably absent in Ireland during the 1990’s, when they were occurring elsewhere (Oldham, 2001). Social constructivist models of learning emphasized the importance of students as active learners, and through social constructivism students were the constructors of understanding through social interactions (Murphy, Varley & Veale, 2012). Encouraging a classroom practice “towards more collaborative and cooperative learning strategies” could encourage students to become more active in their learning of chemistry (Murphy, 2015, p. 148). Philosophical, sociological and psychological perspectives are considered in social constructivism and are placed at the forefront of the theory of teaching and learning. However, a social constructivist methodology was not referred to in the curriculum developments discussed here. No methodology of any philosophical position was discussed.

The curricula, for science specifically, was dominated by the promotion of an inquiry-based approach to learning (DES, 2016b). This is despite inquiry being recognised as a construct of social constructivism (Bachtold, 2013). Inquiry-based learning is a possible method for the promotion of the social construction of knowledge, but it is by no means the only method (Bachtold, 2013). The single focus on an inquiry-based approach to science teaching is potentially worrying, as it could narrow the active construction of knowledge to a single approach. Inquiry-based learning as a wide-ranging approach could undergo simplification into a series of steps to be followed, for the sake of practicality. This issue of narrowing practice to suit the practicality of the
classroom was mentioned in a cross-country meta-analysis study on inquiry-based instruction by Minner, Levy and Century (2010). Issues of the scientific method, which are likely well-ingrained into teachers’ practices, could begin to re-emerge. This demonstrates the issue of an individualised method being developed in curriculum in the absence of a theoretical grounding. A stated methodology could explain why the practice is of value in what it hopes to achieve. Without this the method can become decontextualised.

Evidence of this de-contextualisation was found in a research study in Colombia, which demonstrated that students struggled to connect an inquiry activity to conceptual understanding. If an inquiry activity was, for example, introduced without context, not supported, by either peer or teacher, or not linked specifically to the topic they were doing, students found the sense making of the activity very difficult (Parra, Gutierrez & Aldana, 2015). This could suggest that if the rationale for the teacher was absent, then the students were working without a clear purpose. As stated, inquiry approaches were mentioned in Irish government reports and policies (DES, 2002, DES, 2016 & DES, 2017) as the preferred learning method for the teaching of science. Despite the promotion of an inquiry-orientated approach in Irish and European curricular developments, internationally the research support for inquiry approaches is mixed. Wide variance occurred within research studies that focused on inquiry-based learning, due to the complexity of factors that occur in a classroom. These factors included; culture, background, individual difference, etc. Marshall, Horton and Smart (2009) noted in their inquiry instructional model study, that after decades of research endorsing inquiry-based learning, at best there was only moderate success of systemic implementation seen in American classrooms. The literature surrounding inquiry practices is fraught with uncertainty, and large scale quantitative studies had shown large variance in their results, and attributed this to individual student differences (Areepattamannil, 2012). Areepattamannil’s study, in Qatar, provided evidence of the complexity that can exist within teaching and that flexibility and the context of the situation and person needed to be taken into consideration during teaching (Areepattamannil, 2012). Those results could be indicative of a weakness in the process of inquiry science, and that a link was missing between the inquiry investigations and the scientific target knowledge that was supposed to be promoted through the investigation. Those studies suggested a deviance from the intended theoretical underpinnings of an inquiry practice and the enactment of inquiry in classrooms. The method was de-contextualised from its
original theoretical intentions when enacted in the social and practical setting of the classroom.

**Continuous Professional Development (CPD)**

To accommodate the development of the new junior cycle curriculum, a “comprehensive programme of continuing professional development” was delivered to teachers and principals (DES, 2016a, p. 51). The continuing professional development (CPD) consisted of whole-school CPD, subject-specific seminars, teacher-led CPD and school visits. As a teacher who, at the time of writing was engaged in the educative change, neither teacher-led CPD nor school visits had happened in my school at the time of writing. However, teacher-led CPD had potential to support change, if the teachers involved were adequately supported. The European Commission report “Supporting teacher competence development – for better learning outcomes” (2013) mentioned that “one-shot” or once-off professional development approaches have had a weak impact on the development of teacher competence (European Commission, 2013). The report recognised the teacher as a “reflective practitioner” who took responsibility for the improvement of their own professional practice and their learning. With that understanding of a teacher, the report discussed a move away from technical focused and top-down approaches towards more collaborative and cultural-individual interactive approaches (European Commission, 2013). Formal CPD in Ireland focused on specific pedagogical content knowledge (PCK), for example inquiry-based science learning or assessment for learning. Professional learning in Ireland took a top-down approach and was usually a once-off event. Improvements in professional learning for teachers, as advocated by the recent STEM report, included; CPD activities that modelled exemplar inquiry-based science methods and teaching and were workable, contextual and involved teacher participation and reflection (DES, 2016b). According to the report, these strategies had a higher chance of translating into good classroom practice. This approach could support teachers in the use of new and innovative pedagogies (DES, 2016b). However, modelling a once-off inquiry orientated lesson was unlikely to achieve the high aspirations that the STEM report laid out. Collaborative, interactive, contextual and continued support was needed to generate a change in practice.
This change could be further supported by the teachers engaging in local communities of practice to support and develop a change in pedagogy.

**Assessment**

Policymakers of curriculum in Ireland used assessment as a lever to reform teaching and learning, as they felt change would not be implemented without it (Murchan, 2018). Conclusions drawn from national reports and commissioned research during the period 1992 to 2011 in relation to junior cycle education found that there was a significant negative consequence of the examination system on teachers' practice, which undermined the intended aims of the curriculum and diluted the students experience of the junior certificate (Murchan, 2018). The nature of assessment in Ireland had led to an over-emphasis on cognitive aspects of the curriculum. Assessment was evidenced to be an influential factor in teachers’ practice (DES, 2016b). Due to the nature of the exam (written), rote-memorisation and recall were deemed important skills to develop, to complete the exam. The high-stakes nature of the exam also added pressure to the idea of performance. In the new junior cycle, school based assessments were included, which were to be graded by the teacher for the first time in Ireland. This was an attempt to move teachers’ practice further away from a traditional teaching style, by incorporating formal formative assessments.

The culture of education in Ireland is assessment focused. Concerns were expressed specifically about school based assessments during the National Education Convention (1994). The issues that arose at that time included; decreasing the credibility of the external certificate, negative impact of relations between students and teachers, concern that teachers might be open to charges of bias and pressure from parents (Murchan, 2018). These arguments were also the foundation of resistance to school based assessments in 2012, and in 2015 resulted in a compromise between teachers’ unions and the DES, where school based assessments will not be assessed by the teachers formally, but will remain in practice.

Different perspectives existed between policymakers and teachers regarding the importance attached to assessment and certification at junior cycle in secondary (Murchan, 2018). Policymakers had questioned the
continuing need for certification at the lower level in secondary school, and classed an exam at the lower level as “low stakes” (NCCA, 2004, p.7). However, teachers do not view the exam as low stakes and more than mere communication would be needed to change their mind-set (Murchan, 2018). That is a factor that policymakers might have overlooked in their development of school based assessments. If more communication with teachers, students and parents was engaged with around the function of assessment and rationale of certification at junior cycle, then those stakeholders might, at least, understand the principles of school based assessment and how it could be envisioned in education at junior cycle (Murchan, 2018).

2.2.8 Curriculum Summary

Issues in relation to curriculum and the disconnect that exists between teachers’ practice and curriculum have been discussed and analysed here. Ambiguity in policy was a contributing factor to difficulty in the implementation of curricular change. Ambiguity included an unacknowledged and unstated methodology compounded by the practice of policy borrowing; the use of decontextualised practices from other social contexts. The rationale for curriculum reform was not communicated clearly to teachers and this led to an ineffective embedding of curriculum into practice. The lack of a clear rationale would also have a weak impact on teachers’ current beliefs about education and learning, and would not have the capacity to get the teacher to engage in reflective questioning about their practice. Therefore, there was no perceivable level of change in practice for many teachers. Assessment was found to be a driving factor for implementation of curriculum, but the culture of assessment proved extremely difficult to change. CPD was another area where action was not impacting practice. CPD was mainly centralized and transmissive, and was not an effective method of supporting teacher development, as the teacher and their experiences was often overlooked. Other factors that impacted curriculum change included; lack of clear communication between policymakers and teachers, lack of relevant curriculum resources and the difficulty associated with changing teachers’ belief system.
2.3 Teachers’ Practice

It is widely acknowledged in education research, throughout America, England and Australia, that the quality of learning experiences provided by teachers impacts on the engagement of students in subjects (Osborne, Simon & Tytler, 2009; Bolyard & Moyer-Packenham, 2008). These research findings point to the importance of teachers’ practice on student engagement. The influence of teachers’ practice on students’ attitudes to science was referenced by Osborne, Simon and Collins (2003). In the authors’ review of students’ attitudes towards science they found that, despite the complexity of the issue and the recognition that many factors impact attitudes, the literature pointed to the crucial importance of the quality of teaching on the attitudes of students to science. In fact, variables relating to the teacher and teaching had the most significant impact on student engagement, not curriculum variables (Osborne, Simon & Collins, 2003). It must also be acknowledged that the impact of practice on engagement could be either positive or negative, depending on the practice the teacher enacted and what the teachers, and students, considered as the aim for education. A teachers’ practice is complex and is influenced by many outside factors. Some of those factors could include; the culture of the school, cultural background of the teacher, overall culture of education in the country and the impact of assessment and interplay with curriculum. These factors are not exhaustive, but can all impact on how a teacher enacts their practice. In this section of the chapter, the current chemistry syllabus will be examined as a general representation of senior educational culture in Ireland. This is due to fact that curricula are socially developed within the culture, at the time. Another factor that exerts a strong influence over teachers’ practice is summative assessment and the societal weight associated with these exams at a senior level in Ireland. This examination provides a lens for which to examine current teachers’ practice in Ireland.

2.3.1 Irish chemistry curriculum

In the national syllabus for chemistry in Ireland, the overall aims included the holistic nature of the curriculum and aims for the learners, which included; a foundational course for further study, appreciation of social, economic, environmental and technological elements of chemistry, how humanity has
benefited from chemistry, appreciation of the scientific method and the development of laboratory skills (NCCA, 1999). However, a statement on the cultural or context specific understanding of chemistry itself was absent. Strong themes that were found within the national curriculum were themes of a holistic and societal nature. The holistic theme promoted the overall development of the student, including confidence, interest in the subject, communication and teamwork skills, cultural, historical and moral aspects of the person, and an interest in their own self-development. Societal themes dealt with areas such as; chemistry’s contribution to society and individual’s own lives, becoming responsible global citizens, and sustainability and environmental needs (NCCA, 1999). The societal theme was an effort by the national syllabi to link the students’ social context to their learning, and was reflective of the science, technology and society (STS) developmental approach to the syllabus (Eivers & Kennedy, 2006). The themes were admirable, but contextual links about how they were going to be achieved through chemistry were absent from the syllabus.

2.3.2 Cultural impact on teaching practice

Along with curriculum issues, the culture surrounding education in Ireland was another area that could impact teachers’ practice. The historical impact of culture also had a strong influence on teaching style. Evidence demonstrated that the traditional style of teaching science in Ireland was largely didactic in nature, with the teacher and student in clearly defined roles, and experiments completed using a cook book method (DES, 2002). The OECD Teaching and Learning International Survey (TALIS) lent further support to evidence found by the Task Force, as Ireland was found to have a stronger relative preference for structured teaching practices then other comparison countries (Shiel, Perkins & Gilleece, 2009). Teachers in Ireland were also found to be somewhat less supportive of social constructivist ideas and more supportive of direct transmission beliefs, favouring structuring practices such as; stating learning goals, homework review, checking understanding, and less supportive of student orientated practices such as; co-determination of lesson content, assigning projects, or asking students to create products (Shiel, Perkins & Gilleece, 2009). A typical Irish class could consist of whole-class explanatory teaching with students completing their work individually at their seat. It was
found that teachers’ engagement with group-work and whole-class discussions happened very occasionally (Oldham, 2001). In the same research, there was a disproportionate amount of lower-order skills evidenced in Irish schools, with procedural methods favoured ahead of conceptual and decontextualised knowledge ahead of the application of concepts. The culture that cultivated the use of a more traditional style of teaching proved efficient at superficially covering vast amounts of material (Oldham, 2001). Due to cultural and historical issues ingrained in Irish classroom settings, previous attempts at developing scientific engagement have been hampered (DES, 2016b; Johnston et al, 2015).

The pervading educational culture has had a significant impact on how teachers conceptualise education. An issue that teachers raised, in my school, in relation to their students, was that the students were passive in their learning, and not willing to take responsibility or engage when the opportunity was provided. However, Australian research relating to teaching methodologies stated that passive student learning was partly an outcome of a traditional style of teaching (Loughran, Berry & Mulhall, 2012). A discord therefore existed, as teachers identified an issue with the students, but the questioning of their own practices rarely occurred. Classroom practices could become accepted as normalized behaviour by both the teacher and the students. If the teacher accepted a traditional style of teaching, consciously or unconsciously, then the actions undertaken in that classroom would be directed towards transmission techniques; prominent use of a textbook, students listening to the teachers’ explanations or demonstrations and then practicing what was demonstrated (Goos, 2004). This example highlights that a teachers’ actions can reveal a belief system, even if that belief system has not been formally acknowledged by the teacher themselves.

An American based case study that looked at the professional development of teachers found that the belief and value system of a teacher impacted strongly on the teaching practices that were enacted (Lotter, Harwood & Bonner, 2007). This belief system could be an indicator of the influence that culture has on education within a system and that the teacher was influenced by the culture surrounding them and their own cultural context. The following studies were examples of how a teacher’s practice and beliefs, could be impacted by educational reform. In a Canadian study carried out with pre-
service teachers, their pre-conception to inquiry was analysed, i.e. how open or not they were to the process of inquiry (Rees, Pardo & Parker, 2013). During the study the pre-service teachers engaged in inquiry method courses in their third-level institution, and enacted their developing inquiry practice in their teaching context. During and at the end of the course, the pre-service teachers’ conceptions to inquiry were monitored. An interesting case was a pre-service teacher who, from the initial analysis of perceptions, was negatively predisposed to inquiry, and who’s implicit system and beliefs did not change during the practice. When asked if they would continue with inquiry practices with other classes into the future, they said they would (Rees, Pardo & Parker, 2013). This was an interesting case, as it demonstrated that the teacher was not yet aware of the misalignment between their own beliefs and the rationale of an educational method. This could show that the teacher possessed a limited view of inquiry, but also that there was an inherent misalignment between the teachers implicit set of beliefs and the theoretical understanding behind inquiry.

Capps and Crawford (2013a) showed that limited views on inquiry, from a philosophical and theoretical position led to limited practices of inquiry. Teachers in the American study were focused on basic abilities and skills of inquiry, rather than developing the important understandings surrounding inquiry. It was evidenced that when inquiry practices were present, they were mostly teacher initiated (Capps & Crawford, 2013a). This could be due to the cultural background of the teacher and the educational context they themselves experienced. Those studies highlighted the difficulty of implementing educational change without outlining the rationale and philosophy of the change (Capps & Crawford, 2013a). The teacher, in the previous case, had difficulty in aligning their implicit belief system, with the rationale, value and belief system of the educational change in question. If they were not predisposed (i.e. their philosophical understanding was different to the implemented or mandated change) to this change, without questioning that fact, how would the teacher see that there was a difference in inherent understanding. If there was no acknowledgment of a difference, between the teachers’ beliefs and the rationale for change, this could then lead to narrowed and reduced practices of the intended educational change. Anderson (2002), from an American context, commented that teachers’ focus was on the practicality of the classroom, tasks and activities, rather than the blending of theory and practice and the understanding of conceptual structures within a theory. This practicality focus,
structured tasks for example, was also evidenced in Ireland (Shiel, Perkins & Gilleece, 2009). A point that was frequently mentioned in the anticipation of helping the issue of theory and practice, both in America and Ireland, was the fact that teachers needed support when implementing change (Ratcliffe & Millar, 2009; Erduran & Dagher, 2014), and that the implementation of change would not be easy and would take time. Teachers needed to be supported in the acquisition of new knowledge and beliefs, and specific support needed to be given when changing existing and deeply ingrained beliefs (Kwakman, 2003). Time is a very important, and sometimes overlooked, element of change. In a study by Ratcliffe and Millar (2009) even when appropriate support was provided for the teacher, it was still found that an entire teaching cycle took place before operational changes could be made.

Along with support and time, another important aspect to help the implementation of change, is the active reflection of teachers own practices and beliefs, in relation to the new knowledge and theory being developed (Capps & Crawford, 2013b). A teachers’ professional practice is not only knowledge about how to perform or enact teaching competencies, but also knowledge of what they are enacting and why they are enacting certain procedures. Professional teachers should be able to explain why something was done and communicate the reason for professional decisions taken (Shulman, 1986). However, if rationales are absent from curricula this presents difficulties for teachers when they attempt to communicate their reasoning for professional decisions taken in practice. If there was no rationale interacting between decision taken and knowledge, the teacher could become a technician of the curriculum, carrying out practices but providing no rationale. Pedagogy includes understanding the relationship between teaching and learning which can promote both student engagement and their conceptual development (Loughran, Berry & Mulhall, 2012). A teacher must have awareness of various teaching procedures. Importantly, the mere use of those procedures should not entail an end goal of pedagogy (Loughran, Berry & Mulhall, 2012). Professional learning for teachers encompasses learning and reflecting from experiences and building on those, with the development of students always to the forefront of decisions on practice. In the enactment of professional learning, teachers need to be involved in continuous reflective practice, with the aim to understand and develop new experiences for their students that promote their engagement. Reflection
experiences in the classroom need to be looked at with new and different perspectives (Loughran, Berry & Mulhall, 2012).

2.3.3 Assessments impact on teaching culture

In Ireland, during any educational reform, the most stable aspect to the reform was assessment (Murchan, 2018). The lack of change in assessment in Ireland has ensured that it has become deeply embedded in educational culture and teachers’ psyche. There was acknowledgement of the fact that if the assessment format did not change, teachers’ practice would not change either (Hammond, 2011). Assessment and the culture of education that developed from it, were clear influencing factors on teachers’ practice. Curriculum also had its part to play, as teachers viewed curriculum as a guideline for assessment. Assessment at both junior and senior secondary level in Ireland has impacted teachers’ practice. At the senior level in Irish schools, there is a premium placed on examination performance as the competition for places at third-level is dependent on exam performance. This elevates the Leaving Certificate to a high-stakes exam. Considering the perceived importance placed on the summative exam at senior level and couple that with an over-crowded curriculum, teachers have felt that their only option was to employ a traditional style of teaching (Oldham, 2001). They felt that it was the only possible way to answer the pressure of the high-stake exam and provide success for students (Oldham, 2001). It was evidenced in Irish scientific educational research on learning in schools, that assessment led instruction. This restricted the examination of scientific concepts to the recall of definitions, rather than the ability of students to demonstrate their understanding, by their use of scientific concepts in different applications (Murphy, 2015).

Osborne and Dillon (2008), from an European context, stated that the assessment system had a pivotal role to play in the implementation of pedagogy which enacted curriculum. This was reflected in Ireland with the NCCA acknowledging that changes in curriculum needed to be aligned closely with the assessment (NCCA, 2013). The new junior cycle science specification was hoping to embed inquiry and scientific process further within science education in Ireland. However, the inclusion of the nature of science for the first time would require a major development in teaching culture and the style of the assessment system.
used (NCCA, 2013). The NCCA acknowledged that it would take time to achieve the shift in teaching culture, and expressed that a shared understanding by all partners of the purposes of science was needed, coupled with professional development and peer support within the teaching profession (NCCA, 2013). In the National Strategy report it was stated that assessment should support learning and provide evidence of learning for both skills and knowledge (DES, 2016a). The nature of assessment within the new junior cycle could have a strong influence on the successful implementation of inquiry-based learning and problem-based learning in schools. The assessment’s intended design was to measure a student’s ability to collaborate, design investigations, critique problems and debate and communicate with peers (DES, 2016b). However, assessment for the new junior cycle, as originally conceived, no longer exists. Due to disputes between the countries teachers’ unions and the Department of Education and Skills, the assessment as originally envisioned has changed. Assessment of science for the new junior cycle now consists of a summative exam that is worth 90% of the total marks. A written reflective task on one of the classroom based assessments that will be carried out in third year is worth 10% of the overall grade. Both of those methods of assessment will be marked by the SEC and are external to the school and teacher (Murchan, 2018). This contrasted with the initial aim of assessment in the new junior cycle, which was looking to include continuous assessment through teacher assessment of the two classroom based assignments (CBAs). The CBA’s are still within the structure of the junior cycle but they will not account for any percentage of the students’ overall grade in science. However, they will be included in the students’ profile of achievement. The development of the skills which is being promoted through this educational change is still indirect. This will have implications on practice, as assessment is a driving force for many teachers’ practice. Assessment will remain a major focus on teachers’ practice, as within the Department of Education and Skills there is a “strong emphasis on improving accountability and the use of evaluation to measure outcomes” (DES, 2016a, p.89). For a teacher, measurable outcomes are often-times associated with grades.

The culture of assessment has created a narrowed view on education. In an American study that synthesised research findings on the impact of inquiry science instruction on the effect of student outcomes in science (1984 - 2002), they found that passive methods of teaching, necessitated by an assessment-
focused education culture, did not increase students conceptual understanding (Minner, Levy & Century, 2010). They stated that active teaching strategies that engaged students in the learning process were more likely to develop conceptual understanding (Minner, Levy & Century, 2010). In the light of educational aims to develop lifelong learners and students' ability to apply their knowledge (DES, 2016b), it is apparent, in America, Europe and Australia, that traditional models of teaching do not meet that aim. Teachers need to address their practice, so that students can become actively engaged in the learning process, and in turn their own learning. However, despite the recurrent message of the importance of teachers’ practice on student engagement and attitude, there was little research undertaken to understand what made teaching effective for the student (Osborne, Simon & Collins, 2003). This would require research on a teachers’ practice, and feedback from students as to what helped them to engage with the subject.

2.4 Student engagement

2.4.1 Introduction

Student engagement is an often cited ideal of educational programmes, curricula and policy. However, engagement is a broad term and its understanding can differ from one study to another. In this research study, a number of literature sources are used to help clarify this study’s understanding of student engagement. Factors that can impact student engagement are then discussed and analysed. This analysis helps to build the theoretical framework of this study in relation to student engagement.

Osborne, Simon and Collins (2003) noted in their review of literature relating to attitudes towards science, that educational research must put an emphasis on identifying aspects of science pedagogy that make school science engaging for pupils. They also commented that there is very little research into what makes science teaching effective from the viewpoint of the pupil (Osborne, Simon & Collins, 2003). A vital component of this study is the development of practices that engage students, as stated by the students themselves. Wallace (1996) (as cited in Osborne, Simon & Collins, 2003) concluded, from her
research on students views on learning, that student engagement was enhanced through opportunities for students to take control of their learning, become active participants and develop autonomy in their learning. Minner, Levy and Century’s (2010) meta-analysis of inquiry-based science research lent further evidence to the benefits of engaged students. It stated that when a student engaged in learning there was a greater opportunity for them to develop their conceptual understanding (Minner, Levy & Century, 2010). Student engagement in this study was understood as a student’s active and positive involvement in activities and development of their own learning during the chemistry class. During this study, student actions that were described as ‘engaged’ involved the student becoming autonomous in their learning. This included; the student taking part in learning and activities for their own learning, (demonstrating an intrinsic rather than extrinsic motivation to learn) rather than for the sole purpose of complying with the teacher’s instruction. This manifested through the student engaging with initial instruction and then completing the activity without additional task orientated instructions and corrections to remain on task. Staying ‘on task’ in an activity included actions such as; not getting distracted, talking about the topic or activity at hand and completing the task within time and contemplating questions beyond those given on the topic. This is not an exhaustive list of actions, as the overall understanding of a student being ‘on task’ in this study included whatever might be necessary for them to actively and positively participate in whatever activity might be occurring in the class. An important note in this study was that engagement was not based on a solely cognitive success criteria. A student could positively engage, but could still struggle with a summative assessment on the topic. Their positive active engagement was not tempered by a sole focus on summative assessment goals. In a social constructivist framework, engagement involved the co-construction of knowledge through social interactions and/or mediating tools, which in turn had the capacity to develop the student’s learning. The following section details theoretical themes, from educational literature, which can impact student engagement levels. These themes include interest and relevance for the student in the subject, social opportunities and developing an emotional connection with their learning.
2.4.2 Interest

Student engagement in chemistry is influenced by their own internal motivation and the curriculum as enacted through a teachers’ practice. Presently, the curriculum is outdated, narrowed, contains a cognitive focus, and a culture of traditional and transmissive teaching. These conditions have the capacity to impact negatively on students’ engagement and therefore their conceptual understanding in chemistry. From personal experience, chemistry is an extremely interesting and intriguing subject both in terms of the act of teaching the subject and learning for the students. However, the subject also possesses challenges. No matter how interesting the subject, students have a perception that it is a difficult subject. In 2002, the Task Force on Physical Sciences carried out surveys with students and found that many Irish students did not pick chemistry due to this perceived difficulty (DES, 2002). Interestingly, this report also highlighted the oppressive effect the Leaving Certificate could have on students’ choice. Students in the report stated that they would be more likely to choose chemistry (and physics) if it was easier to get a good Leaving Certificate grade in it, and if there was less mathematics (DES, 2002). The difficulty of the subject could also be seen in other educational contexts. A study by Barthlow and Watson (2014) revealed in an American context, that chemistry classes were among the “most challenging” courses that students would take, placing a high demand on the cognitive requirements of the students (p. 246). The high demand included; the ability to work with abstract concepts, demonstration of highly developed reasoning skills, a well-rounded scientific knowledge base and possessing excellent problem-solving skills (Barthlow and Watson, 2014). The previous requirements could have contributed to the ongoing perception that chemistry was a difficult subject. However, if those skills and processes mentioned were not being enacted in the class, due to time constraints and transmission of content, the subject could further increase in difficulty for the student. The high demand associated with learning in chemistry was also evidenced in an English context. Taber (2010) stated that many students struggled to develop conceptual understanding and could withdraw from learning within the classroom, or finalise their studies without the correct understandings but the attainment of pseudoconcepts. This difficulty with conceptual understanding was also supported in Ireland by the chemistry chief examiner’s reports. The chief examiner noted difficulties with students progression of conceptual understanding. She stated within her report that a
question requiring critical analysis of an unfamiliar context was “a challenging skill and many answers were unsatisfactory” (SEC (State Exams Commission), 2013, p. 15). She went further to state that those questions were discriminator questions to show achievement of higher cognitive skills in some students (SEC, 2013). Students were having difficulty with what were deemed higher order skills, such as evaluation of unknown data, drawing conclusions and critical analysis, and this could be attributed to incomplete conceptual understanding (SEC, 2013). This difficulty with the development of chemical concepts was well recognised in chemical education research literature, and has led to a very active research area; tracing the generation of alternative conceptions in students. Many theorists attributed the difficulty of chemistry to its high learning demand and, at times, abstract nature (Kapici & Akcay, 2016; Taber & Bricheno, 2009). Researchers aimed to further inform the pedagogical practice of the teacher by providing examples of specific concept issues, and how to promote the students thinking along more developmentally appropriate paths (Taber, 2008). However, despite more informed and accurate subject pedagogic content, the transfer of information from the teacher to the student (Shulman, 1986), in a coherent and engaging manner could further address some of the difficulties associated with chemistry. The mediation of content from teacher to student and how that mediated information impacted the student was a vital part of the development of the pedagogy of chemistry in this study and could also develop strategies to alleviate the difficult notion of the subject. It was evidenced that if students struggled to develop conceptual understanding, they could become frustrated and withdraw from learning in chemistry (Taber, 2010). There are many factors that can contribute to the lack of interest in chemistry, and the perceived difficulty of the subject is just one.

The culture of STEM promotion in Ireland, brought the sciences to the forefront of the Irish publics’ consciousness, which was a positive move for science development in Ireland. However, the manifestation of this in schools was that the senior sciences were being seen as a necessity for job opportunities, rather than an interesting and engaging subject. The summative examination’s influence also had a role in this perception. The student view on the senior sciences was evidenced in a recent OECD report that stated; Irish students had a higher than OECD average in their instrumental motivation for science learning. Instrumental motivation was how useful students perceived science to be for their future career or further study (Shiel, Kelleher, McKeown
& Denner, 2016). This could have reflected the prominence of STEM subjects in media and in education. As stated this was a positive step for the promotion of science, but an interesting, and slightly counterintuitive result from the report, was that fewer than one-third of students saw themselves in a science related career in the future (Shiel, Kelleher, McKeown & Denner, 2016). This indicated that the uptake of senior sciences, i.e. chemistry, physics and biology, could be affected in the future, as despite the increase in enjoyment and literacy for science, the demand for a science career is not high. This demonstrated that in recent years in Ireland, the nature of science and interest levels in science have taken bigger strides in development, but this was then contrasted with the uptake and development of chemistry, or any of the senior sciences. This economic focus may be off-putting for students who are uncertain of their employment choices and this uncertainty could impede them from engaging in a creative, imaginative and interesting subject. Also, the chemistry curriculum has not changed in Ireland since 1999, and despite a draft syllabus going to consultation in 2013, the much-needed change has yet to occur. Factors that affected the new syllabus’ introduction included the inclusion at junior certificate level of a completely restructured junior cycle, with the decision to implement change at this level before senior level, and the trailing of the laboratory practical for the senior cycle sciences only taking place in the academic year 2017-2018. In the enactment of the older curriculum, traditional styles of teaching were still evident. The age of the curriculum in chemistry and the volume of topics impacted on student engagement and interest. World topics and issues facing students presently, are not included in the current curriculum and could contribute to the students perception of a curriculum that lacks relevance for them. This decreases the opportunity for real-world topics and challenges, which could impact on student interest in the subject. The curriculum also experiences over-crowding and time for extended work into an area that a student might find genuinely interesting might not happen due to curriculum constraints.

2.4.3 Social

A social constructivist position on learning for science education has implications for that learning. Knowledge is understood to be socially co-constructed from a social constructivist position. Therefore, adopting this
position, scientific concepts do not appear from direct observation of the natural world. Scientific concepts, through a social constructivist lens, could be envisioned as dynamic, fluid, context dependent and “usable tools” that were constructed through the passing of time and helped to explain the environment around us (Murphy, 2015, p. 127). Driver, Asoko, Leach, Mortimer and Scott (1994) suggested that scientific knowledge was symbolic in nature and socially developed. They stated that the concepts within science were;

*not the phenomena of nature but constructs that are advanced by the scientific community to interpret nature* (p. 5).

The phenomena of nature are the objective reality, but scientific constructs are socially developed. The development of those scientific constructs did not emerge easily from simple observation of phenomena, they were developed through social negotiations, debates, interpretations and with great intellectual effort, and imposed on phenomena, in the attempt to explain them (Driver, et. al., 1994). Lave (Lave, 1992, as cited in Packer & Goicoechea, 2000) commented that when learning was viewed as a socially situated activity, it took a social ontological position. This position saw the person as an active being engaged in activity in the context of the world. This involved participation in communities of practice and through this activity was the development of identity in the world, which led to personal and social changes which could equate to ontological change. Educational literature has mentioned that an ontological position was missing in educational discussions, and that the perspective considered in those discussions was mainly in relation to epistemological positions and cognitive growth, without mention of the person or identity (Packer & Goicoechea, 2000). This was an issue I noticed in the review of literature; cognitive development took centre stage in science education research studies, most of the time over the person, their identity and their affective development. If social constructivism took a purely cognitive epistemological position, it could fail to grasp “*the affective, relational, and cultural dimensions of activity*” (Packer & Goicoechea, 2000, p. 235).

An issue that occurred in education curriculum research, was the juxtaposition of the nature of chemistry with the perspective and experience of chemistry that the student might hold. The viewpoint that chemical concepts were socially negotiated and debated, and could be subject to change, can severely jar with a younger students’ perspective of chemistry. The students’
A viewpoint was influenced by their cultural and historical experiences and background, and their everyday experiences with the phenomena around them. Scientific thinking was strange, or as Wolpert (Wolpert, 1992, as cited in Jenkins, 2007) said “unnatural” and is an unconventional way of thinking (p. 276). Science has the perspective of a body of knowledge and facts that need to be learnt, in the attempt to gain an understanding of the subject. Student perspective of the nature of science could be very different to the embodiment of the nature of science as seen by a social constructivist teacher. This clash of ideals produced implications for science teachers, as to introduce scientific concepts, was often to challenge and in some cases, threaten a student’s everyday way of experiencing the world around them; e.g. heavier objects seem to fall faster than lighter objects and based on daily observation, the sun seems to go around the earth, not the other way around (Jenkins, 2007). Methods were sought to help bridge the gap between the students everyday understanding of certain concepts and their scientific understanding of concepts. A method within social constructivism that has the potential to bridge this gap is the enculturation of students to the nature of chemistry. Enculturation, according to Driver, et. al. (1994) involved learners who became “encultured” into scientific practices and theories that occurred within the scientific community, and this enculturation made the scientific practices meaningful on an individual learner level (p.5).

As discussed in science education literature, a key social constructivist role for the chemistry teacher was the mediation of scientific knowledge for learners. Driver, et. al.’s (1994) theoretical paper on the construction of scientific knowledge in the classroom stated that while there were no simple rules for social constructivism, there existed important features that supported learning. They recognised the importance of communication and the mediation of knowledge between the teacher and the student, to support the students’ developing scientific understanding (Driver, et., al., 1994). This entailed the teacher helping the students to make sense of the ways in which scientific knowledge was generated and validated, with the teachers providing different perspectives which could be drawn upon, to help the development of a students’ conceptual chemical understanding (Driver, et. al., 1994). The teachers’ involvement in enculturation was very important and provided appropriate experiential evidence and made cultural tools of the scientific community available to the students (Driver, et. al., 1994). An often-cited method that was used to develop, what were called, students’ misconceptions, was cognitive
conflict (Adey & Shayer, 1993). However, instead of cognitive conflict, which sought to rather aggressively make students confront the limitations of their common-sense thinking, as if it was somehow wrong, a more suitable method was the acknowledgement that different ways of understanding and thinking existed. This led to the idea that different kinds of conceptual models existed in different circumstances (Driver, et. al., 1994). This development of conceptual models was furthered through dialectic communication between the teacher and the students. This involved a dialectic process of communication between the teacher and the student, where information and both points of view were discussed, developed, interpreted and reasoned. However, this dialectic process in practice is not a simple case of teacher and students talking to each other. A concerted effort from the teacher is needed, in order for collaborative and effective dialectic communication to take place. Difficulties arise due to cultural and contextual differences between teachers and students, and if unacknowledged can lead to the misinterpretation of information. Differences in educational contexts between teachers and students was identified in a very interesting study by Schultze and Nilsson (2018), in Finland. They noticed these differences and raised the question as to what method could be used to “bridge the gap between what the teacher communicates and what the students perceive” (Schultze & Nilsson, 2018, p. 2). The study used social approaches such as co-teaching and co-gens, where the teacher in the study co-taught a junior science class with two senior chemistry students. The findings noted that the student co-teachers mediated understanding between the teacher and the junior science students, and that the students had a powerful impact on the pedagogical knowledge of the chemistry teacher (Schultze & Nilsson, 2018). The teacher gained a greater understanding of the difficulties the students faced as described by the students. They also suggested ideas to the teacher in how to approach certain topics (Schultze & Nilsson, 2018). Another study highlighting the social differences between students and teachers was Emdin’s 2007 study based in a New York chemistry classroom. Emdin’s (2007) study explored how cultural rituals influenced urban science classrooms and acknowledged the impact of culture on students learning. Cultural misalignments were identified between the students and the teachers in the school, and Emdin employed co-generative dialogue (co-gens) as a method to develop understanding between the different cultural contexts of the teacher and the students. It was also aimed to develop an understanding into each other’s ideas of success within the classroom. In this study, the students and
the teachers co-constructed new ways of interacting within the classroom, new approaches to teaching and learning and in turn student engagement in chemistry increased (Emdin, 2007). These studies provide evidence that the social inclusion of the student in the classroom and in their learning has the capacity to improve, not only student engagement but also the teacher’s practice.

Some of the issues that have occurred within chemistry teaching in Ireland, were outlined earlier; the perception by students that chemistry was a difficult subject, the cognitive focus of the syllabus, leading to a high learning demand, bypassing the nature of chemistry, and a traditional didactic culture of teaching in Ireland. It was acknowledged that the development of scientific concepts by students could be determined by a traditional approach to teaching which could be further compounded by factual and recipe-like textbooks (Murphy, 2015). Those aspects of education that students face are barriers to their engagement and conceptual development. The adoption of a social constructivist position was attempted with the aim to develop the representation of the nature of chemistry, by the introduction of concepts through their contextual underpinnings, and the enculturation of students into the process of thinking and debates using scientific information and concepts. The social constructivist position also envisaged a more open, social and democratic teaching environment, in which the teacher and students could work together in the construction of both, chemical knowledge and pedagogical practice.

2.4.4 Emotion

In the development of chemistry concepts in the classroom, research acknowledges (e.g. Adbo & Taber, 2014), that students rely on their everyday understandings of the world as reference points when new ideas are introduced. However, the students’ referral to their everyday experiences could develop alternative ideas. It is therefore important for teachers to facilitate engagement (students’ active and positive participation in their own learning) and emotional connection with a topic in the class, as this can help the student to develop their conceptual understanding. In a case study on a 16-year-old Swedish upper secondary student, it was found that the student’s initial ideas offered potential for the development of understanding (Adbo & Taber, 2014). However, if
pedagogy did not incorporate or acknowledge the student’s initial thought processes, there was an opportunity for the student’s understanding to develop down alternative paths to what was initially intended (Adbo & Taber, 2014). Adbo and Taber’s (2014) findings support the concept of identifying students thinking and checking in with its progression in different instructional contexts to better support the development of more effective science pedagogy. This social and emotional engagement of the teacher with the students and their understanding faces difficulties within traditional methods of teaching. In Ireland, it was reported that traditional practices were well ingrained in the psyche of teachers, which hampered the introduction of more social methods in the class (Shiel, Perkins & Gilleece, 2009). Examples of more social and Vygotskian-influenced methods included the development of collaborative, social and co-operative learning environments. It was found in research that those social methods coupled with the promotion of students’ interests encouraged improved scientific concept development (Murphy, 2015).

However, cultural differences between students and teachers (Emdin, 2007; Schultze & Nilsson, 2018) could hinder the social and emotional involvement of students if left unaddressed. Traditional teaching cultures also impact student engagement as the inclusion of student voice is rarely evident. Inclusion of the students’ voice in their learning was stated in research to lead to students feeling empowered in their learning and experiencing achievement (Laux, 2018). These emotions of empowerment and achievement contributed to students developing motivation to learn science (Laux, 2018). The importance of students’ emotional involvement in their learning with the teacher was also supported in Cook-Sather’s (2007) study. She observed the development of a collaborative space between teachers and students and found that student voice was more than asking them for their ideas. For student voice to be effective, the teacher must listen, respond and act on what the student has said (Cook-Sather, 2007). From these studies, students social and emotional involvement in their learning are key factors in students experiencing achievement and constructing knowledge. The teacher has a key role in the development of students social and emotional involvement in the class, and this role challenges traditional cultures of teaching. The involvement of the student in their learning requires the teacher to develop effective and collaborative social practices in the classroom. As stated in Cook-Sather’s (2007) study, the teacher must go further then asking the students for ideas, the teacher
themselves must also socially and emotionally immerse in the learning occurring in the classroom.

The development of the enculturation of learners, a communication process, and promotion of learning towards scientific concept development, was found within the theoretical works of Vygotsky (Vygotsky, 1997). The theoretical work and concepts developed by Vygotsky were used in this study in the implementation of social constructivist methodologies, that could support both the teacher and the student in developing more social practices in the classroom. Vygotsky described scientific concepts with the following features; an ability to generalize, organization of systems, conscious awareness and voluntary control (Wells, 1994). Interpretations of Vygotsky’s writing showed that due to the higher psychological development involved in the acquisition of scientific concepts, they had to be taught through deliberate and organised instruction within a classroom setting (Wells, 1994). This focused instruction set up a dialectic between every day and scientific concepts within a classroom, and provided context for the students. Davydov (1998) discussed in his paper, how Vygotsky’s understanding of scientific concept development was applied to formal learning. Davydov ascertained that if formal learning was properly organized, the creation of a zone of proximal development (ZPD) could be established, which could further the student’s higher psychological development by setting in motion processes and interactions, that without formal learning, might not be achieved (Davydov, 1998). The development of a Vygotskyian ZPD was understood to involve social interactions so that a person could develop their conceptual development towards something that at the beginning of the interaction was slightly out of their conceptual range (Vygotsky, 1997). The assistance within a ZPD could come from both the teacher and fellow students, and it was important to acknowledge that the relationship between students was very powerful in affecting students learning and achievement in lessons (Goldstein, 1999). Social, affective and cultural context interactions and support, that could be set up within a classroom as students discussed topics, promoted the potential internal development of actions (Veresov, 2010). This socially developed and supported lesson which led to internal reflection on the topic due to the initial social interactions, could ultimately lead to development. If learning was not organised to encompass those social interactions and opportunities, then conceptual developments could be very hard to achieve. This was also true if support was absent from the organisation of learning. If
support was not evident during the lesson to the student, the perceived difficulty of a task might seem too great, and they might give up on the activity and therefore the development of the concept in question. Thus, continuous dialogue with students about their understanding of the activity or concept, through questioning and responding to their ideas is a key role for the teacher (Leach & Scott, 2002). The logical and clear organisation of information within lessons could promote both student engagement and learning and lead to the development of productive ZPD’s within classrooms. The considered progression of information and social interactions, supported Vygotsky’s theoretical position of concept development and furthered the importance of contextualised instruction in formal education (Vygotsky, 1997). Another aspect of Vygotsky’s work that could promote student engagement was the recognition of the affective element of learning. This was seen as vital for conceptual development and was strongly evident in Vygotsky’s theories on concept development (Vygotsky, 1997).

2.5 Theoretical Framework

The theoretical framework represented different areas in chemistry education literature, general education literature and reflective literature that were utilised in the study. The theoretical areas discussed are separated in figure 2.2 for the purposes of description, but are, in the practicality of the classroom, all interlinked. Figure 2.2 represents the interaction between the research study, the literature and the research methodology enacted in this study.
Figure 2.2 represents the main theoretical concepts within this study's theoretical framework. The framework contains four circles, set on top of each other and getting progressively bigger as they moved out from the central research question. Separating each of the circles, except for the final and largest circle, are dashed lines to represent that the theory and understandings from one area will impact other areas. The final circle is enclosed by a solid line. The solid line represents the temporal boundary of my study. The research question is enclosed in the centre circle. The closest circle to the research question is the circle that contains the main aspects of my practice in this study. The reason that practice and the research question are the same colour and next to each other is because the research question was generated in my teaching practice. The areas within the practice circle have been discussed earlier in the chapter. The next circle, theory, represents the main aspects of the theoretical framework that will link practice with my studies action-research approach. They are; social constructivism, Vygotskyian inspired learning
strategies and co-generative dialogues (co-gen). The final circle represents the approach taken in this study, action-research, and is discussed further in chapter three. Action research was the approach taken for this study. Plan, implement and reflect represent the main phases of the enacted action research approach. This framework and its circles and cyclic nature could be viewed as spiralling in towards the research question and equally it could be viewed that the interaction between literature and theory were spiralling out from the research question. The shape of the circle was significant as it demonstrated that there was no hierarchy between the concepts, and that each concept impacted the other.

The general framework that guided this research was; a practitioner based action research study, enacted from the ontological position of social constructivism. From this position, use was made of teaching methodologies influenced by social constructivism and utilised the work of Vygotsky which exemplified social constructivism. Cycles of teaching during the year were reflected on using a critical reflection frame and further viewpoints on the information gleaned from the study were provided by a diverse group of students through their involvement in co-generative dialogue with the teacher. The rest of this chapter outlines in more detail the main concepts involved in this framework, through the expansion of some of the main aspects within each concept. An important aspect to remain cognizant of, was that the aspects within the main concepts were ideas that featured within this study, but that they were not exhaustive of all the elements that can encompass the main concept areas. The concepts to be discussed include; action research, theoretical overview of social constructivism, reflection in education and theory of co-generative dialogue.

2.5.1 Action research

Action research was the overarching methodological approach that guided this study, and will be expanded upon in more detail in chapter three. In this chapter, a brief overview of the approach and how it complemented the researcher’s ontological position was outlined. Lewin, often credited with the initial development of the action research approach, saw it as the discussion of problems followed by group decisions on how to proceed (Adelman, 1993).
Action research therefore was a form of social inquiry in which members of different social groups interacted and engaged in dialogue about relationships, and as a collative participated in a learning process that aimed to create social change within their communities (Glassman, Erdem & Bartholomew, 2012). This interaction of different participants in the study was also a key aspect of social constructivism, as the co-construction of knowledge occurred through social interactions and discussions. Lewin developed approaches and methods of action research, and these methods were developed by other theorists and evidenced in Dewey’s work, in the context of progressive education, to then enable schools to enact democratic change within the school community (Adelman, 1993). An action research approach was an interesting process in the formal education process, as a democratic element was often missing in classrooms. An asymmetrical power relationship existed where teachers were, oftentimes, assumed univocal, and the expert, not to be challenged, and where group decisions rarely occurred (Mortimer & Wertsch, 2003). Action research with a democratic focus within educational settings could change or alter the social settings and the preconceived role of the teacher and the student. When considering a classroom, where traditional didactic approaches occurred, the asymmetrical relationship was clear to see, as the teacher controlled the “direction of communication”, and the student had to accept whatever social reality was introduced (Rommetveit, 1979a, cited in Mortimer and Wertsch, 2003, p. 95). It was found, that even when students participated in more open teaching approaches, and asked authentic questions, they were usually using a pre-specified speech genre, which typically belonged to the teacher and was more generally, influenced by the cultural-historical context of the formal classroom (Mortimer and Wertsch, 2003). If students were to become authentic speakers within a classroom setting, then the context, social interactions and process of decision-making had to be changed. Action research provided the basis for social change accompanied by action within a classroom. An issue that occurred within action research was that the experience was transformative for the researcher on an individual level, but larger scale systems and ideologies were very difficult to challenge and slow to change (Cranton, 2011). For change to be seen, I proposed that more people needed to be invested in change and willing to act.

Carr and Kemmis (1986) distinguished between types of action research that could be carried out based on the type of process involved, the type of
people and the setting of the research. The three kinds were; technical, practical and critical action research. Technical action research focused on improving control over outcomes and was researcher focused. Practical action research linked with participatory research and improving practice. The final form was critical action research, which had a more social focus with the emancipation of people or groups from injustice or suffering (Carr & Kemmis, 1986). This is an example of divisions being placed into action research approaches, which could ultimately narrow a practitioner’s action research, either to one specific focus, or make it product driven and measurable rather than process orientated. This discussion point on action research is outlined in more detail in chapter three. 

Teacher-based action research has a tradition of being an activity where knowledge could be generated for engagement in critical and systematic investigation of one’s practice (Colucci-Gray, Das, Gray, Robson & Spratt, 2013). In action research, the process was forefront to developing understanding. The changing of a set action was still recognised to beinterwoven with the cultural processes inherent within the research environment (Kemmis, 2009).

When the teacher was researcher and participant in the study, it led to positives and negatives within the research. It was equally important to acknowledge the negatives as it was to highlight the positives. Hammersley (1993) discussed that he was not convinced of the superiority of teacher as researcher over researcher-based education research. He posited that a teacher-researcher produced educationally relevant and valid knowledge to teachers, and that the exclusion or bypass of the teacher from research or the research on teachers, was undemocratic and exploitative (Hammersley, 1993). Hammersley put forward the argument that the promotion of teacher as researcher was due to the democratic process involved and to the fact that the teacher was an active member and participant of the process. He pointed out an epistemological assumption that was inherent in this thinking; that “knowledge comes from contact with reality” and the closer you are to the phenomena the better. Hammersley felt this was a fragile assumption on which to base an epistemological argument (Hammersley, 1993, p. 432). Freire, a name that was linked repeatedly with action research, particularly participatory research, counters Hammersley’s point when he states that the people who could truly define the relationships found from research were the people directly involved in the ecology of the research (Freire, 1970a, cited in Glassman &
Erdem, 2014, p. 209). Caution was needed in this study in relation to Hammersley’s point, although the teacher as researcher can produce material of value, it was not to be portrayed as a superior research method. This point was important, as acknowledgement that knowledge produced by a teacher-researcher was not superior, it must also be accepted in turn that it was not inferior. A balance between the different point of views and interpretations, of teacher as researcher, teacher as teacher and the vital participation of students, needs to be acknowledged in the analysis of this data. In this study, knowledge was generated in the contextually complex environment of a classroom, and there was value in this knowledge, and it was also supported by theoretical underpinnings which guided the action. This study implemented action research with a theorising practice (Thompson & Pascal, 2012) which helped merge theory and practice rather than drive them further apart due to the practice of classifying knowledge as research or practical. The concept of theorising practice will be discussed in more detail later in this chapter in the section on reflection. This study generated reflective understandings about practice from a professional and personal dimension, as well as more refined and developed pedagogical content knowledge from the interaction of theory and practice.

2.5.2 Social Constructivism

Social constructivism is viewed as a theory of learning by several educational researchers (Bachtold, 2013; Baviskar, Hartle & Whitney, 2009). A general understanding of social constructivism is that learners are actively involved in the construction of new knowledge (Bachtold, 2013). Learners are active when engaging in discourse and social interactions (Baviskar, Hartle & Whitney, 2009). An epistemological philosophical understanding of constructivism is that the attainment of knowledge is viewed as having occurred through construction rather than transmission (Bas, 2012). If this viewpoint was incorporated into the theory of learning in education, it would have profound implications on practice. If knowledge is viewed as being created through social constructions, then the traditional and transmissive models of education would be called into question. Adopting a psychological and philosophical position offered a rationale for the teacher, if that rationale was congruent with the teacher’s value system. I adopted a social constructivist position as I identified with the theoretical
The wider ontological and epistemological position of social constructivism offered an overarching framework in which the methods and outcomes of this study could be situated, and provided a rationale for their inclusion and also their enactment. However, as with all educational change, if the ontological and epistemological position was not acknowledged by the practitioner, then the development of practice would lack a rationale and could remain limited to certain methods and therefore narrowed practice and engagement. Methods when enacted in the absence of an ontological position (overarching methodology) could appear as separate entities. Those methods could end up being added to teaching practices to break up a normalized routine rather than transform teaching and choosing them for a particular pedagogic reason (Loughran, Berry & Mulhall, 2012). The importance of an ontological position in the implementation of any teaching methodology was found in the following studies. Crawford’s (2007) study looked at the development of pre-service teachers and their enactment of science as inquiry in an American high-school context. Crawford stated that a strong factor influencing pre-service teachers’ ability to engage with inquiry, was their own set of beliefs and views of science. The study also acknowledged that learning for the pre-service teacher cannot be isolated from classroom practice. The teachers’ beliefs cannot change in the absence of practice (Crawford, 2007). Learning for the teacher requires relevance, and the most relevant part of their practice is the classroom. Lotter, Harwood and Bonner (2007) looked at professional learning for in-service teachers, again in relation to inquiry practices and in an American context. This research study also mentioned the importance of teachers’ beliefs and conception of science, as this can influence the enactment of inquiry and impact on the student. The student can be influenced by the teacher, as the teachers’ beliefs are transferred through their practice (Lotter, Harwood & Bonner, 2007). The study acknowledged the complexity of factors involved in the development of science instruction and stated the importance of providing teachers with long-term science experiences to support their teaching (Lotter, Harwood & Bonner, 2007). The teachers beliefs, their implicit or explicit ontological position, was evidenced in these studies as a strong influencing factor in the enactment of teaching methodologies. These studies support the acknowledgement and development of teachers ontological position and that explicit discussions in this area could benefit the enactment of methodologies.
In this study, it was acknowledged that social constructivist methods were introduced and utilised in a teaching culture that was slowly evolving from more traditional styles of teaching. The introduction of social constructivist methods aimed to develop; dialogic communication, the active engagement and construction of knowledge by the student in conjunction with the teacher with the aim of promoting problem solving and concept development for the student. The teaching culture, which was situated within more traditional methods of teaching affected not only the teachers understanding of their role in mediating the nature of chemistry, but it also affected the students' perceptions and therefore their perceived role in the classroom. The following study is demonstrative of the importance of acknowledging the differences that exist between teachers and students. Discussion of these differences could promote more collaborative understandings for the promotion of learning in classrooms.

Emdin's (2007) study explored how cultural rituals influenced urban science classrooms and acknowledged the impact of culture on students learning. Emdin (2007) was a chemistry teacher, in a New York urban high-school, which was the context of the study. Cultural misalignments were identified between the students and the teachers in the school, and Emdin employed co-generative dialogue (co-gens) as a method to develop understanding between the different cultural contexts of the teacher and the students. It was also aimed to develop an understanding into each other's ideas of success within the classroom. In his study, the students and the teachers co-constructed new ways of interacting within the classroom, new approaches to teaching and learning and in turn student engagement in chemistry increased (Emdin, 2007). In my study, the introduction of social constructivism was a change to the teaching culture and the use of co-gens and enculturation practices aimed to promote more social practices between the teacher and the students. Driver, et., al., (1994) also recognised the importance of communication and the mediation of knowledge between the teacher and the student, to support the students' developing scientific understanding. Another social constructivist method noted in research that supported students' scientific understanding was the inclusion of student voice. However, the effective inclusion of student voice faces difficulties if implemented within a traditional teaching practice. The inclusion of student voice requires the teacher to not only ask the student for their ideas or opinions, but they must accept, listen and respond to what the student has said (Cook-Sather, 2007). Effective involvement of student voice requires more social practices within the classroom. This reiterates the importance of teachers
identifying their ontological position and a curriculum with a clear methodology that supports social practices. Laux (2018), in her theoretical paper explored research on student voice, using a key terms search and examined literature from a variety of science education sources. Her scope of literature included a variety of education levels, and programmes outside of school, also no restrictions were placed on the country where the research occurred (Laux, 2018). Her conclusion, from the analysis of research, found that the incorporation of student voice in the classroom led to students feeling empowered, due to the students themselves, constructing their own meaning and experiencing achievement. This experience of achievement contributed to the students developing motivation to learn science (Laux, 2018). The inclusion of student voice is supported and promoted by social constructivism and as stated in research studies, promotes student motivation to learn.

Social opportunities, better communication and the inclusion of student voice could promote collaborative environments supporting conceptual understanding. A study by Gillies (2017) discussed a variety of research that focused on the social constructivist aspect of collaborative learning. From research papers analysed, structured collaborative experiences that challenged student thinking, while supporting learning, developed them as problem-solvers and promoted conceptual understanding (Gillies, 2017). The evidence for the development of students as problem-solvers came from a specific study in the review that used Vygotsky’s theory of development (social interactions transfer inwards in the individual) as their theoretical framework to analyse the impact of social discussions (“exploratory talk”) on students reasoning ability (Wegerif, Mercer & Dawes, 1999, p. 494). Wegerif, et al's (1999) study involved 64 eight- and nine-year-old children who were taught a discussion method that aimed to make joint reasoning explicit and that they used this discussion method in group tasks. Discourse analysis of student groups working together to solve test problems was used to explore the possible relationship between student talk and solving the problems (Wegerif, Mercer & Dawes, 1999). The study found that the use of the discussion method improved group reasoning and that individual results on reasoning tests had significantly improved (Wegerif, Mercer, Dawes, 1999). Despite differences in these research reviews and studies, including different data collection methods and different levels of education, the findings support the positive impact of social constructivist methodologies including; the inclusion of the student in their own learning,
motivation to learn, conceptual and reasoning developments, the promotion of a community of learning between all participants in the class and the wider school community and consideration of social and cultural factors that impede and support learning.

Social constructivism’s intended application in this study was to provide an overarching framework for the development of methodologies and acknowledgement of the philosophical underpinnings of the social, cultural and historic values within the context of the study. The inclusion of social constructivism positioned the researcher actively within the social situation and through this activity development occurred which led to personal and social change. This development also acknowledged chemistry as an active and creative science and the replication of that was attempted in the classroom. Aspects of social constructivism that were used in the classroom included; social activity, dialectic communication, enculturation, co-gens and listening and supporting dialogue to inform future actions. Those aspects of the framework considered the wider social, cultural and historical nature of the context, including people, roles and places.

2.5.3 Reflection

Reflection is a prominent practice in teaching and can be found in a wide selection of educational research. It was also the subject of many research studies which have contributed to the wide-ranging literature available on the topic. There is agreement, generally evident, that the practice of reflection was associated with the response to a need for change (Criswell, Calandra, Puvirajah, Brantley-Dias, 2015). The requirement for change can arise in many different forms and from various sources within education. Examples of a change needed within education included; an attempt at improvement in pedagogy, promotion of engagement of learners, more democratic processes within a classroom setting, development of education policy and curriculum development and balancing top-down changes with teacher driven initiatives. Reflection also became an integral part of the preparation of teachers in university contexts (Beauchamp, 2015) and in the continuous professional development of practicing teachers. However, reflection was also a process that was fraught with issues. One of the major issues that emerged, was that
reflection could act as merely a description of teaching without questioning issues in the classroom or assumptions held by the teacher. Without the challenge to assumptions and beliefs, this type of descriptive reflection was effective in reinforcing existing beliefs (Naidoo & Kirch, 2016). There was also a wide gap emerging between the theory related to reflection and the implementation of this theory into practice in the classroom (Beauchamp, 2015). There could be many reasons for this, for example the renewed push for accountability in teaching, which has resulted in a forced and nearly fictional based reflection, with the use of slogans, or buzzwords. This weakens the purpose of reflection as a means for deep thinking (Beauchamp, 2015). Indeed, this educational sloganism limitation, which could be attributed to top-down policy development, was referenced in other sources of literature as well (Smyth, 1989). Reflection was described as an intellectual process that involved action through experience, reaction through reflections, leading to experimental action and further reflection (Cornish & Jenkins, 2012).

Tensions existed between the theoretical understandings of educational reflection as perceived by Dewey and Schön. Dewey’s seminal work on reflection had informed and helped to develop many subsequent theorists, over many years. Dewey viewed reflection as a process that involved phases within the reflective act. These phases included; suggestions for solutions to experiences that lead to dissonance, development of hypothesis’ to guide observation and collection of material, reasoning on the information and finally testing the hypothesis to lead to action. This encapsulated an action reflection model, but also a systematic and scientific process to reflection (Gelfuso & Dennis, 2014). The development of this reflective practice with its scientific approach, highlights the difference in the initial conception of reflection for Dewey and Schön. This disparity was seen in Schön’s work in the development of the epistemological position of universities where knowledge and theory was applied to practice, and Schön refocused this epistemological position towards the generation of knowledge from practice. He felt that the generation of knowledge from the problem settings of practice could occur through practitioner action-reflection (Gade, 2016). For Schön, reflection was an activity, initially occurring within the practice setting, and that such reflection was “intuitive, personal and non-rational” and was more artistic in its nature, leading to the creation of new and uncertain situations (Akbari, 2007, p. 196). This contrasted with Dewey’s work, which could be described as rational and more
scientific in its process. Dewey was applying theory generated in an academic environment, to reflection that was taking place in a practice setting. Schön’s knowledge from reflection was generated through experience in the professional practice setting and due to the interactions within, whereas Dewey’s knowledge links with scientific approaches applied to the practice setting and the results achieved (Akbari, 2007). The tension can be summarized as follows, Schön’s practitioner-based intuition and Dewey’s understanding of rational and scientific thinking (Fendler, 2003).

Thompson (Thompson, 2010 as cited in Thompson & Pascal, 2012) proposed an idea which he described as “theorising practice” which attempted to link theory and practice, which had diverged in reflective practice. Within “theorising practice”, a connection was forged between theory and practice, initially beginning with practice and then drawing on the theory of professional knowledge to help make sense of the challenges within practice (p. 313). Akbari (2007) succinctly articulated;

\begin{quote}
the purpose of reflection, in other words, is not rejection of theory, but promotion of practical knowledge to the level of theory (p. 202).
\end{quote}

The implementation of a theorising practice aids improvement in professional practice, through the linking of theoretical discussions with the living theory of practice. If teachers were to eliminate theoretical discussions, a limitation of the development of understanding surrounding educational practices could occur. The ability to challenge existing theories and naturalized practices would therefore be limited. However, the living theories of practice, with recognition of theoretical understandings, could then be used to challenge or lead to the reconstruction of academic theories. Teachers’ practice and academic theories needed to be intertwined processes that worked together to promote informed practice (Akbari, 2007). A theorist who linked practice and theory, through what he called action and reflection, was Paulo Freire. Freire was an advocate of the dialectic of action-reflection, with the strong belief that one must not only talk about and describe an experience but also act on their environment if they hope to transform it (Freire, 2009). It was this relationship between action and reflection that could lead to a person critically reflecting on their reality (Naidoo & Kirch, 2016). This demonstrated the capacity of critical reflection to enable a teacher to make considerations about what they experienced and to form a habit
of continually learning from these experiences by framing “problems of practice”, critiquing and reframing the problems within a broader context and by taking action that was furthered by this reframing (Kayapinar, 2013, p. 1672).

Another criticism that was levelled against reflective practices in education in recent times, was the neglect of a holistic approach to reflection. The neglect of the affective element ensured that reflections focus remained narrowed on a solely intellectual approach (Beauchamp, 2015). The holistic approach mentioned here again links back to the study’s position of social constructivism and the holistic development of the teacher-researcher. Another important issue with the lack of an emotional dimension to reflection, was the missed opportunity for the full development of the self. The emotional domain related to power and identity of the self. If the emotional domain was missing from reflection the development of the self would be limited, ultimately impacting on the development of the professional aspect of teaching (Thompson & Pascal, 2012). This could result in a one-dimensional reflection in turn leading to a narrowed focus on practice. True change at a reconceptualisation level, which was a vital component of critical reflection, could not be achieved when reflection did not include acknowledgement of emotions. If teachers were to reflect on their profession, they needed to engage both cognitively and emotionally, and reflect on the self, for meaningful change to occur (Akbari, 2007). If emotion was lost, the result could often be a superficial reflection (Edwards, 2017). Transformative change in teaching practices occurred when the teacher experienced the act of implementation of change, both practically and emotionally, and was given time to critically reflect on those changes. A disconnect occurred for teachers if they were asked to interpret educational theories in the absence of both practical and emotional experience and the time needed to critically reflect on the experience. Without these the ability to implement theory and change into daily practice was limited (Martin, 2006). The study’s ontological position of social constructivism provided the theoretical background for the creation through social interactions of a context specific reflective model within this research. Finlayson (2015) stated that researchers that developed reflective practice models over time have developed a reflective practice that was a journey of personal learning and that the definition of reflection used and models developed are of personal choice. Reflective theories that were used in this study included critical reflection (Maharaj, 2016).
Critical reflection as a method sought to acknowledge assumptions that could be naturalized into practice. Maharaj (2016) stated an important difference between reflection and critical reflection. She suggested that reflection was the process of thinking about an experience while critical reflection required a deeper level of reflection where researchers were confronted with the assumptions that guide their actions and experiences. This view of critical reflection was supported by Fook & Askeland (2007) when they discussed critical reflection involving the identification of strongly held assumptions, leading to the implementation of improvement in professional practice. Freire was an advocate of the dialectic of action/reflection, with the strong belief that it is not enough to talk and describe an experience, one must also act on their environment if they hope to transform it (Freire, 2009). It was this relationship between action and reflection that led to a person critically reflecting on their reality (Naidoo & Kirch, 2016). To critically examine one’s practice, an awareness of explicit and implicit representations within teaching also needed to be identified and stated. Explicit representations were based on theoretical knowledge which had been received from formal education, and therefore were easier to identify through reflection. It was found that implicit representations developed through experience and habitual activities, became naturalized by the teacher and were harder to identify. Implicit representations usually lacked a theoretical basis and served a more pragmatic function, the simplification of the ‘chaos’ of the teaching environment. These representations could be very hard to access and can contradict, through actions and words, theories that teachers explicitly claim to follow (Manrique & Abchi, 2015). Critical reflection was a process that questioned the practices and values in my teaching practice and whether my explicit representations were comparable to my implicit practices. It made me question if there was a dissonance between my implicit enacted practice and my explicit professional theory. Throughout the study critical reflection was also continually used as a method to question the effects that occurred due to the action taken in practice, i.e. the effect of the theory (reflective planning) that was applied to practice.
Schön’s model of reflection

During this study, aspects of Schön’s reflective model that were utilised were; reflection-in-action and reflection-on-action. A third reflective process was developed for this study, and developed from Schön’s work on reflection. The third reflective process was reflection-for-action. These processes are discussed in this section of the chapter.

In reflective literature, Schön’s (Schön, 1983, as cited in Akbari, 2007) work on reflection was referenced as “reflection-in-action” and “reflection-on-action” (p. 194) but there was no distant category called reflection-for-action. The concept of reflection-for-action links the practice of looking back and acknowledging previous behaviours, with the attempt to improve and develop new ways of practice. This aim was supported by research conducted by Van Manen (Van Manen, 1995, as cited in Conway, 2001) when he linked reflection-for-action with what he identified as; “anticipatory reflection… future oriented reflection before action” (p. 34). In this study, the use of reflection–for–action also incorporated a Freirean aspect of reflection. Freire (Freire, 1972, as cited in Smyth, 1992) maintained that if a teacher was to uncover the principles that lay behind teaching, they must start with a recognition of their current practice and where their knowledge and beliefs originated from and what impacted on their development.

Reflection–in–action occurred while the action (teaching) was still being carried out (Manrique & Abchi, 2015) and distance from the event had not been created yet. Reflection–in–action provided interesting information that could later be reflected on in the reflection-on-action process. During reflection-in-action, actions that occurred included; field notes on the teacher’s emotion during a lesson, emotional signs from the students (smiles, frustration, etc.), and interactions and comments from students. The events that occurred during in–action was interpreted as “real actions”, as stated by Schön (Schön, 1987, as cited in Manrique & Abchi, 2015, p.16). These were actions that occurred in practice, not what a person theorised they would do (explicit), but what someone did, the practical implicit practice. Reflection–in–action provided experiences that could be reflected upon and these experiences were occurring in a problem based practice.
Reflection-on-action was the reflection that occurred after the implemented action was performed. Reflection-on-action was a more social process than reflection-in-action, and utilised discussions with my supervisor and the co-generative dialogue with students to help shed light on representations that were underlying in my teaching practice. Schön felt that this type of reflection was involved in the problem setting of teaching practices. It was a reflective process in which practitioners of education could become involved in making sense of perplexing issues within the teaching experience (Akbari, 2007) and begin to generate knowledge. Reflection-on-action, in this study, was not a purely retrospective aspect, as originally considered by Schön. Within this study, reflection-on-action used Smyth’s (1992) “reconstructing” reflective model to provide detailed reflections that were developed into future actions (p. 299). According to Smyth, reconstruction as part of a reflective practice looked at how things could be done differently, with acknowledgement of the socio-cultural context. In the ‘reconstruct’ element, the teacher-researcher developed an awareness as to how they were influenced by the socio-cultural context surrounding them, began to recognise and account for the existence of those limitations or constraints, and continued to work towards improvement (future orientated) (Smyth, 1992). Future orientated thinking had to be involved in reflective planning to develop the continued improvement of practice within teaching. Wilson (2008) supported this view as he identified the lack of a future aspect to reflection as a limitation of Schön’s model. He articulated the concept; “reflecting-on-the-future” as a reflection on what could be possible when certain actions were employed in future practice (p. 179). This consolidated theorising practice, as it was a future orientated method of reflection that included engagement with theoretical concepts, that could then be enacted in practice, with the aim of positively affecting that practice.

2.5.4 Co-generative Dialogue

Co-generative dialogue was used throughout this study. Co-generative dialogue (co-gen) was a form of discourse in which teachers and students could partake in a collaborative effort to set in motion positive changes in teaching and learning (Martin, 2006). Co-gen incorporated Vygotsky’s theory of concept development and the importance of a social environment and could act as a
dialectic communicative method (Murphy & Carlisle, 2008). It was used as an approach to avoid a narrowing of the reflective practice and importantly for the inclusion in the study of the students’ perspective (Martin, 2006). The students’ perspective was vitally important in facilitating the critical reflection of teaching practices and experiences in the classroom. To gain an insight into student understanding and how the reflectively planned instructional strategies were affecting student learning, co-generative dialogue was the approach that provided this valuable aspect to the study. Those dialogues offered other benefits, including; inclusion of student voice, social discussions and the co-generation of solutions to issues in the classroom.

Certain procedures were employed in the implementation of co-generative dialogue with the purpose of lessening the power hierarchy that culturally existed between a teacher and a student (Murphy & Scantlebury, 2010). It was due to the aim of the readjustment of power structures within classrooms, that the following procedures were implemented, according to research on the topic. It was mentioned in educational research that when students and teachers were interested in the improvement of teaching and learning in the classroom as a collective, and all parties assumed the responsibility for that intention, the co-generative dialogue method demonstrated positive impacts on teaching and related student outcomes (Chauhan, 2013). The co-generative dialogue (co-gen) was also a means for generating democratic understandings as an ethical praxis and was a viable research method (Stith & Roth, 2010). During the co-gen, interactions occurred between peers, student to student, and between student and teacher. An imperative of co-gens was that the participants engaged in dialogue as different but equal members with the overall aim of improvement in their context, the classroom (Stith & Roth, 2010). The concept of equal members is an extremely important aspect of the co-gen, where the input of one member was as important as any other. All comments and discussions had to be valued. These interactions were occurring to learn about another person’s perspective and that all perspectives were treated equally (Martin, 2006). The equal interaction of experiences and perspectives could lead to an alternative power dynamic being created in the co-gen than the power dynamic in the classroom. The development of an improved learning environment began from interactions and listening to other perspectives, leading towards the co-construction of meaning (Martin, 2006). The equal interactions cogenerated action strategies that were
difficult to develop from a single perspective or if the interactions were unequal (Murphy & Carlisle, 2008). Ethically (democratically) the co-gen also provided a speaking opportunity to members of the education community that previously had a minority voice (Stith & Roth, 2006).

2.5.5 Student Voice

The inclusion of the student and their voice, in a learning environment, is supported in a variety of educational research studies. In a theoretical review of literature, Laux (2018) analysed the inclusion of student voice from a wide range of science education sources. She concluded that student voice led to a feeling of empowerment for the students. One of the specific studies Laux (2018) mentioned was a research study based on an ethnographic approach, that examined the voices of two middle school students over a three-year period (Furman & Barton, 2006). Furman and Barton (2006) generated qualitative data from the students work in developing a science video for school. The inclusion of student voice, was evidenced through the students’ freedom to choose topics that were of interest to them for the video, once they could explain why they were scientific. The researchers concluded that the students used their voice to construct identities that they cared about. The study also supported the inclusion of student voice in curriculum as it can have a positive impact on student engagement in science (Furman & Barton, 2006). They also stated that learning communities that valued student voice would be more successful in promoting student participation in that community (Furman & Barton, 2006). When the students voice, their ideas and opinions were incorporated in lessons, this had the potential to empower their learning (Laux, 2018). Further support for the involvement of students in their learning, was found in a research study that sought student opinion on practical work in science classrooms (Toplis, 2012). In this study, the researcher interviewed 29 students from three different schools in the UK and found that students viewed practical work as interesting and highlighted social and personal features that were important to them included; social interactions, trust and autonomy (Toplis, 2012). However, the researcher also mentioned that there were many factors at play in this study (gender, age, social-economic backgrounds, etc.). An ever-present condition of classrooms is the complexity of the social situations within, so the involvement of the student in their learning, is a vital approach to help the teacher navigate processes within classrooms, to help support and promote learning. For this
process to be effective, research found that the teacher must delve deeper than asking token questions of the students (Cook-Sather, 2007). Teachers must truly listen, respond and act on what the student has said, in order to develop positive collaborative environments in classrooms (Cook-Sather, 2007). These studies provide powerful evidence of the impact of social constructivism and the inclusion of the student and their voice can have on the development of teachers’ practice and student engagement in general.

2.6 Conclusion

From analysis of literature in the areas of teachers’ practice, curriculum and student engagement the issues presented are complex and mirror the complexity within all classrooms and sites of learning. A disconnect between the intended curriculum in Ireland and the enacted practices in the classroom was evidenced in the literature. This can, in part, be attributed to a strong assessment culture, inconsistent and ineffective CPD and a strong culture of traditional teaching styles. These factors are contributing to students experiencing a lower engagement in sciences in Ireland, especially the senior sciences, as seen by lower numbers taking up those subjects.

This study implemented a social constructivist approach to teaching, supported by a critically reflective practice. Vygotskian influenced teaching methodologies were utilised throughout the data collection process. This approach endeavored to incorporate more social and democratic processes to re-dress the traditional nature of the classroom and develop more active and engaged students in their own learning. Student engagement was promoted by the acknowledgement of the importance of student voice in any teaching and learning environment. This was supported using co-generative dialogues. This methodological approach has the potential to promote teacher and student engagement and the development of pedagogical practice and could address issues within curriculum development and analyse features of CPD that are more effective for both student and teacher.
Chapter 3: Methodology

3.1 Introduction

A brief overview of the methodological approach of practitioner action research was introduced in chapter two. In this chapter, an expanded account of action research is outlined. The historical development of action research is considered, and the development of different action research approaches, particularly in the field of educational research is discussed. There is an elaboration on the application of action research in education, and the contextually developed use of action research in this study. This study was an inductive inquiry investigation into the evolution, development and outcomes of a teacher professional development learning initiative. The investigation proceeded with the backdrop of major curriculum reform attempts in Ireland. The study employed practitioner action research, with qualitative data generated using various data sources developed and used during teaching. Teacher reflections, lesson plans, field notes, and the conversations between students and myself in the co-generative dialogue were the main sources of qualitative data. This data was then analysed using thematic analysis (Braun & Clarke, 2006) to discover if social constructivist designed methodologies impacted on the teacher's practice and in turn on student engagement in the classroom.

3.2 Research Sample

This was a self-study and the focus of the data collection was myself as the teacher, during the research. Data collection on my practices included field notes from lessons, reflections I engaged in and actions I took during lessons. I have taught in the school that was the site for this study for the last eleven years. The study school was a large all-boys post-primary school in Kildare, Ireland. I taught junior certificate science, physical education (PE) to all levels and was the only senior chemistry teacher in the school. The student sample in this study consisted of a 5th year chemistry class for the academic year 2016-2017. There were 24 students enlisted for that year, and due to the context of
the school, the population of the class was all male. 5th year is the first year of senior cycle in Ireland and the students age range was between 16-17 years upon entering the class. The students had made their own subject choices for 5th year in April of the previous academic year, 2015-2016. Students in the school had the option of entering a transition year (TY) after completion of their last year at junior cycle, 3rd year (14-15yrs). This resulted in students entering 5th year from either completion of 3rd year or after completion of TY. Two out of the 24 students in the year 2016-2017 came from 3rd year, the rest had all just completed TY. All students consented to participate in this study, with only one student stating that they did not consent to being videoed. That was accommodated in the study, by having only certain lessons videoed and the camera was pointed at the teachers desk and myself, and did not show any of the students. Also this student declined to be involved in the co-generative dialogues as they were being videoed.

### 3.3 Research Question

- “Can social constructivist methodologies affect teacher practice, and/or student engagement in chemistry?”

In this study, one question formed the basis of the study, and three sub-questions were generated to provide focus to areas within education that can influence teacher practice and student engagement. The three sub-questions are listed below.

- “Which social constructivist methodologies impacted on my practice, and how?”

- “How did the social constructivist methodologies and practice affect student engagement?”

- “How does the current chemistry curriculum relate to social constructivist methodologies?”

A principal objective of this study was to identify social constructivism’s impact on teaching. If favourable, then aspects of the methodology that may develop a
teacher’s practice could then be identified. Practical applications of social constructivism could then inform future pedagogical practice. However, teachers have demonstrated limited engagement with learning approaches and curriculum methods in Ireland, resulting in a divergence between intended curriculum aims and enacted curriculum practice (e.g. NCCA, 2013; Kennedy, 2013). Teachers’ resistance to curriculum change has historical and sociocultural influencing factors. Traditional teaching methods including direct transmission and structured practices have more support in Ireland compared with more open and constructivist ideas (Shiel, Perkins & Gilleece, 2009). The focus on high-stakes summative examinations in Ireland has further embedded a traditional approach by teachers (Murchan, 2018). This traditional culture is due in part to the high volume of subject content within curricula. Traditional styles of teaching have proved efficient at covering vast amounts of material at a surface level (Oldham, 2001). This is a brief overview of the difficulty involved in changing teachers’ practices, due to the complex influencing factors surrounding education in Ireland. The evidence from this study could provide a system of supports that could help develop teachers’ practice.

3.4 Timeline of Research Approach

Figure 3.1 gives a visual representation of the timeline of this research study and also identifies various data collection points and when they occurred. The study was divided into action research cycles which coincided with the five academic terms of the Irish school year. The data collected and understanding gleaned from each action research cycle feed into and informed the next research cycle. In every research cycle lesson plans were developed and delivered, teacher reflections were written after each lesson and then a collective end of week reflection was written. Artefacts of student work including work in class and their homework was photographed to build up an understanding of their development within the class. To ensure student anonymity, the artefacts of student work were coded for identification by the researcher and no student name was identifiable on the artefacts. Field notes were also recorded short hand on the printed out lesson plan, for a majority of the lessons. The filed notes included; incidents of note in the classroom and student comments or questions that gave an indication of how the lesson was
progressing, positively or negatively. Field notes were usually recorded during lessons which contained a high proportion of active social learning occurring through learning activities. The taking of field notes was possible during these lessons, as the students were working and I was able to take more of an observer role in the classroom. Cycle four and five of this study contained co-generative dialogues as additional data collection methods.

Figure 3.1 Timeline of the research approach

3.5 Methodology

This section of the chapter includes a brief overview of the methodology that was developed and utilised in this study. Figure 3.2 represents a flowchart of the methodology used in each action research cycle, including the focus areas and data sources employed in this study.
In figure 3.2 social constructivism was the research paradigm that encapsulated the ontological and epistemological position of the study. Knowledge was understood to be constructed through social interactions and collaborative dialogue, which generated development and social change. Action research, more specifically practitioner action research (green box) was the methodology of the study. Action research was based on changing teaching practices, reflecting on teaching and involving student voice on teaching. These three actions were the focus areas of the action research in the study. The three focus areas are one level down from the methodology in the purple boxes. Underneath the purple boxes are the data sources of this study. These sources
of data included actions taken during the study; development of lesson plans and field notes, also, reflections recorded and co-generative discussions. The data collected over the study then underwent thematic analysis. The rest of the chapter details the contextualised action research that was developed, discusses each focus area in turn, leading into the data sources and how the data was analysed.

3.6 Action Research

3.6.1 Brief historical development of action research

Lewin, an oft-cited theorist in the field of action research, characterised research for social practice as a “comparative research” that looked at the conditions of a social situation and the effects of different forms of social action on the social situation (Lewin, 1997, p. 144). The aim of the research was the enactment of informed social action in a social environment. Lewin articulated that the development of academic literature without practical action was not a sufficient aim for that type of research (Lewin, 1997). Group discussion of a problem, followed by a group decision on how to proceed was an important aspect of Lewin’s research approach. He felt that those directly involved in the social group, be it factory, community or school, had to carry out the chosen social action. After investigations of the condition of the social situation and the effects of the action that occurred, the group made decisions, monitored the consequences and discussed future actions. Lewin’s vision of action research had to include the active participation of those involved in the social situation and action developed from the exploration of problems that they identified and anticipated (Adelman, 1993). Lewin’s process has been described as a three-step plan of action that spiralled back to the start of the plan again. The three-steps included; “planning, implementing and assessing one’s research” (West, 2011, p. 90).

Despite the inclusion of the social participants/practitioners in Lewin’s field research, trained social scientists carried out the research. The participation of the practitioners was dependent on the guidance of the social scientists, rather than being truly driven and developed from within the social
system. Herein lay an inherent tension within action research. It was described as an emancipatory research approach for people in certain social situations. However, the methodological rigor of the research, action and understandings derived from such research, was questioned if a social scientist or university researcher was not involved (West, 2011). Action research for social change deemed the partnership between trained researchers and a social action group that recognised the need for change, was the optimal situation for action research (Glassman, Erdem & Bartholomew, 2012). Practitioner action research was not seen as a valid form of research, as it was the account of the researcher and not the teacher that was produced. However, this position has been questioned most notably within a social constructivist emancipatory framework, where research on people rather than with people was deemed undemocratic (Hammersley, 1993). Knowledge through a social constructivist frame involved the co-construction of information that developed between participants and in the active engagement with the social situation. Participation in the social situations therefore was a prerequisite for the generation of this knowledge and for action researchers, they could not remain a spectator (Murphy & Carlisle, 2008).

Despite the continued reference to Lewin in relation to action research, it would be more accurate to acknowledge that it was not one theorist that developed action research, but an ensemble of social activists, researchers, governmental and non-governmental organisations who developed the approach. This acknowledgement is important in avoiding a reductionist thought, that action research was somehow a single approach rather than the combined community of inquiry that was necessary for action research to succeed (Glassman, Erdem & Bartholomew, 2012). With the understanding of a collective community of inquiry involved in action research, a broader understanding of action research needed to be employed. This broadening of action research methodologies will be discussed later in the chapter.
3.7 Action research in education

3.7.1 Different understandings of educational action research

The roots of action research within education was linked to a few main theorists in different settings. In the United States of America, education action research had roots in the progressive education movement and the work of John Dewey. Lewin’s work was focused on social workers in America in the 1930’s and the influence of action research in terms of education in America was not seen until the 1950’s (Feldman, 1996). Researchers at that time saw action research as an opportunity for teachers to begin to engage in the emerging field of the scientific study of education that occurred in the classroom (Feldman, 1996). Corey was an influential educational action researcher and advocated for research to be undertaken by teachers as a methodology to improve their practice (Hammersley, 1993). In the United Kingdom, curriculum reform and the professionalisation of teaching were factors for the implementation of action research. In Australia, efforts were being made to develop a movement towards collaborative curriculum planning. The focus in each of those contexts used action research to develop more participatory education (Noffke, 1994). Carr and Kemmis (1986) understood action research to be a “form of self-reflexive research” undertaken by teachers in the social setting of their classroom, and in a wider sense their school, encompassing all those interactions. Carr and Kemmis (1986) extended this position when they distinguished between the type of action research that could be carried out based on the type of processes involved, the type of people and the setting of the research. The three types of action research were; technical, practical and critical action research. Technical action research involved looking at improving control over outcomes and was deemed researcher focused. Practical action research had the aim to educate practitioners to act wisely for the long-term benefits of their practice and linked with participatory research, to give the participants a voice. The final form was critical action research, which had a more social focus with the emancipation of people or groups from injustice or suffering (Carr & Kemmis, 1986).

Wallace (1991) commented that action research was an extension of the reflection that teachers would engage with on a regular basis, but with the aim to promote understandings in relation to theory and be more rigorous in data collection. Stenhouse (Stenhouse, 1975, as cited in Luttenberg, Meijer &
Oolbekkink-Marchand, 2017) considered the primary aim of action research to be the development of a solid reflective practice. Classroom action research which emerged in the United States in the 1980’s developed the conception that action research was a problem-solving process and that it needed analysis of data with the purpose of solving the problem (Feldman, 1996). Teacher research had a slightly different understanding to classroom action research, even though both emerged around the same time, albeit through different researchers. In teacher research, the teachers began researching ways to improve their teaching and their students writing. This research was carried out through the completion of reflective journals, the collection of samples of children’s work and writing and through collaborative groups they discussed and critiqued each other’s work as they made it public (Feldman, 1996). Stenhouse (1975) and Elliott (1991) (as cited in James & Augustin, 2018) broadened the understanding of action research by advocating the concept of “teacher-as-researcher” and the importance of problem solving within practice (p. 335). The focus of the teacher as merely a problem-solver in practice was interpreted as a limitation to both the teacher and the possibility for change. It was important to acknowledge, as Edwards-Groves and Kemmis (2016) did, that action research for the teacher must consider the cultural, political, historical and economic conditions in which the context of the practice is situated. Action research as a research approach that encompasses reflection, theory and practice with the aim to produce solely practical knowledge that would be useful to teachers in practice (Kim, 2013) is limiting both to teachers and the approach. Other influential educational action researchers included Kemmis, McTaggart and Nixon (2014) who described fundamental features of the approach as the implementation of ideas in practice, with the aim of improving practice, and as a method of increasing knowledge relating to the curriculum, teaching and learning. The implementation of ideas in practice could then lead to the production of “context-specific evidence about the process of learning and the aims of teaching” (Colucci-Gray, Das, Gray, Robson & Spratt, 2013, p. 127). These understandings are just an example of the variety of interpretations and methodologies that exist for action research. These understandings also share key common themes. Within the different varieties of action research a core approach seemed to include the implementation of an idea (outcomes, policy, reflection, problem-solving, curriculum planning, etc.) with the aim of improving practice. Another common thread seemed to be the development of a more participatory approach to change in education.
3.7.2 Developments in educational action research

Social and democratic aspects were common features of initial action research. Theoretical models of action research endeavoured to promote a “democratic vision of human interaction” (Glassman, Erdem & Bartholomew, 2012, p. 277). However, the features of educative action research seem to have deviated from initial action research. Educational action research included aims such as; problem-solving, improvement of practice and professionalisation of teachers. The promotion of democratic processes was not an overt statement in many of the understandings mentioned above. Action research was originally a social and educative based intervention for minorities or communities with entrenched problems (Lewin, 1997). However, as action research developed and was applied to various settings, researchers adapted approaches for those different settings which led to the emergence of different theoretical models. Within educational action research a technical focus on the enactment of action research was evident, as practice relating to outcomes and professionalisation came through more often as the desirable aims (Noffke, 1994; Carr and Kemmis, 1986). Educational action research was focused on technical issues and outputs. If teachers were to engage in research from a social constructivist position, a difficulty would be encountered from the outset, if acknowledged. An asymmetry of power exists in classrooms and continues to be a significant influencing factor on the cultural context of classrooms in Ireland. An example of that asymmetry of power was the prevalence of a traditional didactic style of teaching, with the teacher and student prescribed to defined roles (DES, 2002). The traditional style of teaching also favoured direct transmission practices that were less supportive of student-orientated practices (Shiel, Perkins & Gilleece, 2009). This culture demonstrated an asymmetry of power between teachers that subscribed to that style of teaching and their students. Action research should promote democratic principles within practice, generate knowledge relating to practice, challenge ingrained assumptions that exist within practice and empower teachers in transforming and gaining ownership over their own profession. Participation in action research should seek to re-interpret and gain new understandings in scientific, personal, professional and political spheres. Understandings in those separate but overlapping fields could be reconstructed, through action in practice and theory, and their meanings furthered to generate new and more comprehensive forms of knowing (McTaggart, 2018). A more
comprehensive form of knowing would be more holistic in nature compared to the sole focus on practical or technical knowledge.

In educational research literature, it was discussed that action research as a methodology had the potential to initiate real improvement in schools and practice. According to Somekh (2006) the person directly involved in education was the one positioned for the initiation and generation of change and improvement. In her book, Somekh (2006) states that the research methodology that could achieve this improvement was action research. Teachers were in the immediate space in which the process of learning occurred and had a unique opportunity to negotiate improvements in that learning daily (Stoll, Fink & Earl, 2003). Educational action research that also engaged in democratic processes could attempt to lessen the power inequality that can exist in classrooms. Involvement in reflective social action with the students had the capacity for holistic development of new understandings that could in turn influence and improve practice (Somekh, 2006).

The rise of teacher action researchers came about due to divergences between intended curriculum aims and practice within classrooms. The top-down and centralized approach and dissemination of methods and techniques, reduced teachers to simply executors of an evidence-based method (Colucci-Gray, Das, Gray, Robson & Spratt, 2013). This was also seen as undemocratic and issues were being seen in the classrooms, such as the misalignment between curriculum aims and practice. There was a movement in the 1980’s to begin the recognition of teachers as authorities in their own right and that they possessed validated knowledge about their classroom practices. Teachers were being recognised as more than “recipients of university-generated knowledge” (West, 2011, p. 89). This was further supported in the work of Stenhouse (Stenhouse, 1975, as cited in Noffke, 1994) with the movement that recognised teachers as professionals who theorise in practice rather than merely implement educational theory. However, the dissemination of information and evidence-based practice in Ireland continued to use a top-down, centralised model which originated in government policy (e.g. DES, 2002). Despite the recognition of teachers as professionals who theorise in practice, participation in methods to improve practice at a classroom level was slow to occur. It was slow due to various constraints on teachers including; time, resources and support. As previously stated, an asymmetry of power existed
within classrooms, but it also existed outside of classrooms, with governmental policy directing classroom practice. In educational literature, action research was a social and democratic research approach that could alter and shift traditional power structures pertaining to knowledge (West, 2011). As a methodology that teachers could employ, it could shift power structures in social interactions, both at individual levels and at a wider community level. Lewin referred to anxieties that different groups experienced with the introduction of action research. One of those anxieties observed was that groups in power; management, leaders, politicians and government, experienced a threat to their power, when they were restricted or questioned in what they were trying to do (Lewin, 1997). The group in power can change, depending on which system is focused on in education. At a national level, the DES is in power and teachers engaged in action research could disrupt and question that power. At a school level, management and the cultural status-quo are in power, and again, if a teacher engages in action research they could disrupt the existing system within the school.

In Ireland, pre-service teachers carried out action research based projects which linked to their emerging practice in the classroom. The aim of this practice, was to give teachers the skills to become reflective action researchers in their practice during their future teaching years (Noffke, 1994). The methodology of action research in teacher programs, gained international recognition as it provided a genuine form of inquiry (Noffke, 1994). However, when the pre-service teacher gained employment, they could experience conflict when in-service professional development was through a centralized, top-down approach (Colucci-Gray, Das, Gray, Robson & Spratt, 2013). This contrasted with their previous involvement with action research and inquiry of practice. The top-down approach of pedagogical change was compounded further by the culture of accountability that had pervaded education, with greater references to “accountability” appearing in national reports (DES, 2016a, p. 89). At a government level, the centralized model of professional development appeared effective, as expertise was centrally positioned and the instructional models and methods were simply transmitted outwards, like charge through a conductor (Feldman, 1996). However, those conductors were people. Direct transmission of any information, let alone educational approaches, was dependent on genuine meaning occurring between people, and even with that, different understandings emerged as people had experienced different cultural
backgrounds and worked in very different contexts to each other. This top-down and centralised model had little success in America (Feldman, 1996), and struggled in Ireland, and Europe as well (European Commission, 2013). Despite the limitations of the centralized approach to professional development, involvement in self or collective educational action research was still hindered in Ireland, due to constraining factors existing within the school system.

Action research as an approach was used in many different social situations, in many ways. In fact, even within the same field, e.g. education, each situation contained different social interactions and contexts. This resulted in a variety of models of action research being implemented. Rather than viewing this as a limitation, action research as a methodology demonstrates an ability to respond to different cultural and contextual situations. This contrasts with a methodology that is applied to different situations in a strict manner, and does not allow for contextual differences within settings and people. Action research as an approach is flexible and wide ranging and can take into consideration the multitudinous different social interactions that occur in social settings. Action research, through critical reflections and cycles of action could respond to a contextual situation, in a more open manner then a strict structural approach. It is a methodology which could provide a custom approach to a complex situation rather than a generic model that is forced on a system. This position was also supported in action research literature. Elliott (Elliott, 1991, as cited in Adelman, 1993) put forward the argument that when distinctions were made between action research methodologies, the understandings developed were then narrowed to the specific methods within that specifically defined methodology. Elliott voiced the argument that theorists who made distinctions would have difficulty acknowledging that, for example, a critical outcome (social) could have arisen in what was originally deemed a practical type (practice, outcome) action research (Elliott, 1991, as cited in Adelman, 1993). Hopkins (2014), echoed Elliott’s misgivings about distinctions and discussed concern in relation to action research models that had quite specific frameworks and prescriptive conditions set to them. He felt that when action research models became too prescriptive in their design, the specificity entangled teachers so that they became dependent on following the structure of the model. This had the effect of narrowing the potential of the methodology and inhibiting the teachers independent action, which was occurring in a unique context (Hopkins,
Action research occurs within a complex system, and to narrow a focus on one aspect could mean the generation of a blind spot to other aspects.

Action research in education has evolved over time to incorporate more flexible and contextualised approaches and to promote and further the practice of the teacher, for the betterment of the student. However, despite the benefits of action research, involvement with the process by teachers is very low. Contributing factors to this include; constraining governmental factors such as top-down policies and enforced change, the pervading traditional culture within schools and limited supportive structures for such inquiry in Ireland.

### 3.7.3 Limitations of an action research methodology

Some limitations of action research have already been discussed, including the narrowing of its focus to prescriptive models, the debate over the ownership of the research if both practitioner and researcher were involved and the validity of practitioner based research. What follows is a discussion of particular (specific) limitations of an action research methodology that were faced in this study. Action research in education occurs at the interface of policy in the classroom. Tensions include the previous values of the teacher interacting with alternative evidence-based practice developed from action research (Colucci-Gray et al, 2013). A school could be described as; “a rule-governed entity, a coherent whole with entrenched habits of power” (Glassman, Erdem & Bartholomew, 2012, p. 274). When a teacher engages in action research, they confront the discourses of school and government policy. That confrontation could challenge the values that the teacher had both experienced and adhered to, due to the autocratic distribution of policy developed curricula (Colucci-Gray et al, 2013). This acknowledgement of tension then requires the teacher to critically examine their values in relation to past and present teaching practices. Critical examination of teachers practice included their values and their self-image as a teacher. This deconstructing of historically rooted ideas and views is necessary for change and new learning to occur, but it brings with it challenges and discomfort which some teachers might be unwilling to face (Dadds, 2003). During this study, tension occurred between my previously held values and evidence-based practices and this confrontation provided challenges. However, the process of critical reflection, and support from my
A supervisor helped me to acknowledge that these challenges were progressions of learning, something to actively engage with rather than something to be feared. An immersion in educational learning theories aided my critical reflective practice, as I began to recognise culturally confined practices within my profession and then began to question them, and my role in enacting such practices. The identification of culturally confined practices provided, in turn, further challenges. Within a school context, to change what is culturally accepted can be daunting for both the teacher and students. It can also be perceived as somewhat threatening by other teachers and management. To overcome these challenges, an open approach to all changes in pedagogy was adopted by the researcher, which included open discussions with students, management and other teachers. Through informal and in-class discussions and co-gen dialogues, the students could also voice their opinion about the changes. Feedback from colleagues and management was also taken into consideration. The consistent practice of recognising and confronting challenges and discomfort ensured that I continually examined the interface of policy, evidence based practice and deeply ingrained historical ideas and views. This was not an easy process, but a necessary process within action research, as it helped to challenge existing practices and the values within. It also provided the platform to try and enact change in a democratic, ethical and sustainable manner.

Another cultural limitation on an action research methodology in an educational context is government led policy which promotes accountability, measurement and excellence. The concept of excellence is assessed according to predetermined targets and the perceived need for improvement in practice in the classroom (Colucci-Gray et al., 2013). This interaction with government policy and focus on measurement had led to a techno-centric rationality within educational research, including action research methodologies. This has created an environment which holds the perception that definite, if simple, answers that are supported by data were the pinnacle of research (Stirling, 2010). The practice of action research became narrowed in its focus due to government policy influence. Complexity within research would not aid the government in their top-down approach to the dissemination of their self-determined evidence-based practice to the masses. The rise of external controls and outcomes-based objectives in education was an area for concern for the broad social implementation of action research (Noffke, 1994). A
narrowing of practice to change specific teaching methods to aid the achievement of a measurable outcome, was contrasted with action research’s intended aim of collaborative social efforts in education to work towards a reconceptualisation of curriculum or indeed schooling (Noffke, 1994). In education research studies, action research using collaborative methods had the potential to develop a profession that was motivated by ethical and social justice issues as well as technical ones (Noffke, 1994). An important aspect of action research was the complexity it comprised and that the approach was not simply a “product-drive” (Colucci-Gray et al, 2013, p. 132). In this study, attempts to avoid a techno-centric and top-down approach to research, acknowledged from the outset that teaching was a complex social system, and that measured changes needed to be observed within the system, rather than taken in isolation. Observations, reflections and understandings were continuously brought into the next cycle of teaching, during this study. The voice of the students was important during the process, as teaching was acknowledged as a social relationship between the teacher and the student. The study also used an emergent data collection process to avoid the action research becoming narrowed to an isolated teaching method. These precautions sought to avoid a “product drive” (Colucci-Gray et al, 2013, p. 132) during this study.

An aspect that was absent from education action research studies, was the teachers own development, professional and especially personal. Professional inquiry as a method for professional development had to acknowledge the significance of the teachers own learning and that this needed to be communicated and valued (Reeves, Redford & McQueen, 2010). Another interesting critique for teacher action research was the fact that action research encompassed a social and collaborative element. However, teachers involved in action research could find the social and collaborative element difficult. Teachers experience more isolation and less collaborative interaction on a day to day basis than many other professionals outside the field of education (West, 2011). Historically, teaching was quite an individualistic profession with authoritative and transmissive approaches used in the classrooms and very little professional interaction with other teachers. To employ action research in education was to develop collaboration in a formerly individualist culture. Collaboration in this study was developed through open conservations with colleagues, critical conversations with my supervisor and productive dialogues
with my students. This approach helped to promote the social and collaborative element of action research and help alleviate some of the issues of individualistic dominant thinking.

3.8 Researcher Reflexivity

Before the explanation of the action research approach that was implemented in this study, acknowledgement of my position within the research must occur. In the enactment of action research, I originally identified as a practitioner (teacher) within my social situation. This could produce reflexive issues, which I have attempted throughout the study to remain conscious of, by describing and reflecting on areas where reflexive issues arose (Powell, 2006). My enactment of action research was for the completion of an academic qualification and I had the support of an academic supervisor. In an examination of action research literature there was evidence that the motivation to carry out action research was externally orientated (Johnston, 1994). This was true of my research. It was rare that a teacher initiated the research approach themselves. This finding had implications for schools and raised concerns over the institutionalization of action research if it was driven by external forces (Johnston, 1994). This presented reflexive issues, as even though my initial motivation for this research was to improve practice, there was now the motivation to complete the research as part of an academic qualification. An issue that could occur would be the narrowing of the research focus to a professional orientation, at the expense of other aspects of learning and development (Reeves, Redford & McQueen, 2010). An effort was made in this study to lessen the impact of the academic accreditation by first acknowledging it as a reflexive factor in the research, and secondly by ensuring that personal and social impacts were discussed, and that the social encompassed democratic and political aspects of the study. I as a practitioner, acknowledged that the uncovering of assumptions within my practice, would have been difficult to achieve without support and guidance from my academic supervisor, an established researcher. The acknowledgment of the impact of my supervisor was supported in a paper by West (2011). This paper stated that in conjunction with teachers, university faculty with their research expertise aided teachers in their contribution of relevant information to the research community and helped
them develop to become more critical practitioners in their field (West, 2011). Without my supervisor’s experience guiding me, the findings and in turn generated understandings from the research could have developed down quite different paths, and could have encountered some of the commonly cited limitations of action research. One of those difficulties could have included non-critical reflection during the process, which could have led to the description of events rather than critical appraisal of underlying behaviours. This was alleviated to some degree by acknowledging that I needed to remain conscious of my reflexive issues (Xerri, 2018) and through critical conversations with my academic supervisor. Another limitation could have been the narrowed focus on cognitive results, countered in this study by an emergence in theory, through a comprehensive literature review (Lincoln & Guba, 2000) which generated more diverse theoretical concepts and a bottom-up approach to coding data, rather than the application of pre-set codes on data generated (Braun & Clarke, 2006). Through acknowledgement, reflective questioning, critical discussions, immersion in literature, and a conscious awareness, I attempted to place the reflexive issues of my position as teacher and researcher to the fore of this study and make clear its impact on the study.

3.9 My action research approach

The primary objective of this research was the implementation of methodological change into my teaching practice in the subject of chemistry. The generation of knowledge in relation to subject content occurred, but that was not the initial aim of the study. Through the development of my teaching practice, I was seeking to provide a better educational experience for my students and this linked with the moral aspects of teaching and the ethical/democratic processes that were rooted within action research (Feldman, 1996). A process of theorising practice, based on the knowledge gained through an engagement with literature in this study, will utilise both theoretical knowledge and practical experience (Thompson & Pascal, 2012). Thompson stated that a better connection between theory and practice could be achieved, through the investigation of practice, coupled with the use of the theory of professional knowledge to help make sense of challenges within practice (Thompson & Pascal, 2012). The inclusion of the aspect of a theorising practice
in action research led to a spiralling process where knowledge was derived from practice and practice became informed by knowledge and theory (West, 2011). This practice also engaged with Elliott’s (Elliott, 1991, as cited in Feldman, 1996) concept of “reflective educational practice” (p. 516). He discussed that when inquiry, improvement of practice and professional development were placed within a moral framework, action research could seek to integrate teacher development, syllabus development, research and philosophical reflection into an amalgamated concept (Elliott, 1991, as cited in Feldman, 1996). This was demonstrative of the overall aim of my action research approach.

The understanding of the terms action and research that were used in this study were; research was a systemic critical inquiry that was made public and action was that a better understanding of a complex system was gleaned from acting within that system and paying attention to the effects of the actions implemented (Feldman, 1996). Systematic inquiry implied that a certain procedure and format was used in the process (James & Augustin, 2018). As outlined, there was a great diversity in interpretation and understanding for the term action research. In this study, the term action research related to practitioner-oriented inquiry into my teacher’s practice and students’ engagement in the classroom (Mamlok-Naaman & Eilks, 2012). This research, through systemic critical inquiry included three main phases; planning, implementation and reflection. These phases reflected Lewin’s three-step process, with reflection used as a term instead of assessing (West, 2011). Reflection in this study incorporated an element of assessment as part of the critical reflective process. Data sources used during this study included; reflective planning leading to the development of lesson plans, field notes, reflective diary and co-generative dialogue with students. The inquiry occurred in the problem-setting of the classroom and the use of action was informed by theory. The research led to theory enacted changes which were implemented in the classroom. These actions and their subsequent effects generated a developing understanding of practice and theory, that in turn developed my pedagogy. The planning for the inquiry was informed by education research and the findings from practice informed the theory that was being enacted in the classroom, which led to greater understanding of the complex context bound system of the classroom. Understanding was derived from practice, supported by theory and was applied to practice again. This process continued to develop
deeper understandings about practice and theory and the spiral of action research continued (West, 2011). This was an important aspect of my study, as it employed theorising practice, the development of both theory and practice and not one over the other. If the sole generation of educational theory was the focused aim of the research, then it would not take into consideration the complexity of practice. Likewise, if improvement of practice was enacted without the inclusion of educational theory, practice would remain blind to certain aspects of educational theory that could be beneficial to progress (Luttenberg, Meijer & Oolbekkink-Marchand, 2017).

This study’s action research adopted the view that an abstract set of rules or procedures could not be directly applied to a complex context. Instead the context and culture in which this study occurred was taken into consideration and judgement, communication and experience were called upon as much as scientific educational pedagogic knowledge (Hammersley, 1993). Action research through this approach produced context-specific understandings about the processes of learning in the given context (Colucci-Gray et al, 2013), and the development of the teacher’s self-image, both personal and professional. Action research also examined my personal beliefs and the connections between them and my teaching practice, with the aim of finding an equilibrium between teaching practice and personal values and beliefs (Colucci-Gray et al, 2013). An important outcome for this study, was not only the production of knowledge that could contribute to a developing understanding for teaching, but the development of a “different way of knowing”. This different way of interpreted knowledge then facilitated a bridge between theory and practice, which generated, not singular knowledge, but a new vista on understanding practice (Colucci-Gray et al, 2013, p. 130).
Figure 3.3 represents the cycles of impacts that occurred within my action research approach between the different focus areas of the study. Action research was employed through the systematic inquiry of practice guided by social constructivism. The initial impact during the research is represented by the arrow going from social constructivism/action research towards changing teaching. This demonstrates that research into social constructivist methodologies and action research was utilised to develop planning to support a change in teaching practice. This arrow continually feeds into the planning for changing teaching throughout the duration of the study. This was an example of Thompson’s theorising practice (Thompson, 2010 as cited in Thompson & Pascal, 2012). Research based planning supported the generation of lesson plans for this changing practice. This demonstrated the main aspect of the
planning part of the action research in this study. Research-based lessons were then executed in practice and this equated to the implementation part of the research. During the implementation of the informed lesson plans, field notes on experiences during the lessons and reactions of both the students and the teacher were recorded. Field notes were short hand descriptions of incidents that occurred during lessons, that were then written onto the printed lesson plans for each lesson. The incidents included aspects of the lessons that were both positive and negative, from both the teacher and students perspectives. A large representation of field notes included student responses to planned activities, i.e. student comments (good or bad), student engagement levels (i.e. their capacity to stay on task, taking personal responsibility for their own learning), student development of understanding and student questions that could demonstrate both understanding and difficulty with the planned activities. Reflecting on the teaching experience was another focus area and represented the reflection part of action research in this study. Reflection was used as a method to take careful consideration of the effect of the actions taken during the practice of teaching. Reflection during this study involved different processes, that were gathered together into a digital reflective diary. End of lesson reflections were hand written into a reflection section on my lesson plan template. Generally, this was the back of the lesson plan which was blank, with the heading reflection and I wrote into that space. These daily reflections built into weekly meta-reflections and the weekly reflections helped to develop the cycle meta-reflections. All reflections were initially hand written and then transcribed into the digital reflective diary when possible. The digital reflective diary was a password protected word document on my computer. Reflection on teaching then informed and impacted the research orientated planning for changing teaching. In this action research cycle, education literature informed practice, practice developed reflection and reflection informed and impacted practice, and the cycle continued, with research again informing a now impacted practice. A methodological issue of individual focused reflections was lessened as the reflections were discussed and informed by dialectic discussions with my academic supervisor.

The third focus area of the research was the involvement of student voice on teaching. Student voice was incorporated in this study through the collection of student artefacts and field notes on students actions, reactions and understanding over the entire period of the study. Another inclusion method for
student voice was co-generative dialogues (co-gens). The co-gens took place during cycle four and five and were held with student representatives from the chemistry class. Cycle three was due to have at least one co-gen, however the short time of the term, and inopportune timing for the students resulted in no co-gen occurring in that cycle. Co-gens were not attempted in cycle one and two as the reality and effort of changing practice and developing data collection practices, while working full time, was acknowledged as the focus during that time period. The change in teaching practice impacted on the students. Involving them in co-gens, to include their voice and opinion on the changes to teaching further impacted the teachers’ action research change to practice. The involvement of the students included their opinion on social constructivist methodologies of teaching that were being used in the class and what was effective for them. In the following part of this chapter, the focus areas of pedagogical change, reflection and student voice on teaching are discussed, along with different practices carried out in each focus area which provided sources of data for analysis during the study.

3.9.1 Changing teaching – Focus area 1

Pedagogical content knowledge (PCK) was understood to be a link between teachers’ knowledge of content and pedagogy of choice that included rationale not just procedure (Shulman, 1986). To develop PCK it was acknowledged that reflection on experiences in the classroom and the use of different perspectives could promote understanding into practices that could promote student development (Loughran, Berry & Mulhall, 2012). Reflective planning during this study was aided by research into chemical content knowledge and social constructivist methodologies. Action research cycles allowed for practice and reflection on the practice, to inform the next cycle of reflective planning.

Part of the focus in planning was towards social learning and social constructivist teaching methodologies. Reflective planning was informed by previous teaching experiences as well as educational research. A limitation of reflection, stated in other areas of literature, was the lack of planning or use of previous experience to help inform future actions. To create a more informed critically reflective practice, issues of planning were incorporated into reflection (Thompson & Pascal, 2012). Reflection-for-action was therefore used as a
method to aid and develop reflective planning on pedagogical change. During reflective planning, critical reflection was used to question and challenge previous teaching practices and why those practices were followed. This process allowed me to question my ingrained beliefs as a teacher and I began to dismantle and regrow my teaching values from a more informed position. This informed grounding came from the interaction between experience and research into theories of social constructivism, educative pedagogy (for example Vygotsky, 1997) and the practice of reflection. This reflective planning led to the development of units of work that took into consideration chemical content, pedagogical approaches, the students ability to develop through the learning activity and rationale for the decisions and actions taken. This was the initial action of pedagogical change.

**Data source: Lesson plans**

Lesson plans encompassed social constructivist learning methodologies, chemical content and the pedagogical knowledge of the teacher to develop the students understanding of chemistry. The theoretical constructs within the lesson plan were being carried out in the complex reality of the classroom. The lesson plan was a link between subject content, learning approaches and the progressive development of the student. Teaching in a social constructivist manner was aimed at promoting experiences that got students to become active participants in their learning process (Gordon, 2009). Some of the experiences that promoted the students into active participation included; problem based learning, inquiry activities, dialogue with peers and teacher, exposure to multiple sources of information and opportunities for students to demonstrate their understanding in different ways (Gordon, 2009). These experiences were identified through the action research cycles and developed into the lesson plans to further promote a change in teaching.

During this study, I used a trial and error process for the development of the lesson plan format. This was a productive method of development, as each of the lesson plans grew from the previous format and improved. The format also benefitted from the use of the lesson plan during practice and how it aided or not, my development of the lesson. Reflection also provided insight into the how the lesson plan, content and format might have impacted the lesson. During this study, four different formats of lesson plans were used, before the fourth
format was developed as the final version to include; learning outcome of the lesson, teacher and student guides to the lesson, key terminology to be used (if needed) and homework. This format was also a daily lesson plan, rather than a weekly format as used previously.

**Data source: Field source**

Field notes provided a record of what occurred during the lessons, and to a lesser extent the co-gens. As I was a participant in the study the field notes were short-hand notes on my lesson plans, or notes during the co-gens, and mainly recorded student comments, positives aspects of a lesson or times where there was a difficulty or I was uncertain of something in a lesson. In general, the notes tracked emotion, of both the teacher and expressed emotion of the student. The field notes were transcribed and provided contextual information from in-action practices for the teacher reflections after the class. The field notes were also an attempt to reduce bias and try to recall with as much accuracy as possible what happened in the classroom. The field notes were not needed to the same extent in the co-gens as these were videoed. Field notes were recorded in lessons with high student activity. In this study, a lot more of the lessons were student-centred rather than teacher-centered, which provided the teacher with the opportunity to note and short hand record different interactions, comments and questions as she was observing the students working.

### 3.9.2 Reflecting on teaching – Focus area 2

In the development of a social constructivist influenced teaching methodology, an aspect also developed was the teacher. It was important that the teacher critically reflected on the practices employed, through the action research cycles. This critical reflection of the teacher allowed for implicit and explicit belief systems to be examined in relation to the actions taken in the classroom. This reflection was also a social process, which ensured that normalized behaviours for the teacher were revealed and conceptual change began to occur at a practitioner and practical level. Reflection within action research was used to address the complex reality faced by teachers in practice and asses the resultant effects of the actions taken.
The purpose of recording reflections after classes, was to capture, as much as possible, a true account of in–action practices that occurred. Through this I was also able to capture the self-developmental awareness of issues and constraining contexts and practices in the classroom. I was aware of the complexity surrounding the issue of the temporal boundary of the concept in-action and that reflection–in–action could verge into reflection–on–action, as distance, with time, occurred. The development and use of the in–action reflections linked to a discussion in Kayapinar's 2016 paper. He indicated that in–action reflections could be saved to be built on previous observations and to build observations to be then used as reflection–on–action. This practice of building the reflection–in–action experiences resonated with the method of "describing" developed by Smyth (1989, p.6). Describing was the creation of a text of elements. With the creation of the elements that occurred within practice, I was using those elements to problematize issues within teaching, and gain perspective as to how those problems were solved habitually in practice (Kreber, 2005). It was evidenced that the compilation of field notes and lesson reflection could provide a rich data source for the examination of actions and words in-context (Maharaj, 2016). Limitations to the practice of lesson reflections included; an over identification of prominent instances which could result in ignoring less prominent events and the human tendency to recall events more favourably than they occurred (Gelfuso & Dennis, 2014). In the effort to lessen those effects, the lesson reflections and field notes were made public to my academic supervisor and video was used to record my teaching, and to act as a recall event for further reflections. Even though there were limitations with this process, lesson reflection after the event helped to capture reflection-in-action as it occurred.

Use was made of a digital reflective diary during reflection–in-action and reflection–on–action. The use of the diary enabled the development of a discourse about my teaching and helped to organise an account of those experiences in a way that helped me find and speak with my own voice (Smyth, 1992). The reflective diary was written in my daily vernacular and as Smyth
stated, that created a genuine ownership of the experiences for the teacher. Reflective diary comments included feelings, reactions, initial interpretations, speculations and a working hypothesis and this setting for autobiographical notes created a reflective record of my behaviour and emotions during this study. The organisation and gathering of the reflective diaries also developed into the ‘informing’ part of Smyth’s (1989) reflective model and looked at what the experiences could mean and what pedagogical principles and actions could be uncovered. My reflective diary in this study was not a dedicated notebook as the term might conjure, but a dedicated section within every printed lesson plan I enacted during the school year. Figure 3.3 provides a diagrammed representation of the cyclic use of reflection in my practice, during this study’s action research.

![Figure 3.4 Representation of the cyclic use of reflections during the study](image)

Figure 3.4 also represents the integral nature of reflection in this study. Beginning with planning for pedagogical change, which was discussed earlier, the orange arrow then directs towards the planned action being implemented in the classroom. During most lessons, field notes were taken, based on emotions felt, impact of action and student comments. The aim was for the lesson reflection to be written as soon as possible after every class. Lesson reflections were written for the majority of lessons throughout the entire academic year. At the end of each week I gathered together the daily lesson plans, including field notes, with the reflections and transcribed them into a word document on my
desktop. This collection of reflections represented my weekly reflections. From the weekly reflections, improvements that could be made were noted, and incorporated into the planning for the next week of lessons, which began the cycle again. The informed actions were implemented in practice, which led to lesson reflections and then, again, into weekly reflections. Those weekly cycles and reflections were built into the major cycles, which were determined by the terms in the academic school year. There were five major cycles of action research with the weekly cycles building to end of cycle reflections, and then the end of cycles bringing informed actions into the planning for the next cycle of research and teaching. This process provided immediate feedback which disseminated back into practice, and this practice continued to build on itself during the year. My reflections included my interpretation of what occurred within classes and provided me with an opportunity to critically assess what was occurring within the study. The diary allowed me to analytically and systematically interrogate my thinking, actions and assumptions and my interactions with the students during the study (Mooney-Simmie, 2007). The diary method also promoted engagement in some preliminary data analysis (Braun & Clarke, 2006). The diary allowed me to reflect on the workings of each lesson and to decide how I could best facilitate subsequent lessons, for example, ensuring opportunities for student voice or modifying a teaching approach in response to feedback received.

3.9.3 Student voice on teaching – Focus area 3

Co-generative dialogue (co-gen) was used in cycles four and five of the study and provided an opportunity for the students to voice their opinions on what was happening in the classroom. In this study, four students were selected from the students who volunteered from the chemistry class. The four students were chosen as they were representative of the variety that existed within my chemistry class. The four students all had different academic abilities and different cultural backgrounds. Their diversity was important, as they could act as representatives for their classmates within the co-generative discussions. They were informed that when they were discussing or giving their opinion, they should try to act as representatives for their classmates. In their responses they were to attempt to incorporate what their peers might say, rather than completely individual and subjective responses. It was important to think about
what students ‘like them’ thought of different ways of learning within the class. In all three co-gens, the student group remained the same. This was decided in consultation with my academic supervisor prior to the co-gens. This decision was informed by experience of another researcher who upon changing her co-gen members each time, reflected that a better relationship could have been developed if the group of students had remained constant. The guiding idea or question within each of the co-gens ran in this study was; “how can we improve learning in our class”. Co-generative dialogue was a method to create a more democratic process within classrooms in turn, providing a rebalancing of power, away from teacher-centric towards a teacher-student collaborative learning space (Martin & Scantlebury, 2009). Co-generative dialogue was not a once-off event, as it needed to be developed over time and could be different for every group that it might be completed with.

The co-gen carried certain procedures that should have been adhered to by all involved, from the start of the co-gen and throughout. The procedures had the intention of lessening the impact of the asymmetry of power that could exist in the classroom, and developed a collective responsibility for the improvement of learning. The students were asked, as a class group, if they would be willing to take part in discussions with me outside of class time, in relation to the learning that was happening in the classroom. The discussions were to take place at lunch time and this information was given to the students. The co-gen members were chosen from the students who volunteered to take part in the discussions. The majority of students in the class expressed an interest in being involved in the discussions. The student co-gen members were from different spectra of the ability level that were present in the class. This was to provide a voice for as wide a range of the student population as possible, as the student participants were representatives for the class. It was decided, as part of the procedures, that all information and action decided upon in the co-gen would be brought back to the whole class for further discussion or agreement. This was part of the co-gen procedure to ensure ethical practice (Stith & Roth, 2006), in the effort to avoid a small proportion of the class determining actions for the whole class community. The co-gen, ideally, would have taken place outside of the school building, but due to time constraints, this did not happen. Instead, a meeting room, that students did not normally frequent was used. All participants sat in a circle at the same physical level, with no one person sitting at a higher level than others (Stith & Roth, 2006). The rules of the
co-gen were stated from the outset, and at the start of each co-gen, those rules were stated again. This was to ensure that all participants were aware of the rules and their responsibility towards them. This collective responsibility led to co-generated discussions with a collative goal agreed upon at the end by all parties involved. Ethically, each member of the co-gen was responsible for each other’s freedom and equal voice. If the rules were not held, the effectiveness of the co-gen as a collective agent for change was hampered (Stith & Roth, 2006). The rules of this co-gen included; everybody’s opinion and ideas were important, students were representing their fellow classmates, one person at a time should speak and that the rest would honour that, no one (including me) would speak over a person and any co-generated action/solution would be brought back to the class. It was important, in the equalisation of power, that students experienced their feedback and opinions being taken seriously and that co-generated solutions were brought back to the class and enacted in the classroom. The students were told that their thoughts and feedback were important, and if they did not experience positive or real outcomes from this, then the cycle of trust and interaction built up could be broken (Stith & Roth, 2006). Dialogues that occurred within the co-gen space provided an experience in which no voice was privileged and suggestions were given as to actions that could help improve learning. These suggestions were then enacted upon in the classroom to promote the action of learning in the class with the teacher and the students (Murphy & Carlisle, 2008).

**Data source: Co-generative dialogue**

With the implementation of co-generative dialogues in this study, I encountered some difficulties. Some of the difficulties included; practical issues, such as timing and finding a free meeting room when needed, a dominant personality in a quiet group, Irish students tending to be very shy in expressing their ideas and reverting to a hierarchal teacher position during the first co-gen. The reversion to a teacher position, in the initial co-gen went against a core ideal of the co-gen: the attempt to minimize the power hierarchy that could exist in the classroom (Murphy & Scantlebury, 2010). In a feedback session with my supervisor it was pointed out that the first co-gen was set up in a formal manner that resembled an interview. Rather than the entire co-gen group (five people including me) sitting in a circle, all the students were on the opposite side of the
table to me. Not until this was pointed out to me, did I recognise the indirect re-enforcement of a power hierarchy in the co-gen rather than the minimizing of it. This experience illustrated to me bias within my teaching practice that was well ingrained in my behaviour, that bias being the, nearly default, hierarchical power position of a teacher that I had occupied in the classroom. This hierarchical position led to difficulties in the facilitation of a truly collective and collaborative space with my students. The formal atmosphere and asymmetry of power within the co-gen had to be pointed out to me by my supervisor, as I had not recognised it, in either of my reflections. This could be a genuine difficulty with the enactment of co-generative dialogue in Ireland. The position of the teacher has been well ingrained in the culture of schools and this affected how students responded and how the teacher conducted the dialogue. True engagement in a collective and equal dialogue required support and practice.

Another methodological aspect to the implementation of co-gens was the Irish context of this study. An important contextual note was that the majority of research concerning co-generative dialogue was American based and this research informed the procedures that were used in the initial co-gen. It was recognised that there are cultural differences between America and Ireland in regarding the enactment of co-gens and a prominent difference included the Irish students’ reluctance to engage in discussion, compared to American students. Aside from the American-centric research into the area of co-gen methods, there were also very few studies set in Europe. This led to a contextual issue within my study; the Irish males within this study found it difficult to talk to me, as a person rather than a teacher, and found it difficult to discuss education topics with each other. This could be representative of the classroom environment, where normalized behaviour was to interact with the teacher, on a question and answer basis, and not their fellow students. For this method to be used in this context, a few practical adaptations were made based on experience, context and discussion with my supervisor. In planning for the subsequent co-gens, I discussed with colleges and my supervisor methods to help encourage the students to become more comfortable with the possibility of taking part in discussions. A colleague who had previously taken part in student group meetings, said the nature of the classroom tended to come through once you, the teacher, were in the room. He suggested, from his experience, an ice-breaker question that all participants, including me, engaged in answering. This led to the opportunity of a change in the power dynamic occurring. This
information was given during an informal conversation, but it was a method that I employed to some success. My supervisor made a number of suggestions which included; a smaller table so that all people could sit around it equally, some food and leaving the room for the facilitation of more open discussions to occur between the students themselves. Another method introduced into the co-gen was contextually developed resources that generated discussion about classroom practices. The students were getting used to the method we were engaged in, and the development of equal agency between both the students and teacher was emerging from this contextual setting (Murphy & Scantlebury, 2010).

Educational research showed that students needed repeated exposure to experiences and information over time to begin to construct meaning and appropriate the new information and way of being into their current understanding (Martin, 2006). An important acknowledgement was that teachers, as people, were no exception to this, and needed time to make sense of new information and practices (Martin, 2006). A co-gen was not a once off event, it needed to be developed over time and there existed the possibility that it could be different for each group that it was completed with. However, if managed correctly a co-gen could help to provide a platform for teachers to better understand their students and how to motivate them. It could also help the student with the subject becoming more comprehensible, as teaching strategies would be able to link with student understanding in the promotion of student learning (Schultze & Nilsson, 2018). The implementation of co-gens could also act as catalytic research, as this action moves beyond theorising and verbalizing problems to acting to resolve the problem (Martin, 2006). In this study three co-gens took place throughout the academic year and each lasted roughly 45mins. The dialogues were then transcribed onto a word document. It was originally envisioned that five co-gens would take place near the end of each cycle. However, due to time constraints and student availability this was not achieved.
3.10 Data Analysis – Complete

Caution was heeded, from a social constructivist position, regarding the condensing of vast amounts of generated data and of the formulation of codes which may not have fully encapsulated the essence of what occurred during this study. I was also fully aware that my interaction with the data and participants in the research impacted on me as a researcher and personally and that my interpretation of the data in turn was impacted. As a teacher-researcher, my understanding of developing pedagogical methods through practice deepened as the study progressed due to interactions between theory of content and practice of teaching, teacher reflection and feedback from the students in the lessons. Understanding developed the action research, but critical reflections were also used to question my impact on the interpretation of data and to provide a critical voice. Data was generated from field notes on lessons, lesson, weekly and cyclic reflections and transcripts from the cogenerative dialogues that occurred between the teacher and the students. Initial data analysis during the cycles of action research involved preliminary analysis of the generated data into meta-reflections that were compiled from the data gathered during each cycle of inquiry. The meta-reflections were generated from the reflective diary entries and field notes on the classes (the written effect of the action applied).

Schön’s reflection-on-action and critical reflection were utilised, and initial themes emerged from the diary entries and the discourses that occurred in the classroom. This meta-analysis of themes and discourses was developed during the action research, based on the material the teacher produced during each of the cycles of action research (Colucci-Gray et al, 2013). This reflective work and generation of initial themes was also made public to my academic supervisor and dialectic discussions of the themes, as they were emerging at the time were discussed. Informally the themes were also discussed with my colleagues, but those discussions were not recorded. Reflection-on-action reflected on the actions taken during teaching experiences, and critiqued the ability of those actions to promote learning. The generation of meta-reflections and the themes that emerged from them have been described as a means to transfer experience to an applicable form of theoretical experience, based on past learning experiences (Martin, 2006). This was also supportive of theorising practice and the merging and promotion of practice into theoretical practice. While there was a directed textual approach which governed much of the data analysis technique, there were also elements of intuitive researcher
interpretation of the data which were recorded in methods other than those mentioned, e.g. student work during lessons, student interactions at a group level in the class, informal discussions with colleagues. Those methods represented the contextualised practice elements of the study and that they provided rich descriptive detail in which the generated data could position.

Complete thematic analysis (Braun & Clarke, 2006) of the total data generated did not begin until after the data generation was completed to allow time for critical review conversations with my academic supervisor and distance from the initially created themes or conceptions. While the analysis was data-driven, the themes and codes identified were evidenced to be situated within the literature referenced in chapter two. Thematic analysis was the method employed for the data analysis of the study. Table 3.1 is an adapted table of Braun and Clarke’s (2006) “Phases of thematic analysis” (p. 87) which was used in this study to guide the development of themes.

Table 3.1 Adapted “Phases of thematic analysis” Braun and Clarke (2006)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description of process</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Become familiar with the data</td>
</tr>
<tr>
<td>2.</td>
<td>Generate initial codes</td>
</tr>
<tr>
<td>3.</td>
<td>Search for themes</td>
</tr>
<tr>
<td>4.</td>
<td>Review themes</td>
</tr>
<tr>
<td>5.</td>
<td>Define and name themes</td>
</tr>
<tr>
<td>6.</td>
<td>Produce the report</td>
</tr>
</tbody>
</table>
Thematic analysis was utilised to provide a framework for the generation of themes in this study. Use of this framework sought to avoid an issue that can occur in qualitative studies where themes could be described as “emerging” from the data, but lacked sufficient evidence as to how they emerged (Braun & Clarke, 2006, p. 80). This method also offered flexibility for this study in how the themes were determined. In this study, an inductive (bottom-up) approach was used and the themes identified were linked with the data produced rather than being driven by the researcher’s theoretical question or the assignment of data to a pre-set coding system (Braun & Clarke, 2006). The following description used the phases from Table 3.1 and detailed how thematic analysis was developed in this study.

I transcribed the data in this study myself, as it was felt that it was a key phase of thematic analysis to familiarise yourself with the data content. The transcribed data was typed into a word document that was formatted to have a coding margin along the right-hand side of the page (see Appendix 1 for example). I also wrote informal notes and thoughts that occurred to me during the transcription into a coding notebook that I kept throughout the process. In the second stage of the process I printed out the transcribed reflections and transcripts of cogenerative dialogue and attempted an initial coding. This initial coding involved marking interesting remarks, events or incidents with a pen. The coding was by hand and I used different coloured pens and highlighters to denote a difference between codes. The codes were open (not pre-set) and the transcripts went through two-to-three initial coding attempts. Evidence of the initial codes and the method I used to code can be found in Appendix 1.1. During the third phase, a search for themes within the codes occurred. A theme was deemed a pattern that captured something significant or interesting in the data (Braun & Clarke, 2006). I struggled with the search for themes, as from my number of initial codes I found it difficult to group them coherently, or at all, into themes. I decided to approach this phase in a slightly different manner and organised my codes into two distinct areas, and they were; positive critical incident and negative critical incident that occurred during lessons or the co-gens. This process helped me to group my codes with a bit more clarity and from there themes within the two areas began to appear. In the fourth phase, the review of themes became more formal, and I included tables of themes with processes within initial drafts of my findings chapters (Appendix 2).
development of those tables began with a post-it method, with the names of each of the themes derived from phase three on a separate post-it and I moved them around an A3 page to see if there were any overlapping themes, or themes which were distinct and existed on their own. I found that strategy quite useful and employed it for the final phases as well. Those tables were also reviewed by my academic supervisor and underwent several developments. For me, the fifth and sixth process melded together. It was in the act of writing the report that refinement upon refinement of the themes occurred. At the stage of near completion, the themes still underwent analysis of the specifics within, to further the study’s analysis. I found that in the attempt to analyse the study, further thematic refinement occurred, and this led cyclically back to further refinement of analysis regarding the study. Those two phases were interesting and illuminating for me, and were more closely aligned than I initially envisioned. The main themes within this study fall inside three major elements of the practice. They were; teachers’ practice, student engagement and (impact of) curriculum. These three major elements have been the organising factor for the findings chapters in the next section.

**Authenticity and Trustworthiness**

Through an action research approach and data analysis, this study sought to examine the impact social constructivist methodologies had on the teacher and the students. Observations and examinations of interactions between the teacher, students and the methodologies was integral in that process. The social constructivist position in this study acknowledged that different cultural and social background existed within these interactions and it was important that those different perspectives were accounted for throughout out the research (Wassell & LaVan, 2009). This was not a positivist study and the metrics of validity and reliability are inconsistent with social constructivist research. Consistent with the constructivist paradigm that underpins the methodology of this research, Guba and Lincoln’s (1989) authenticity criteria was employed to evaluate the data collection process in terms of authenticity and trustworthiness (as cited in Wassell & LaVan, 2009). According to Guba and Lincoln, in order for a study to be authentic and trustworthy, it should meet five criteria; fairness, ontological authenticity, educative authenticity, catalytic authenticity and tactical authenticity (as cited Wassell & LaVan, 2009). Table 3.2 is adapted from a table in Murphy, Carlisle & Beggs’ (2009) paper examining
co-teaching, it’s different models and criticisms and the use of Guba and Lincoln’s authenticity criteria (as cited in Murphy, Carlisle & Beggs, 2009). The table evaluates this study’s methodological approach under the criteria of Guba and Lincoln’s (1989) (as cited in Murphy, Carlisle & Beggs, 2009) authenticity criteria.

Table 3.2 Adapted table of Guba and Lincoln’s (1989) (as cited in Murphy, Carlisle & Beggs, 2009) authenticity criteria

<table>
<thead>
<tr>
<th>Authenticity Criteria</th>
<th>Key Definition</th>
<th>Evidence in my study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fairness</td>
<td>Multiple and overlapping data resources and rich descriptive data which accounts for participants' diverse perspective</td>
<td>Variety of data sources such as lesson plans, reflective diary, cogenerative dialogues with students', field notes and observations, artefacts from classroom activities. Development of a researcher-participant relationship where the researcher actively engaged the students in the process and the perspective of the students are continuously considered.</td>
</tr>
<tr>
<td>Ontological Authenticity</td>
<td>The degree to which participant’s emic constructions are developed, enhanced or expanded</td>
<td>Participation in cogenerative dialogues promoted the identification of ways that learning experiences could be structured to increase students’ autonomous learning and teachers’ (the researcher) agency.</td>
</tr>
<tr>
<td>Educatively Authenticity</td>
<td>The educative criterion which evaluates the participants’ understanding of and appreciation for others’ constructions of reality</td>
<td>Use of cogenerative dialogues, student artefacts &amp; field notes to recognise how different students learn and how they respond to social constructivist learning approaches, as individuals and as a collective.</td>
</tr>
<tr>
<td>Catalytic and Tactical Authenticity</td>
<td>The extent to which action is motivated and participants are empowered to act</td>
<td>Cogenerative dialogue as a field that allows participants in the research to be involved in proactively theorizing and catalysing change. The structure of cogenerative dialogue allows students to actively contribute to teaching and learning, increasing their social and symbolic capital. The development of more democratic roles within the classroom.</td>
</tr>
</tbody>
</table>
3.11 Ethics of the study

The ethics procedure laid out in the School of Education (Trinity College Dublin) handbook was followed and the nature of the study, the information given to the participants and the consent asked of them was cleared by the School’s Research Ethics Committee (appendix 3). The nature of the research was transparent, always, to the participants and they were made aware that the overall inquiry related to their participation in cogenerative dialogue as students in cooperation with the teacher, with the aim to collaborate to improve practice in the chemistry classroom. Due to the research being carried out on children under the age of eighteen, the ethics level of this study was at level 2. The research would have a moderate risk, due to the age of the participants. The research was carried out on the site of the researchers own school and place of employment; therefore, Garda vetting through the teaching council was sufficient and secured. The focus of the research was the researcher, but student voice was extremely important and ethics was sought for collection of student generated data and video recordings of the students during the cogenerative dialogues. Co-generative dialogues with the students began once ethics had been approved. All students within the 5th year chemistry class received an information sheet, which contained information about the overall purpose of the study, and included the possible risks and benefits of participation in the study. Student consent sheet and parent/guardian information sheets and consent sheets were also distributed. On the parent/guardian information sheet I included my professional email address and the phone number of the school, in case they wanted to ask any questions about the study. It was made clear to both students and parents that involvement in the study was on a voluntary basis and the students were informed that they could leave the research at any point, without having to give any explanation. Pseudonyms were used for the students’ names throughout the study and in this thesis to further confidentiality and anonymity. Video data and associated transcripts were stored on my personal desktop computer and on a memory cloud. Electronic data on the desktop and cloud could only be accessed using a personal password. Printed copies of transcripts were stored in a locked cabinet.
Chapter 4: Impact of social constructivist methodologies on teacher practice

(Findings and Discussion 1)

4.1 Introduction

The main research question of the study is; “can social constructivist methodologies affect teacher practice, and/or student engagement in chemistry?”. The first sub-question of this study is the focus of this chapter; “which social constructivist methodologies impacted on my practice, and how?”. The findings within this chapter provide evidence that social constructivist methodologies affected teacher practice and detail which approaches were effective and how they impacted practice. Elements of my practice that were affected by social constructivist methodologies included; pedagogy (learning and teaching), assessment and reflection.

This study utilises an action research approach and observations of the researcher concerning teaching approaches, student reactions and comments are noted. The researcher at points in this chapter, discusses their previous practice and how that relates to experiences during this study. Any comparison mentioned in this study is relative to the researchers own previous experiences (similar students in previous years), not a comparison to a control group. The first section of this chapter details the impact social constructivist actions had on the teacher’s practice, specifically learning in the classroom. The following sections discuss assessment and then reflection, and the impact social constructivist actions had on those practices. Teaching, assessment and reflection, comprise the main sections of this chapter. The three areas are represented in table 4.1, which includes a summary of the impacts that were experienced during the study. The final piece of this chapter is a discussion on how social constructivist methodologies impacted my teaching practice.

The social constructivist approach to planning led to the development and practice of many learning and teaching methods within the classroom. These methods were developed with the aid of Vygotskian principles, which included; the social construction of knowledge, instruction to lead development and the importance of social interactions. The promotion of student
engagement, i.e. active and positive student involvement in their own learning, and social interactions were developed using social constructivist designed learning activities in the classroom. These learning activities also accommodated for greater formative assessment to take place and the incorporation of critical reflection into teaching practice.

Throughout chapters four, five and six, different written fonts are used to signify the difference between information from the teacher’s reflections during the study and the students’ comments and discussions during the co-generative dialogues. The teacher’s reflective thought and information from the reflective diaries and field notes, is in a Noteworthy, italic font. The student input is in a Futura font and is also in italic.

Table 4.1 Summary of main areas of the teacher’s practice and their impacts

<table>
<thead>
<tr>
<th>LEARNING</th>
<th>SC+ Method implemented</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>New learning unit – scientific enculturation</td>
<td>Development of a social constructivist understanding of the nature of chemistry</td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td>Implemented dialogue in the classroom</td>
<td>2.</td>
</tr>
<tr>
<td></td>
<td>Introduction of support was required for students during discussions involving the nature of chemistry</td>
<td>3.</td>
</tr>
<tr>
<td></td>
<td>Development of new resources for teaching which that promoted active collaboration between students</td>
<td>4.</td>
</tr>
<tr>
<td>Change of the sequencing of learning</td>
<td>Developed a better understanding of progression for the subject of chemistry from student feedback and reflection</td>
<td>1.</td>
</tr>
<tr>
<td>Peer learning</td>
<td>Inclusion of a social element of learning promoted the active engagement of students</td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td>Social interactions provided opportunities for the development of learning</td>
<td>2.</td>
</tr>
<tr>
<td>Developed use of open questioning</td>
<td>From initial struggles, developed a better questioning method to be used in class</td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td>Recognised the importance of the feedback from the students when using these questions</td>
<td>2.</td>
</tr>
<tr>
<td>Use of problem-based activities and the application of concepts as tools</td>
<td>Reconceptualised the development of learning activities and resources</td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td>Recognition of importance of students applying what they have learnt rather than the repetition of information</td>
<td>2.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ASSESSMENT</th>
<th>SC Method implemented</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formative assessment using open questioning</td>
<td>Recognition and implementation of formative assessment as a method of monitoring learning development in the classroom</td>
<td>1.</td>
</tr>
<tr>
<td></td>
<td>Reconfigured teaching approaches based on student feedback</td>
<td>2.</td>
</tr>
</tbody>
</table>
4.2 Impact of social constructivist methodologies on teaching in the classroom

This section details five learning strategies that were implemented into the teacher’s practice during this study. The impacts of each of these strategies are stated in table 4.1. The strategies were developed from research into the area of learning theories, specifically social constructivist methodologies relating to teaching. The five strategies were; the inclusion of a new unit of learning incorporating scientific enculturation, the change to the sequence of learning in the class, the use of peer learning to develop dialogue between students, and between the students and the teacher, developing the use of open questioning through lessons and the design of problem based activities that encouraged the students to apply the concepts they developed through the classes. The impacts that resulted from each of the learning strategies is discussed within each strategy’s section and the effect they had on the teacher’s practice. The research, development, implementation and reflection of these learning strategies moved pedagogy away from a previous traditional teaching approach, towards a more open and social pedagogy.

4.2.1 Introduction of a new learning unit – scientific enculturation
Implementation

One of the first strategies implemented to effect change into teaching practice, was to change the curriculum sequence of previous years. The introduction of a new learning unit, which incorporated scientific enculturation, provided opportunity for discussions on the evolving nature of science and the inclusion of dialogue during the lessons. The social impact on science and the use of dialogue in the lessons, were aspects of social constructivism that were supported and developed throughout this study. Through social constructivist research and planning for this study, a self-contained learning unit called scientific enculturation was developed. The unit contained six lessons, with the application of scientific skills being an overarching aim of the lessons. The lessons also included the presentation of chemistry, and science in general, as a human endeavour that is subject to the social conventions of time, and the inclusion of dialogue between participants in the class. The structure of the enculturation unit and the focus for the lessons can be seen in table 4.2.

Table 4.2 Summary of the plan for the scientific enculturation unit that was implemented in this study

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction – What does chemistry mean to them? Discussion – Do scientific discoveries always follow the same path? (Examples given to promote thought)</td>
</tr>
<tr>
<td>3</td>
<td>Patterns and problem solving. Through investigation. Objectives – develop recognition of patterns from given data, develop problem-solving skills through inquiry cube activities, and make predictions based on given evidence and patterns</td>
</tr>
<tr>
<td>4</td>
<td>Modelling and evaluation. Model Tube activity – develop a working model and discuss difficulties associated with models and observation and application of other models in science</td>
</tr>
<tr>
<td>5</td>
<td>Evaluating evidence. Evaluating evidence, communication and ethics in science. Mario Molina activity sheet and the responsibility of scientists</td>
</tr>
<tr>
<td>6</td>
<td>Summation activity – incorporating all scientific processes. Develop an understanding that science will change with time and the development of new technologies. Creation of a chemistry toolkit – skills or ideas they think they might need for studying chemistry</td>
</tr>
</tbody>
</table>

The enculturation unit provided support for the students when introducing the social constructivist nature of chemistry, which could be quite
different to their initial conception and experience of science, both within and outside school. The nature of chemistry presented within the unit demonstrated an understanding of chemistry that could be broader in nature than the science the students might have encountered during their junior certificate. The unit also aimed to develop communication skills, through dialogue and scientific discussions.

The development and introduction of a scientific enculturation learning unit had a very strong impact on my teaching practice and on my conception and understanding of science. This strong impact manifested in many ways, and the next section details the four main impacts the approach had on my practice. The impacts on my practice include; the development, and engagement with, a social constructivist understanding of the nature of chemistry, implementation of productive dialogue in the class, recognition that the students needed support when developing their understanding of the nature of chemistry and the development of new teaching resources that promoted active collaboration between students. The following section discusses in more detail the four main impacts on teacher’s practice from the implementation of the scientific enculturation learning unit at the beginning of the year.

**Impact 1: Development of a social constructivist understanding of the nature of chemistry**

During the development and implementation of the new learning unit, a growth in personal understanding of the social constructivist position of the nature of chemistry occurred. This understanding incorporated the idea that the nature of science is impacted by the social context and that as a human endeavour, it is both tentative and evolving. This was seen in teacher reflection (see appendix 4 for example of teacher reflection), near the end of cycle one;

*I would like to try to de-demonize the unknown for them [the students] a little bit – not to confuse them, but to let them know that the unknown is not a bad thing. It is in fact something that should excite the curiosity within them and understand that science only moves forward because of the unknown.* (Teacher reflection)
In this reflective extract, the evolving understanding of the nature of science and how humans can progress science, emerged in my thinking and in my interactions with the students. Engagement with social constructivist research and its implementation into teaching, has broadened my outlook on science. The progression to a more socially constructivist understanding was furthered through the recognition of alternative opinions, the social impact on science, and that understanding of phenomena was constantly evolving as knowledge continued to grow. Experience was gained in instruction that promoted learning using a social constructivist approach, through the experience of this learning unit. It was the engagement with research into social constructivist methodologies that moved pedagogy from a mainly traditional stance, to a more open and evolved understanding. The development of questions to promote student engagement and thinking was incorporated into lesson plans in this study (see appendix 5 for lesson plan). This development of thought provoking and engaging questions was at a much higher level in this study, when compared with the development of lessons in my previous practice. Previous practice did not include time spent pre-planning curiosity, or thought-provoking questions. An example of curiosity questions that were developed in this study can be seen in the following example;

*Do you think discoveries in chemistry/science have always followed the same set of rules/path? Why or why not. What type of skills would a scientist need in today’s world? (Lesson plan, see appendix 5)*

The development of questions that critiqued the traditional scientific method and posed more open questions demonstrated the growth of my personal understanding on the social constructivist nature of science. The development of these questions demonstrated that I appreciated the need to probe students thinking and understanding, and get them to start questioning what was happening around them, just as I was with my teaching practice. During the fourth lesson in the enculturation unit (see appendix 6 for lesson plan) there was evidence of a student alternative approach used in an activity (model tube activity, see appendix 6), as a teaching opportunity. The incident was described in a reflection after the class;
A group managed to develop the same movement using a different method which was used as a teaching point. This was used to demonstrate that different points of views or methods can be used but we can still arrive at nearly the same point. (Teacher reflection)

The recognition of the student’s alternative approach, as a positive aspect of the class, was evidence of the development of pedagogical process towards a more social constructivist understanding. In this lesson, this experience was taken as an opportunity to demonstrate that different methods were possible, and more likely to occur when compared to a rigid structure of procedure. The understanding of chemistry as an evolving, human endeavour continued to develop throughout the study. Through research and the development of this learning unit, a social constructivist understanding of the nature of chemistry developed, along with recognition of how this understanding impacted on chemistry teaching.

**Impact 2: Implementation and development of dialogue in the classroom**

In school, students spend much of their time sitting down and listening during traditional teaching style lessons. Progressing from research into social constructivism, it was recognised in this study that an important culture to change was the transmission of information from teacher to student. The transmission of information, in many cases, resulted in an inactive and passive student. A strategy employed in this study to impact a change in traditional teaching culture was the introduction of dialogue during the new learning enculturation unit. Dialogue was promoted through the design of collaborative activities which took place during the enculturation unit. An example of a collaborative activity that promoted the use of dialogue among the students was evidenced during lesson two of the learning unit (see appendix 7). In this activity, students worked together in pairs, to gather as much information as possible about an unknown object that was concealed within a closed box. The activity promoted student dialogue through the design of questions that could further their thought process in achieving the aim of the task. These questions can be seen in figure 4.1.
Due to their engagement with the task, students communicated readily with their partners in relation to the main aim of the activity. Their dialogue promoted their active initiation of investigation before I prompted them. This was mentioned in the reflection from the lesson:

*I noticed that before I gave the second or third question above, [questions to drive learning, figure 4.1] students themselves were picking up objects and moving them and weighing them in their hands to compare against what was in the mystery box (Teacher reflection).*

In this example, the students’ engagement with dialogue to achieve the aim of the task provided evidence of an initial change to the transmission culture. The students became actively involved in their own learning, i.e. they engaged with the activity.

The increased use of dialogue also encouraged the development of students as active participants in their learning. In the following example, recorded as a teacher reflection after a practical class (sometime after the enculturation unit), the brief vignette notes that the students themselves, engaged in discussion which led to them connecting the learning objective to the task. The students were active participants in this lesson and took the lead in their learning, rather than passively waiting to be told what to do next.
... but with a practical demo and peer talk, hopefully the introduction to the topic was a bit smoother ... They worked well on the ordering and reasoning, with nearly all groups getting the order correct and the majority linking the correct reasoning. First experiment in a while and the organisation of the students was of a very high standard. (Teacher reflection)

The initial enculturation learning unit developed dialogue between all participants of the lesson, as evidenced in the examples above, both during and after the unit was completed. It also helped students understand that dialogue and discussions would be a normalised practice within the class, rather than the exception. The development of communication skills within this unit was a starting point. Once dialogue was established, then the ability of the students to interact with their peers in a supportive and educationally co-operative manner was fostered. The unit was also trying to break the traditional expectation that students might associate with a classroom setting. Expectations could include; passive listening to the teacher and completion of individualised tasks. During this study, the students were very much the focus of the lesson and had to engage with the material and become active in their learning. The habit of dialogue continued, and grew in importance for the students, throughout the study.

Important impacts of the use of dialogue in the class included; students developed communication skills during the unit, movement away from a traditional teaching culture and the active involvement of students in their learning. Another impact, due to the inclusion of dialogue in the classroom, was the recognition that students needed support in the development of a social constructivist nature of science. Support was required as students could experience difficulty when the nature of science that was presented in the lessons during the study ran contrary to their experience of science. Dialogue was an important contributing factor to the teacher identifying student issues during lessons. Without dialogue with the students, the identification of these issues would be more difficult, and could go unacknowledged, due to the lack of interactions with students.
Impact 3: Introduction of support for students during discussions involving the nature of chemistry

Due to the introduction of dialogue in the classroom, and discussion with students, it was recognised that students could struggle with the nature of science and that providing them with support could benefit their learning. In the following teacher reflection, I noted that students struggled with an investigation task in class, and on reflection acknowledge that more support would be needed in future for the students to progress their learning.

Students found trying to plan for the investigation quite difficult ... I would support this better the next time and realise they do need more guidance, particularly at the start. (Teacher reflection)

The recognition of this difficulty for students led to the introduction of additional support during lessons. It was appreciated that if students became frustrated with an activity, they might disengage and this could impact negatively on the development of their learning.

The need for the provision of support in developing the nature of science, could be attributed partly to the experience of science the students had in the junior certificate. The development of skills relating to a social constructivist nature of science could be difficult to achieve if previous experimental techniques involved the students following instructions from the text-book, in the absence of context or application. Evidence of this difficulty was experienced during a class activity of pattern identification in the enculturation unit (see lesson plan, appendix 8). Students found the activity difficult and it was reflected that an initial activity could have familiarised the students with the process of pattern identification.

Some students found the cubes quite difficult and did not experience accomplishment -> could have introduced an initial activity for practice to introduce the concept a bit better. (Field Note)

The recognition of patterns by the students might have been a skill that they had not engaged with on a frequent basis in school previously. This incident demonstrated that students could struggle with concepts that they were
unfamiliar with. During the enculturation unit, there were skills and ways of thinking that the student might not have experienced on a continuous basis, and due to this, they needed support in developing and applying these new skills.

**Impact 4: Development of new resources for teaching, that promoted active collaboration between students**

The resources and activities that were developed for the scientific enculturation unit are evidence of the further progression of the teacher’s pedagogical practice. The growing understanding of a social constructivist nature of science encouraged the creation of resources that aimed to promote communication and collaboration between students. Influenced by the constructivist position, resources also developed the relationship that chemical concepts have to the wider social context, as evidenced in the teacher reflection below.

*I looked at the skills and processes involved in scientific reasoning ... I thought I would focus on some of these processes and develop the students thinking in these areas, all the while linking back to where this fits into science and beyond. (Teacher reflection)*

The incorporation of these aspects of social constructivism led to the development of new resources for teaching, due to the impact of educational theories on pedagogical practice.

In the enculturation unit, a variety of introductory activities were utilised to promote a greater understanding of the nature of chemistry. The developed resources encouraged the active involvement of the students in their own learning and challenged the students appropriately. The majority of the introductory resources, for the unit, were from the Royal Society of Chemistry and were adapted slightly for a senior chemistry class in Ireland (see appendix 6 for sample activity). These resources provided thoughtful activities on the development of scientific skills that could be utilised throughout many aspects of science. An example of students’ increasing their understanding of the nature of chemistry and becoming actively involved in their learning, was seen in the development of models. The students engagement with a task on the development of simple models, provided them with a recognition of the intellect, social and collaborative effort required to put forward an abstract scientific
model. This recognition aided students understanding that scientific models are continuous developments of ideas rather than final products, even if this understanding was uncomfortable for the students initially, as seen in the following lesson plan reflection.

\[\text{Overall I thought the class went well, there was good involvement by the students and they were engaged in all questions and activities...} \]
\[\text{The understanding around models is developing I feel, but the “not knowing for certain if its right”, seems to still be a source of frustration for the students. (Lesson plan reflection)} \]

The impact of the development of new resources for teaching included a new thought process for the development of activity in the classroom, influenced by key aspects of a social constructivist methodology.

4.2.2 Change of the sequencing of learning

Implementation

The aim of the change to the sequence of learning was to put in place a logical progression that would help the students' learning. Sequencing of learning took account of Vygotsky’s theory that instruction could lead development (Vygotsky, 1997). In this study, the application of this theory into practice involved considered planning of topics within chemistry, with the aim of linking the information as logically and as progressively relevant to the students as possible. Changing the sequence of learning was not a linear process and involved planning, but also recognition that feedback from students informed what progression was accessible and relevant to them.

The sequencing of the curriculum involved analysis of the overall order of the major topics within the curriculum, and the logical and progressive links within each topic. Consideration of past teaching experiences, recommendations and guidelines from the department of education and various in-service training all informed the development of the sequence for this study. Table 4.3 shows the difference in topic sequence between the chemistry book that was used in the study's context, the sequence from the chemistry curriculum (NCCA, 1999) and the sequence of learning employed in this study.
Table 4.3 Differences in the curriculum sequence between the chemistry text-book, the national syllabus and this study’s curriculum plan

<table>
<thead>
<tr>
<th>Text-Book – ‘Chemistry Live’ (Kennedy, 2014)</th>
<th>Chemistry Curriculum (NCCA, 1999)</th>
<th>Chemistry plan for this study</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The Atom (Historic development)</td>
<td>1. Periodic table</td>
<td>Unit 1: Scientific enculturation learning unit</td>
</tr>
<tr>
<td>2. Arrangement of electrons in the atom (Bohr, Spectroscopy, energy sublevels, wave nature of electron, atomic orbitals)</td>
<td>1.2 Atomic structure</td>
<td>Unit 2: Elements and the Periodic table</td>
</tr>
<tr>
<td>3. The Periodic Table (Elements, historic development, modern table, atomic &amp; mass numbers, relative atomic mass, isotopes, mass spec, electronic configurations, electrons in orbitals of equal energy)</td>
<td>1.3 Radioactivity</td>
<td>Unit 3: Historic development of the atom</td>
</tr>
<tr>
<td>4. Chemical Bonding (Ionic, covalent, shapes, electronegativity, intermolecular forces)</td>
<td>1.4 Electronic structure of atoms</td>
<td>Unit 4: Atomic structure</td>
</tr>
<tr>
<td>5. Chemical equations, tests for anions</td>
<td>1.5 Oxidation and reduction</td>
<td>Unit 5: Radioactivity</td>
</tr>
<tr>
<td>6. Trends in the periodic table</td>
<td>2.1 Chemical compounds</td>
<td>Unit 6: Electronic structure of atoms</td>
</tr>
<tr>
<td>7. Radioactivity</td>
<td>2.2 Ionic bonding</td>
<td>Unit 7: Oxidation and reduction</td>
</tr>
<tr>
<td>8. The mole concept</td>
<td>2.3 Covalent bonding</td>
<td>Unit 8: Bonding (Electronegativity, covalent, ionic)</td>
</tr>
<tr>
<td>9. Properties of gases</td>
<td>2.4 Electronegativity</td>
<td>Unit 9: Shapes of molecules and intermolecular forces</td>
</tr>
<tr>
<td>10. Stoichiometry 1 (% element in a compound, empirical formula, masses &amp; volumes from balanced eq’s)</td>
<td>2.5 Shapes of molecules and intermolecular forces</td>
<td>Unit 10: Gas Laws</td>
</tr>
<tr>
<td>11. Acids and bases</td>
<td>2.6 Oxidation numbers</td>
<td>Unit 11: The mole and stoichiometry</td>
</tr>
<tr>
<td>12. Volumetric analysis: acid – base</td>
<td>3.1 States of matter</td>
<td>Unit 12: Acids and bases</td>
</tr>
<tr>
<td>13. Oxidation and reduction</td>
<td>3.2 Gas laws</td>
<td>Unit 13: Titrations (acids and bases/Redox)</td>
</tr>
<tr>
<td>14. Volumetric analysis: Redox</td>
<td>3.3 The mole</td>
<td>Unit 14: Rates of reactions</td>
</tr>
<tr>
<td>15. Rates of reactions</td>
<td>3.4 Chemical formulas</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.5 Chemical equations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.1 Concentration of solutions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.2 Acids and bases</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.3 Volumetric analysis</td>
<td></td>
</tr>
</tbody>
</table>
The implementation of the change to the sequence of learning resulted in one significant impact. The impact was that the teacher developed a better understanding of progressions of chemical content that are useful and helpful for the students. This impact effected peer learning and the development of conceptual understanding as the study and methods progressed. The improvement in progression could not have occurred without acknowledging the important feedback the students provided as they worked through different lessons and activities.

**Impact 1: Teacher development of a better understanding of progression for the subject of chemistry from student feedback and reflection**

The impact of the change to the sequence of learning in the classroom, was not the development of a sequence that could be replicated, but the recognition that progressive development of a topic was student-dependent. The students’ prior knowledge, experiences and ability to engage, all impacted on how a topic could progress. Therefore, feedback during lessons and recognition of progressions that supported the students active engagement with their learning was a vital component for the development of contextually progressive learning. In this study, several aspects of the chemistry curriculum, compared to previous practice, were changed. This included the introduction of the new scientific enculturation unit, the re-development of radioactivity and re-structuring of a new unit of chemical bonding.

An example of positive progression within the study, was the unit of learning developed for radioactivity, as evidenced in the following teacher reflection.

*One of the positives from this week and a bit of last week, is that I think I have developed quite a good unit for radioactivity for the future. The scientist cards, to the introduction of energy from nuclear with the atomic bomb discussion … One was a parent ringing in regarding his son’s radioactivity poster project … that he really enjoyed doing the research and the father then thanked me and said he felt this was real learning (Teacher reflection)*
In the teacher reflection, the positive conclusion for the topic was generated from student and parent feedback and student active engagement rather than the teacher themselves. The planning of radioactivity included the incorporation of the key social constructivist aspects of this study; dialogue, collaboration and links with the wider social context. The increased use of a social constructivist methodology, progressive developmental links between concepts within the topic and recognition of the student response, led to the majority of the students actively and positively participating in their learning during the radioactivity lessons. The development of activities to promote student engagement, interaction and thinking in this unit, were progressions from the learning engaged with during the scientific enculturation unit. An example of an activity in radioactivity that promoted student engagement was the student investigation into half-life. Figure 4.2 shows the students working on an activity into half-life and presenting the data using tables and graphs on whiteboards around the classroom. Student engagement was very high during this activity, observed through student discussions, collaborative work and the ability to produce, as a team, a final product (data chart with conclusions).

![Figure 4.2 Radioactivity Half-life investigation in class](image)

Within the co-gens, students mentioned radioactivity as a topic they liked, and that the skittle experiment helped their understanding of half-life. An
example extract of the second co-generative dialogue (co-gen) transcript can be found in appendix 9.

**Steven:** *I like the extra experiments, Michael has there. Like the marshmallows and the colours and the skittles when we were doing radioactivity. Just kinda helps. Like the experiments really help normally and now I feel like the more we do the better I understand it.* (Co-gen)

This extract from one of the students in the co-generative dialogues demonstrated that not only did the students like the activity but that crucially the student’s active engagement with a progressively appropriate activity helped to develop their understanding. There was a logical development of information within the unit, and this aided the progression of the students’ expanding knowledge of the subject.

The sequencing of lessons, was a constantly evolving process, and one that was informed by critical reflections, student feedback and awareness of difficulties arising within classes. During one of the topics in the study (oxidation and reduction), there was an example of student feedback highlighting an issue with the progressive relationship between concepts. The students highlighted an aspect of chemistry that was included in oxidation and reduction, but had not been covered yet in the class. The students, from field notes during the lesson, struggled with this aspect of oxidation and reduction. Their feedback highlighted an issue that was overlooked in planning, and this signified the importance of acknowledging feedback from students. The active engagement of the students with the content of the lessons, aided the development of progressive logical links in the sequencing of chemical topics. Discussions with students during learning also provided valuable information on the students’ ability to comprehend the sequencing occurring within the lesson which aided formative assessment, and played a crucial role in developing student understanding.
4.2.3 Peer learning

Implementation

The incorporation of the peer within this study was another significant change to teaching practice. Peer learning is a very important aspect of social constructivism and supports productive social interactions in a formal learning environment. The willingness of the students to engage with their partners to help aid understanding, was a crucial element to the success of social learning. This was evidenced in the following student comment, when he recognised the benefit of supportive and productive social learning relationships.

Victor: I’ve realised that it is more beneficial if I choose someone that I will actually learn with (Co-gen)

Peer learning was a structured component of the process of dialogue within the classroom. It began in the enculturation unit and continued throughout the study. It involved the students working in pairs during lessons, where they would tackle questions, investigations, research projects and experiments that they encountered in the class. Students had the opportunity to change their partners at certain points during the year.

However, it was acknowledged during the study that students as social beings also all had unique ways of interacting, and the successful implementation of the process had to be balanced with the complex interactions that occurred between the students.

The dynamics of my classroom, like any classroom, is complex. With 24, high achieving, competitive students mixed with quite dominant characters → disagreements and friction will happen (Teacher reflection)

This complexity with inter-relationships between students, was initially overlooked in planning, but became an issue of classroom management. From the study, students tended to work better with someone they knew, or someone who they felt could help them. The changing of partners was an evolving process and introduced new inter-relationships each time the students switched. This was a challenging aspect of peer learning and one that needed
effective classroom management by the teacher, to ensure that groups were developing productive relationships.

Peer learning also has a huge impact on teaching practice and that manifested in myriad ways throughout the study, through teacher practice and student engagement. In this section, two impacts of peer learning are discussed. The first impact was that the inclusion of a social element of learning, promoted the active involvement of the student with the lesson or activity. The second impact was the recognition that social interactions provided the opportunity for the development of learning. Social interactions provided examples and evidence of the occurrence of the social construction of knowledge in the class.

*Impact 1: Inclusion of the social element of learning promoted the active engagement of students*

The inclusion of dialogue and a social element to the classroom, had a marked impact on the students. High levels of student engagement were evidenced when an activity incorporated social interactions. This increased engagement was compared to the teachers previous experience of a similar activity or topic with a previous student group. Students in this study were active in their discussions and remained on task, with the aid of a summation sheet to record their development of understanding with the topic in question. Peer learning and social dialogue became regular components of the chemistry class during the study. The social element of the class encouraged the active engagement of the students. This was evidenced through the teacher’s field notes and reflections during the study. The following extract, one from field notes and the other from a teacher reflection, occurred on different days in the study.

... particularly enjoyed Wednesdays class as the students were very engaged and it was quite a hands-on class and activities. (Field Notes). Students were very active and engaged on all tasks throughout the classes... (Teacher reflection)

Activities that were documented as on-task (high engagement in the activity) in reflections were activities that were based around peer learning and problem-based dialogues or activities. This demonstrates the active
engagement of the students when participating in shared social learning. There is support for these **on-task** activities within the students’ co-generative dialogues also, as these activities were more frequently mentioned by the students themselves, and from the full class group in the evaluation activity at the end of topics.

The following is an example of a classroom activity that incorporated social opportunities for the students. Activities which contained a challenge or puzzle that the students had to decipher usually elicited high engagement levels. From teacher reflections on the lesson involving the *ideal gas equation challenge* (see activity, appendix 10). Observations indicated that the students initially found the activity difficult, but that this difficulty stimulated dialogue. From walking around the class, after giving time for discussions, the students then had on-task and relevant questions to ask me, stemming from their discussions.

*The students struggled initially which was good, it got them talking and discussing that initial block... I think the students enjoyed it as well → they were engaged and on task throughout. And the discussions were on task and like I said – physically engaging with the tools in front of them* (Teacher reflection)

The students were faced with an initial challenge and their communication skills came to the fore, as all groups remained on-task, despite said initial challenge. The development of problem-based activities that included a social element, provided the students with opportunities for discussions, encouraged communication and supported the development of their learning. The students were active and engaged in the tasks that were developed using this methodology. Pedagogical practice was impacted strongly by this learning strategy.

**Impact 2: Social interactions provided opportunities and support for the development of learning**

Evidence from the students, during the co-gens, demonstrated that the social element of the classroom provided support for them during their learning. They
also acknowledged that as the year progressed, the importance and value of the peer learning increased for them.

Steven: Ahm... I don't know. I thought, ahm... (pause) just different people it’s easier, it’s like having, you know when you’re with two different people, it’s like having, ahm, two different teachers nearly (Co-Gen)

Kevin: I think the partner... like it’s increased in value more now... it’s so much easier to like turn around to the partner – would you explain this, instead of interrupting you. (Co-Gen)

Realization for the student that their peer could be a resource and help them within the class, had the capacity to change the power dynamic in the classroom. The teacher was no longer the only source of help or understanding in the class. This was important, as a ratio of 24:1 could mean that student questions might not get answered and support at the appropriate time might not always be guaranteed. Social processes in the classroom created more democratic practices, which led to an increase in engagement by the students in learning activities. It also demonstrated a more social constructivist classroom, with the idea of an expert being dispelled.

Kevin: I found, as soon as I moved up to the front, I wasn’t even understanding much more of you, but like with the two lads, I was like, this is so much easier (Co-gen)

More democratic social interactions also impacted the teacher’s traditional role, which was evidenced in the movement away from transmission methods of teaching, to the facilitation of learning in the class. For the teacher, it was important to acknowledge that students needed support due to the complexity of the subject. That support could be achieved through productive social interactions between the students themselves, not just from the teacher. One of the students, during one of the co-gens, also highlighted a difficulty with the teacher being the sole source of knowledge in the classroom.

Steven: I think it's important that like the students know, that they need to ask questions cos I think however you (the teacher) explain it, there’s going to be something
Steven highlighted the need to ask questions as an important aspect for him in learning chemistry. He pointed out that the teacher might not realise they can overlook something in their explanations, and that such a situation can impact on the students’ development. The use of peers within the class, can support the practice of asking questions to continue the promotion of learning. Students can, and did, turn around to their peers to ask a question, when the teacher might not have been available.

4.2.4 Developed use of open questioning

Implementation

This strategy looked at the deliberate consideration of the type of questions that could be asked in a class, particularly questions that engaged student thinking about a given topic, and further questions that helped the development of understanding within the topic. The use of an open style of questioning as opposed to closed, attempted to elicit the students’ response and understanding rather than enforce the teacher’s curriculum.

The development of an open questioning practice resulted in two impacts during the study. They included; the teacher’s progression to an improved method of questioning in the classroom and that through questioning the teacher recognised the importance of student feedback.

Impact 1: The development of an open questioning practice provided support for student learning

Difficulties were initially experienced with the conscious use of open questioning into practice during the study, but the practice improved through continued implementation over time. The following is an example of the teacher’s struggles...
with the development of the style of questioning during the first cycle of teaching in the study.

What I am having difficulty with is how to phrase my questions → do I go ‘big’, ‘how does this provide evidence of energy levels?’ or build it up with scaffolding questions: - What do you notice with the graphs? - Can you try and explain what is happening with sodium? - How does Bohr’s model and explanation help → if at all? (Teacher reflection)

The type of questioning developed through trial and error and ranged from; thought-provoking questions to introduce a topic, questions to elicit deeper thinking by the students and questions to promote problem-solving during an activity. The use of open questioning was to help the students’ progression towards a deeper understanding of the topic, so that they could begin the application of concepts to different situations.

The following are examples that occurred during the study which provide evidence that the improved practice of open questioning provided support for student learning. During the gas laws topic, the students carried out an experiment to determine the relative molecular mass of a volatile liquid through the use of given formulas. Students, from previous experience, have found this topic quite challenging. In this study, an investigation was developed, through problem-based learning, that encouraged the students to apply the principles of the experiment in a different context. The investigation incorporated an issue which occurred in an everyday context and the students had to solve the issue in question. The resource sheets for the activity can be seen in appendix 10. During this activity, questioning was used to promote and support student thinking. Questions took into consideration the students’ ability and what they were finding difficult in the activity. Part of the practice was getting the students to explain their current thinking on the activity. Questioning allowed for the identification of issues when they emerged and for a decision to be made as to what kind of support might be needed. An example of an issue that the students experienced in the ideal gas equation challenge, was how to measure the volume of the gas with the apparatus provided. This was mentioned in reflections during the lesson;
They found getting mass and volume difficult – issues with volume.
They were linking the previous experiment to this one and trying to fill the canister [gas stove] with water once they took out the gas.
(Teacher reflection)

The issue was identified from listening to the student explanations on how they were planning on addressing the challenge, and questions were asked, like the following:

Other than the experiment the previous day, have you ever collected gas before? If you can collect the gas, could you measure it?
(Teacher reflection)

Students engaged with these types of questions, they provided support and promoted student thinking during the activity. This method of questioning proved productive in furthering the students’ attempts at the exercise, as evidenced in the final part of the lesson reflection.

I think the students enjoyed it as well → they were engaged and on task throughout. And the discussions were on task and like I said – physically engaging with the tools in front of them... a lot of what they (the students) were happy with, were parts I had put time and effort into planning → the gas laws and the formulas. (Teacher Reflection)

A second example of the open questioning practice supporting learning was experienced during an activity specifically designed for this study. The activity was the generation of shapes of molecules according to the Valence Shell Electron Pair Repulsion theory (VSEPR). The task included the students creating the five different shapes of molecules, according to the theory, out of play doh and tooth picks (appendix 11). In this activity, based on student feedback during the lesson, support was needed when creating a 3D shape using a 2D diagram. An issue that occurred was the misrepresentation of the 3D shape of methane when the students were building that model. The issue the students encountered was recorded in the reflection of the lesson.

Most groups found the 3D modelling of methane … quite tricky and built the 3D models as they look on 2D paper … methane was made
In supporting the students to overcome this difficulty, questions focused on; what was the difference between 3D and 2D, and where was the space around the molecule. Students were also asked if they were using all the space that was available to them. These questions promoted student thought and dialogue in their pairs, and they began to manipulate their model. The students also commented in the co-generative dialogue about this issue with methane. The questioning about space and what was the difference between 2D representation and 3D representation, seemed to have supported the students learning.

Michael: I really liked the modelling as well, cos do you know the one that has, like, the four (he was talking about the building of the methane molecule, and the shape a tetrahedral takes in 3D space) and like when it was three is was ... one hundred and twenty degrees, it all kinda made sense. And then when it was on the four I was kinda confused, as why it was one hundred and nine and not ninety, but then when you see it, in 3D it makes way more sense. (Co-gen)

In this example, it is clear to see that support around the concept of how to move things in 3D space supported this student, and others learning. Other students development was seen in their own self-correction of their models after open questioning by the teacher. The open questioning provided support for students when they were uncertain or when something was new to them. The questions, most of the time, were trying to draw on the previous knowledge and experience that the students had themselves, but were sometimes unsure whether they could use it in a new and uncertain context.

Impact 2: Recognised the importance of feedback from the students when applying open questions

Open questioning allowed for dialogue between teacher and students. It was felt that the increased use of open questioning, allowed for a more
collaborative learning process, in which the teacher learnt from the student as well as the students learning from the teacher. The following is an example of a teaching experience where the feedback from the students, further developed the questions that were used in the class.

Another topic that was re-developed to incorporate increased active student engagement compared to previous practice, was the historic development of the atom. During this topic, use was made of a resource by the Royal Society of Chemistry (RSC). The RSC developed infographics that contained biographical and scientific achievement information on some of the prominent scientists that were associated with the theoretical development of the atom (appendix 12). These scientist cards were modified so that they suited the learning outcomes of the Irish curriculum to be used within the topic of the historic development of the atom. The scientist cards were given to the students during the topic, and in their pairs, they read and interpreted the information and attempted to answer the questions that were on each card. The engagement of the students with this activity was recorded in the reflection of the lesson.

_‘I gave the work to the students, it was their responsibility to read and develop the ideas, with the help of the guiding questions. And the students did that... Their atomic posters and timeline work – for the majority was very good.’ (Teacher reflection)_

It was clear from questioning and the experimental summaries from the students, that some links of information were missing on certain cards. Each of the cards contained a few of the vital pieces of information necessary to inform the historic development of the atom, although it was not possible to include all detail. Feedback during discussions in the class and questions, provided evidence that students found some of the information difficult, as some conceptual links between the scientists and the discoveries were absent. Further questions were developed by the teacher in response to the feedback, in the attempt to promote understanding around the development of these historic experiments (developed questions can be seen in appendix 13). One example of the development of questioning was seen in the physicist, James Chadwick’s card; there was no question present about why it was a difficult task to try and find a neutron. This omission was discovered by the teacher when students had difficulties in answering information on James Chadwick and why
it took him over a decade, from Rutherford's predication, to find proof of these particles. The inclusion of this type of a question could stimulate students understanding of the difficulty Chadwick was faced with in his attempt to discover a sub-atomic particle that had no charge. One of the meaning questions that was developed because of student feedback was;

*Rutherford proposed the existence of neutrons, but why did it take Chadwick another eleven years before he could provide evidence for their existence?* (Question sheet, appendix 13)

Those questions helped to bridge some of the gaps in understanding that the students had, without giving the information directly to the students. They still engaged with the questions, but the sequencing of the question to develop information had improved. Those developed questions were included in the revised cards that are still used in practice currently. Eliciting meaning as a questioning style, which prompted the students to think, had also improved due to the increased experience at linking the students’ experiences with the scientific concepts. The students had increased opportunities to succeed in answering the questions which created connections for the information and therefore supported the students learning.

### 4.2.5 Use of problem-based activities and the application of concepts as tools

*Implementation*

Problem-based discussions and activities were designed to promote dialogue and the development of scientific and chemical thinking. These activities were an opportunity for the student to apply their understanding, and an opportunity for the teacher to formatively assess the development of the students in that regard. Dialogue could become difficult for students when they faced a challenging situation in their task, e.g. something that they both found difficult to answer, as evidenced in the following reflection.
I do think I should have structured a bit better their tasks (a lot of off-task talking today, more than usual), had a bit more guidance. Thinking that they could have come up with the reasons for the atomic trends, without giving the terms (until later, anyway) might have been a bit of a stretch for the students (Teacher reflection)

In future situations an importance was placed on the role of support to enable the students themselves to progress through a problem-based activity. A balance of support, without the teacher completing the task was developed. The balance of support was important to take into consideration, as too little support could lead to the student perceiving the difficulty or challenge to be too great, and result in their withdrawal, or step-back, from the activity. However, too much support could negate the student completing the work and application of the topic by themselves, therefore hampering development of learning. When the right balance of support was reached, students engaged with problem-based activities and began to apply their learning, as evidenced in the following teacher reflection after a metals reactivity investigation.

Students were engaged, thought it was quite a thought provoking investigation, and required them to take time over it to figure the chemistry out. (Teacher Reflection)

The active involvement of the students with the constructivist designed activities was very powerful for the teacher. The students’ active involvement in considered and appropriately challenging activities demonstrated the students’ natural curiosity and their motivation to learn.

They enjoyed the reactions with the copper sulphate and mixed things together near the end → curiosity – they want to see what will happen. (Teacher reflection)

The implementation of this approach resulted in two important impacts on teacher’s practice. The impacts were; the teacher reconceptualised how to design and develop learning activities that included and engaged the students, and recognised the importance of students applying what they had learnt rather than the repetition of information.
Impact 1: Reconceptualised the development of learning activities and resources

The reconceptualisation of learning activities and resources happened over time and their development was influenced and informed by student feedback. This reconceptualisation was also impacted by research and engagement with the social constructivist methodology. Student feedback demonstrated that they engaged with puzzle-like problems and challenges where they had to apply their learning. Students also exhibited high engagement levels when these activities included a social element. An example of one of these resources was a mock murder case that included; background information on certain poisons, mass spectrometer readouts and a crime scene that included background information on four possible suspects. The resource was thought provoking as there was also no clear-cut answer, which generated debate in the class. This resource was designed by the RSC, and worked extremely well in a senior chemistry class in Ireland. Evidence of this can be seen in the teacher reflection below.

In Thursday’s class, a very good and informed debate occurred around the homework given. All students had the work completed and some were asking me who was the murderer before class, some before school. They seemed very engaged by that sort of work, and there was no clear-cut answer. They could have presented 3 viable suspects with the information given. One student requested they get homework like that in the future. Which I thought was a good sign -> homework was a context bound puzzle essentially. (Teacher reflection)

The positive feedback and engagement with the activity by the students prompted the development of more learning activities with a sense of a challenge and of solving a problem. This style of activity was popular among the students, and involved the application of their knowledge in the pursuit of finding a possible solution to the problem or challenge posed.

Another example of the change in approach to the design of learning activities was during the anion identification experiment. Students can sometimes find the experiment quite overwhelming, due to the high number of identification tests and the volume of reagents that must be used. This year, at the end of the investigation, the students had to identify an unknown compound
using the information they had generated during the experiment. The students applied their information to a very high standard and identified the unknown very quickly, thinking through what would be the best reagent to use first, that could rule out the most possible anions. This was again outlined in the reflection after the experiment.

The test for the ‘unknown’ worked well and I put an extra challenge on them to try and use the least amount of sample to work out what chemical it was - had to plan it. Most groups worked very well, and quickly (most completed in a few mins) ... Overheard one of the students say to another “this is like real science” (Teacher Reflection)

These activities required the students to use and apply the concepts they had learnt. The reconceptualisation of the approach to learning activities was impacted by; the importance of social interactions, acknowledging student feedback during lessons, developed understanding of the nature of chemistry and an increased use an open questioning practice. The social constructivist methodology employed and developed through this study, combined to change pedagogical approach to the development of learning activities and resources. The development of activities that encouraged the application of concepts through a puzzle or challenge medium generated high engagement among students.

**Impact 2: Recognition of importance of students applying what they had learnt rather than the repetition of information**

The previous section mentioned the application of concepts. It was seen that students engaged with activities and resources that challenged them to apply what they had learnt. Students actively engaged in the process of developing their thinking towards application of concepts and developed their understanding of those concepts. The application and understanding of concepts was continuously supported in the class, rather than the traditional practice of learning-off disparate parts of the course. It was also emphasised to the students that application of information required effort and that they would be supported in their effort to apply their thinking.
And convey to the students that this new information will take time for them to get their heads around and to keep working. That linking concepts takes an extra effort for the students, and again need to give time and tasks to help that (Teacher reflection)

Application and understanding was encouraged throughout the lessons and was aided by the redevelopment and reconceptualisation of learning activities.

However, from observations during meta-reflections, activity alone was not an automatic for optimal learning environments, nor did it promote the application of concepts, if it was not given the considered time needed in planning. In the following example from an energy emission lesson, there is the reflection of the teacher and then the comments from the students, during a co-gen, on the same lesson.

I think the class went well, the students were thoroughly engaged and they could see a spectrum from the light bulb in the classroom and the idea of bands of light could be seen and talked about (Teacher reflection) Kevin: I never got that one (Steven: turns and nods to Kevin) that’s the one where you pass the light through it? Steven: Uhm, that’s my, that was my worst kinda chapter (Co-gen)

The presumption that active students were learning students was a fragile assumption, as it was recognised in this study that student activity did not automatically equate to the development of understanding or application. This was evidenced during the emission spectrum topic in the study. Despite the students being actively involved in the emission activities, during revision of the topic, the students mentioned the difficulty they had with it and that they were still unsure regarding emission spectra. The understanding of student-active in this study was when the student partook in an activity, but the learning intention or purpose of the activity was not made clear. Lack of clarity could be attributed to the lack of adaptations to try and support the student in their learning and an uncertainty as to how and why the concept could be applied. Students could not conceptualise the link between the activity and the concept as they were not supported in their development of learning. Students in this sense were engaged in busy time, rather than genuine learning and development. Student-centered was understood as the student being placed at the centre of the
learning, that the learning was designed and adapted for the student in the attempt to apply their learning and promote understanding in the best way possible. The development of this line of thinking, active vs centered, was realised over the course of this research study and from engagement in critical reflection and in critically reflective discussions with peers, academic supervisor and literature. An example of a critical reflection on the issue of students engaged with the activity vs students engaged in their learning follows;

From reflecting on lessons, students’ activities and engagement levels, a distinction has been seen between ‘student active’ and ‘student centered’. From my reflections, I have found that as well as lessons being organised to optimize learning, I have recognised that just because students are active, does not automatically equate to them developing understanding. (Teacher reflection).

When students began to apply their learning in this study, they were actively engaged in both the activity and the learning and were supported to progress their thinking. When this occurred, this was an example of the student being the centre of the learning and planning. It was seen in this study, that promoting the students to apply their learning, encouraged a deeper development of understanding.

Michael: By the end of the chapter, it always kinda fits in and it’s actually really nice when you… get to the end and you know it’s kinda… in your brain, then. (Co-gen)

4.3 Impact of social constructivist methodologies on assessment

Implementation

Engagement with the social constructivist methodology and the implementation of the learning strategies, had a marked impact on assessment in the classroom. Assessment in this study encompassed the development of the teacher, the student and the effectiveness of learning methods, rather than the
assessment of grades. Experience from previous practice, demonstrated that the practice of formative assessment was difficult. Formative assessment is the monitoring of student learning throughout the lessons, rather than at the end of a unit or year in a summative exam. Formative assessment developed in this study through a combination of having more social processes in the classroom, increased open questioning practice and activities that engaged the students. The engagement of students in activities, resulted in the teacher being able to walk around the class, ask questions, provide support and monitor the learning.

There were two main impacts on assessment owing to engagement with the social constructivist methodology. The first impact on assessment was the teacher’s recognition and implementation of more formative assessment in the class and that it could be used as a method of monitoring the development of learning in the classroom. The second impact on assessment was the re-evaluation and re-configuration of sequences of learning due to in-class student feedback.

**Impact 1: Recognition and implementation of formative assessment as a method of monitoring learning development in the classroom**

Formative assessment was a process that developed throughout the study. The increased student-student interactions provided opportunities for the teacher to go around to different groups and ask questions, or ask the group to explain their work or idea.

One illuminating moment for me was when I looked at the terms-sheet one night and could not understand what one of the students had written → to me it made no sense. Or I could not put my sense on his writing/understanding. Instead of saying to the student the next day, what was that, or giving him no marks if it was a test → I asked him again about the term individually and he explained the idea very well. I then told him I found the term he used difficult to understand, could he explain it to me. He did → and it made sense when he explained it, just didn’t have it written. (Teacher reflection)

Feedback from the students provided the teacher with valuable information as to how they were appropriating the content of the lessons. This provided a
method of monitoring the learning development of the different students within the class. This method provided the teacher with opportunities to support students at their point of difficulty.

An example of a formative assessment process in this study was the practice of term sheets used during different units. In the above example the unit was, trends within the periodic table and the resource can be seen in appendix 14. A term sheet was a resource that was developed and implemented in this study, to help students become familiar with the chemical terminology that they encountered during a topic. The sheets included the new terms of the topic, questions to situate the terms within the students prior learning and progression towards the application of the terms within the concept. The term sheets were developmental resources that also incorporated the social element of peer learning in their enactment. Students discussed the terms on the sheet, agreed on their understanding and then engaged with the questions in the resource. As the students worked with each other and the resource, the teacher was provided with the opportunity to engage in formative assessment. The students’ developing incorporation of the new chemical terms into their lexis and prior knowledge, was assessed through teacher questions. During these lessons, students could be asked to explain their reasoning or understanding of the terms within the resource. The lessons were focused on the development of the students understanding and application of the terms. The method also helped to monitor the students learning development in the class.

This is the students first time encountering trends and most of the terms I am talking about in this unit. Of course some are going to struggle → the terms have very little context for them and I need to be mindful of that fact...I have learnt that this topic takes a lot more time than I initially thought. Students are finding linking the atomic structure to trends very difficult. Some students are also having trouble with the amount of new terms and are getting confused.

(Teacher Reflection)

In this reflection, the teacher, through formative assessment practices recognised that the students were having difficulties with the new terms. It was recognised that for understanding to develop, the students needed more time to work through the conceptual ideas behind the new terms. An added element
of formative assessment, particularly for the teacher, was the collection of the term sheets at the end of the class. Feedback was provided to the student either written or orally the next day. For the student, the term sheet could become a tool that could be refined and improved to help develop the understanding of the terms and the progression of those terms towards application. The collection of the term sheets also highlighted if there was anything in the teacher’s organisation of the learning that was proving difficult to understand for the students. Collection of the term sheets provided assessment on the development of both the learning organisation of the class and the monitoring of learning of the students.

Impact 2: Reconfigured teaching approaches based on student feedback

Another important impact of assessment within the study was the opportunity to evaluate the progression of teaching within lessons. This evaluation was aided by both the collection of the term sheets and information gleaned during in-class experiences. Formative feedback for the teacher came from discussions with students as issues that occurred regarding lack of clarity in explanations, or as confusing progressions which were highlighted during those discussions. Formative feedback provided a valuable insight into the perspective of the student and was used as a learning experience that promoted the teacher’s pedagogical development.

A number of students’ have expressed their difficulty with the terms in chemistry, finding them difficult and a lot of them. This technique gave the students the time they needed to try and figure out and get their head around some of these terms and how they link together. I started this technique this week and called it “shared listening” in the lesson plans. (Teacher Reflection)

An example of an incident in class where an approach was reconfigured based on student feedback, was the topic of shapes of molecules. During an activity that involved the students creating 3D models of common molecules, I recognised a bias within my own thinking. This recognition arose from
interactions with students and the work they were presenting. In my reflection, I observed that the student work reflected the teacher development of the topic. From observation of the student work and discussions, I had to acknowledge that there was an over-reliance on 2D representation in my explanation of molecular shapes, due to several of the student groups modelling some of the molecule shapes using a 2D orientation rather than a 3D orientation. This implicit 2D bias in my thinking could be due to previous practice and a reliance on the text-book to illustrate shapes. Due to this line of thinking, I had not acknowledged the support students needed in their transference of a 2D representation to a 3D model. This in turn impacted on the students’ development of the 3D models and this was mentioned in my reflection after the class.

This was a very illuminating lesson for me personally, as I missed the initial error the students were making with the models, because I am so used to seeing a certain format as well. I didn’t notice, at first, methane built as its 2D model – in a cross format, flat on the table, or completely vertical if standing on the table, and not the correct 3D model … The 3D was not being used, because it was not understood yet. (Teacher reflection)

In this classroom experience student feedback impacted on the teaching approach and developed pedagogical content knowledge (PCK) regarding the topic of molecular shapes. As part of current teaching practice, the 3D representation of the shapes of molecules plays an important instructional aim in the development of intermolecular forces. To further assist students with the visualisations of the 3D shapes, the commercial molecular kits are not used in this initial work. The reasoning for this, which links to the development of PCK from this study, is that the commercial kits have the placement of the bonding pairs pre-determined. If students use these initially, they have not fully engaged with the concept of the placement of bonding pairs around a 3D object. In the initial activity, the students use Play Doh and toothpicks to create the molecules. Based on student feedback and assessment of the experience, the teaching approach was adjusted regarding the development of the shapes of molecules. The importance of a three-dimensional understanding of shapes was explicitly acknowledged, as it can impact the understanding of intermolecular forces and the application of those concepts.
Formative assessment provided the prospect for interaction with the students and the development of understanding to occur between the students and the teacher. Without the opportunity for collaboration, the opportunities for learning that were experienced would not have occurred.

4.4 Impact of social constructivist methodologies reflection

Implementation

This section details how critical reflection of my teaching practice led to the recognition of processes that benefited the students within the learning environment. The critical reflections were also informed by feedback and responses from the students, both within the class and during the co-gen. Engagement with this study led to personal reflections and findings which impacted professional practice. The use of reflective practices helped to challenge previously held assumptions and question previous behaviours within my teaching. Reflection, as a method of awareness and development of practice, was not formally used in my previous teaching practice.

The use of social constructivism resulted in three important impacts on reflective practice in this study. The impacts included; the development of a greater awareness of the social and cultural constraints that surround teaching, recognising the importance of re-evaluating previous teaching behaviours in light of the presence of constraints and the importance of establishing positive relationships in the classroom.

Impact 1: Developed a consciousness toward social constraints surrounding teaching in Ireland

Improved consciousness of social actions and constraints was informed by the continued enactment of a questioning practice and the opportunity for interactions with students during teaching. Both processes helped me to
develop a critically reflective position on actions taken within my teaching practice. Engagement with critical reflection developed an awareness of the social impacts surrounding teaching. As the reflective practice progressed, I acknowledged some of the difficulties that could have arisen in my previous practice due to unquestioned behaviours and normalised habits. With the aid of reflection, I also acknowledged the constraints that were personal and sociocultural and in turn affected the Irish education system. Examples of such constraints included; unquestioningly following previous practice, teacher-centric view of education rather than student-centric, the perceived pressure of the exam and completion of the course. During this study, I demonstrated a willingness to re-evaluate previous behaviours.

Throughout the study, reflection led to the unveiling of previously unacknowledged and unseen constraints within both my practice and the education system. Participation in a reflective practice developed a greater awareness of interactions that occurred within social events. This awareness provided me with the ability to begin questioning the purpose of certain actions and structures within education. The examination of what influenced the early research question of the study was one of the first self-reflective meta-analysis pieces developed by the teacher. The research question in its initial incarnation took a measurable view of education and looked at the how an inquiry process in science could develop a student’s scientific reasoning, with the use of PISA (Programme for International Student Assessment) style questions to measure development. The development of this question demonstrated the influence of accountability that has pervaded education. An economic focus of measurability is influencing education, and through reflection, this influence was identified in my initial research question. With the benefit of experience and developed reflective practices, I saw that the initial question I was engrossed in answering was systematic of the education system and policies that surrounded me in my teaching.

I also noticed a sociocultural constraint on the education system. Through reflections, I observed that neither myself nor the students were particularly comfortable with uncertainty. This fear or distrust of the uncertain, could be linked to an issue with school culture in Ireland, namely the summative assessment’s influence on education. The strong focus on exams impacts both students and teachers. Due to the high stakes weighting of exams in Ireland,
there exists a perceived need to perform in an exam and achieve the exact wording necessary for optimum grades. The performance nature of exams has generated a need-to-know environment in schools, which does not accommodate for uncertainty. Performance in relation to exams could be deemed one of the most important outputs of senior education. This could be happening to the detriment of true learning in those classrooms. This awareness led me to question my previous behaviours in teaching. Questioning also brought awareness to other areas within teaching and behaviours that were previously unquestioned and mostly unseen. Another issue that was previously unacknowledged, was the perceived pressure of time constraints linked to exam culture. In my reflections during the study, I commented on the pressure of time on numerous occasions. This happened most frequently at the start of the study, but also at the start of a revised topic when a new method was being implemented. The pressure of time influenced how topics were presented within the class. The time constraint had previously led some teachers to revert to a transmission model to ensure that content was covered. A detrimental thought process could emerge, when the pressure to cover material supersedes the development of understanding, leading to the detriment of learning.

Improved consciousness and awareness of social constraints increased my critical reflective capacity as a teacher, as I became aware of the contestable practices inherent in teaching.

**Impact 2: Recognition of the importance of re-evaluating previous behaviours**

Engagement with a reflective practice promoted increased awareness of social constraints, and demonstrated that actions in education could be contested. An important impact of reflection was the development in my practice of re-framing and re-evaluating past teaching experiences. Throughout the study, there was evidence of engagement with a re-evaluation process regarding previous behaviours. Aspects that aided the development of re-evaluation included; engagement in a critically reflective model of action research, a willingness to engage with a questioning practice and acknowledgement, through different sources, of previous social constructs that existed within the education system. Throughout the study and through the enactment of the reflective process, the
open approach to questioning improved further, and this led to further experiences of re-framing and re-evaluation. Areas where re-framing took place were personal and educative in nature.

The following is an example of the re-evaluation of a personal experience during this study. From reflective practice, it was acknowledged that I feared the unknown. Before this study, I would have stated that I was an open person, that I was willing to change and try new things. However, through my reflections and analysis of the reflections, negative emotive language in relation to uncertainty came through. An example was that the implementation of a new method or idea in the classroom usually generated uncertainty and negativity in the reflection before and after the event.

I find trying to contextualise this [electron transitions] for the students difficult ... I find I can lose students here, at this point. They find it too strange and mind blowing. Some really do not like the idea of something that everybody is struggling with. (Teacher reflection)

This negative uncertainty also manifested when a theoretically developed method did not translate as I would have hoped into the classroom.

I am not sure how successful this class was, I think I felt disappointed that it didn’t go as well as I had hoped in my head (Teacher reflection)

I acknowledged that those situations, when something was unfamiliar or uncertain, made me uncomfortable. However, from the self-recognition of that behaviour, that fear and uncertainty was re-evaluated and re-framed as a valuable learning experience.

It was illuminating for me personally, as when I started this inquiry process I felt blind. I was not sure where I was going with this, was what I was doing right, am I looking at the right things, doing the right thing, recording the right stuff, etc., etc. Lots of questions! From the 1st cycle I have learnt that this is a process... I have started on a journey and I have now taken the 1st step. I still don’t know where it
It developed an empathy within me for the students when they had to face something unknown and uncertain in the class, and that they needed support and time when dealing with unfamiliar situations. I personally, from the re-evaluation of the unknown into a learning experience, tried to adopt a positive stance on an uncertain situation, remembering that it was a moment of opportunity more than a moment to be feared.

**Impact 3: Recognition of the importance of establishing relationships in the class**

During this study, there was evidence of improved interactions, which were compared to the traditional interactions that can occur between the teacher and the students. Interpersonal relationships are extremely context bound and can depend on the personality of the teacher and how they might engage with students and with a reflective practice. The improved interactions had a few favourable factors in this study. I increased my awareness to the world around me through engagement with the professional doctorate programme and this led to the development of more open and aware thinking. The students themselves were in fifth year in post-primary school in Ireland and had chosen to study chemistry after their junior certificate years. The act of choosing the subject, could have led to greater motivation from the class. Finally, the students that traditionally choose chemistry in my school, tended to have higher academic ability. All those factors could have combined to create a particularly positive environment, but motivation and work, from both me and the students, was still required for that to be achieved. Evidence of improvement in interactions with students came from a variety of sources. There was evidence from my personal reflections, when I documented that there was very little behaviour issues within the class. The following is a comment made after a periodic trends unit.

_Students were very active and engaged on all tasks throughout the classes. The shared listening through the week worked very well, from my point of view → students were on task and I got feedback._
every night on their thinking about a certain topic. The level of information I received was very good. (Teacher reflection)

The observation made within the teacher reflection was indicative for a large portion of classes. The lack of behavioural issues was a pertinent point, as the classes were very practical and required discussions nearly every lesson. The practicality element of the lessons previously led to behavioural issues as the students were not fully engaged with the work in the classroom. During this study, I developed a methodology that promoted student engagement in their learning, rather than the setting of activities. A positive rapport was also evident with the students in the classroom. This was supported further by anecdotal evidence from outside sources, namely parents and colleagues. During a parent–teacher meeting, the majority of the parents said their son was really enjoying the classes and found the subject very interesting.

Sample comments from the parents of different students: “Really enjoying chemistry, really likes the class”, “Loves the subject and the class”, “really likes the subject and the class. Is enjoying it”, “Mam said he is loving the subject and finds it very interesting. (Teacher reflection)

What was interesting about this feedback, was that it was not exclusively from the parents of students with higher academic performance, it was across the full range of ability within the class. Colleagues also mentioned, informally, that students were talking about chemistry lessons themselves, before that teacher would start their lesson, and commented that the students seemed to enjoy what was done in class. Language teachers, due to oral preparations, also mentioned the increased number of students who mentioned chemistry as their favourite subject. Finally, and most importantly, was the evidence from the students themselves, found within co-generative dialogues and from general discussions in and outside of class. The following were comments from a few of the students during the co-generative dialogue;

Michael: I feel like the class is really... like smart and helpful... I’m able to kinda think outside the box a bit more... like I’ll take more time to understand it. Kevin: I like the way it’s taught in our class. It’s completely different to any other class. Victor: our chemistry class is so much more engaging.
So, there’s kinda more of a motivation to kinda learn. (Co-gen)

Another aspect that possibly helped the positive interactions, was my increased ability to re-frame my understanding of difficulties in the classroom. Difficulty in the classroom was no longer linked with a failure of the teacher in instruction or failure of the student in listening. Since knowledge was socially co-constructed in the social constructivist classroom, time was given to gain an understanding of what the difficulty was and whether there were different ways to approach it, or if it was a miscommunication, which could be rectified. That idea of failure can be very detrimental to the social atmosphere within a class, for both the students and the teacher. Difficulties and misunderstandings always occur within a classroom setting, but during this study an effort was made to develop understanding between the student and the teacher.

This study’s social constructivist methodology promoted the active engagement of students in their chemistry lessons. The methods that were developed and utilised from social constructivism included; relevant and problem-based learning activities that incorporated, sequencing of learning, peer learning, open questioning and the students beginning to apply scientific concepts. This transformative approach to teaching practice was accompanied and supported by formative assessment and the implementation of critical reflection. Each of the different strategies had unique impacts. However, the strongest impact was when they worked together, and within my practice, students were engaged with chemistry. A significant result for the social constructivist methodology developed in this study, was the evidence of improved interactions, both socially and in terms of education between me and my students.

4.5 Discussion – how social constructivist methodologies impacted my teaching practice

4.5.1 Introduction

The implementation of social constructivist methodologies in this study had an overall positive impact on my practice as a teacher, both professionally and
personally. Engagement with this research developed my understanding of constructivist methodologies and in turn my practice progressed towards more social, student-centered and reflective teaching approaches. This progression was seen relative to my previous practice, which was more traditional in nature, i.e. very little social interaction and mainly teacher-centered. Evidence from this research demonstrated that teacher conceptual change occurred. This research approach promoted conceptual change, which impacted my teaching practice positively. Elements of this study could inform the development of continuous professional development services for teachers. Another vital impact of social constructivist methodologies in this study was the effect student voice had on my teaching practice. Student voice contributed to the improvement of learning from the perspective of the students in the study (e.g. development of better resources and better sequencing of topics). It also positively informed my pedagogical practice. This afforded the students with the opportunity to become actively involved in their own learning, as their voice was informing (their) learning. The final major impact was the development of positive social relationships within the room and between me and the students. The three areas are discussed in more detail in the next section.

4.5.2 Impacts on my teaching practice

Teacher engagement promoted conceptual change

During this study, I became more engaged with my practice, or more accurately, I experienced a re-engagement. In previous years, I had experienced a lull in terms of my motivation for teaching, and got to a point where I was not challenging myself, which consequently impacted the students general engagement. During the data collection phase of the study, I experienced an engagement in my teaching and anticipated the students’ response to my lessons. Many of my lesson reflections and field notes from lessons captured my engagement and enjoyment with teaching using social constructivist methodologies. An example of one of these is seen below.

... particularly enjoyed Wednesdays class as the students were very engaged and it was quite a hands-on class and activities. (Field Notes)
This extract from my field notes demonstrated my renewed engagement with my teaching practice during this study. Engagement with educational theories surrounding learning and social constructivist methods of teaching combined to promote my enjoyment and students engagement, as evidenced in the following teacher reflection.

I have really enjoyed it (data collection) despite the difficulties. And the class that gives me the most joy is my 5th years. I enjoy trying to think of ways to contextualise the learning for them → come up with more active ways of learning and develop sequences that can/could develop their learning. And I really enjoy (and am nervous) about seeing how the students respond to my ideas and what ideas they have and what I learn from them. (Teacher Reflection)

However, there is little evidence in literature about a change in a teacher’s engagement or enjoyment with their practice. Research has focused on technical aspects for the teacher, e.g.; implementation of an approach and developing their core beliefs (Lotter, Harwood & Bonner, 2007). Focus on a technical approach to teaching in absence of an emotional aspect, can leave teachers alienated from the process. They can become technicians of a method rather than practitioners of a complex social process (practice). Vygotsky noted that the affective element of learning was vital for conceptual development (Vygotsky, 1997). From this study, to support teacher conceptual development, involvement with the approach, both conceptually and affectively, is necessary for change to being to occur.

My re-engagement with teaching and the social constructivist methodology used, resulted in strong impacts on practice. The main impacts on practice included; motivation, conceptual change and the movement from a traditional teaching approach, to a more open and social practice. The progression of conceptual change resulted in the introduction of new learning strategies and the development of new resources. Participation in the doctorate of education programme, exposure to literature on theories of learning, support from my supervisor and development of reflection, all combined to support the development of my core teaching conceptions. In this study, the development, design and delivery of my self-designed scientific enculturation unit had the biggest impact on my conceptual development and engagement with the social constructivist methodology. During the enculturation unit, a reconceptualisation
of the nature of chemistry lead to a reconsideration of my understanding of pedagogy. Engagement with social constructivist literature and the development of understanding that practices and constraints within education were socially derived, changed my outlook surrounding issues faced in my practice. An example of this change can be seen in a teacher reflection acknowledging a difference between practice in this study and previous practice.

This could be the first time in my career that I have actually given the time needed for students to grapple with the ideas in the topic (atomic radius). Previous years I would have moved on from this topic much quicker (I think that’s why my planning is so off) and taken for granted that when I asked the students if they were ok with the concepts and they said yes – that they were telling the truth. (Teacher Reflection)

This change was internal to me and impacted my belief system and caused me to re-evaluate how I viewed education due to a re-evaluation of my understanding of science. My habits of practice began to change (Thompson & Zeuli, 1999) and continue to do so, due to continued engagement with social constructivism and a reflective and engaged practice.

Lotter, Harwood and Bonner (2007) in their study on inquiry professional development of in-service teachers in America, stated that successful professional development must assess and address teachers’ core conceptions. However, teachers’ beliefs can be very difficult to change, as they are usually somewhat based on practical knowledge built up from classroom experience that has been learnt over many years (Lortie, 1975, cited in Lotter, Harwood & Bonner, 2007). Research that investigated the influence of teaching conceptions on teachers use of inquiry practices, acknowledged that teachers’ beliefs can act as “filters” through which instructional strategies and information about learning and knowledge can flow from the teacher to the student (Lotter, Harwood & Bonner, 2007, p. 1319). These filters are sociocultural influences on teachers practice and can lead information to be filtered, causing distortion. My recognition of sociocultural influencing factors on education, through a developing understanding of social constructivism and reflective practice, contributed to my change in understanding and promoted a change in the
students. It is widely stated in educational research focused on professional development of both pre-service and in-service teachers, that teachers’ core conceptions have the strongest impact on their ability to enact change, and that impacting and developing their conceptions could generate real change in teachers practice (Lotter, Harwood & Bonner, 2007; Crawford, 2007; Duschl & Gitomer, 1997; Ratcliffe & Millar, 2009). This discussion highlights both the difficulty and importance of identifying and supporting teachers’ conceptual understandings of learning in Ireland. Support and engagement with different theories of learning could help a teacher identify their philosophical position in relation to learning, and that, along with other cultural factors (e.g. development of curriculum, assessment), could provide development for teachers away from a more traditional style of teaching. However, there is very little support in Ireland for teachers engaging in questions about how they view education and learning.

This study provides evidence of conceptual change occurring for a teacher, when engaged with action research, informed by educational theory and when supported and emotionally invested in the process of improvement. This study supports a model of continuous professional development in Ireland where teachers are at the centre of reform, not simply implementers of change. An study conducted in America also calls for a more teacher-centric approach to reform. Blanchard, Southerland and Granger (2008) investigated the learning of four science teachers during and after a six week professional learning experience. They noted impediments to teacher change including the teachers theoretical readiness to learn (Blanchard, Southerland & Granger, 2008). This can be an often overlooked aspect in relation to teacher change, that needs to be given more consideration. Another finding from their study, was that sustained teacher change required teachers to rethink their practice at the deepest level, their beliefs and values (Blanchard, Southerland & Granger, 2008). If a teacher is not theoretically ready to address their core conceptions, then teacher change is very difficult to achieve. Ratcliffe and Miller (2009) added further support to the importance of teacher involvement in reform and CPD programmes. In their English based research study they noted that teachers practice can be changed, but that it required time, considerable support and professional development that encouraged reflection on practice (Ratcliffe & Miller, 2009). My study has supported the findings in research, that to develop teacher conceptual change, their philosophical position in relation to the change
needs to be identified. This can help to identify the level of support that might be required for teacher conceptual development. Time and support are important elements, as are the relevance of the change to the teacher’s practice. Experiencing the change in practice can have a powerful effect on a teacher, both professionally and emotionally.

**Impact of student voice on developing formative assessment in teaching practice**

A social constructionist position supports that knowledge is not transmitted directly from an *expert* to another. Instead knowledge is viewed as being actively and socially constructed by the learner (Driver, Asoko, Leach, Mortimer & Scott, 1994). The was one of the main aspects of social constructivism that was used to guide lessons and interactions and the reason why student voice was important in this study. As knowledge is socially constructed, an account of teaching only from the teacher would have a narrow focus and would not comply with the practice of a social constructivist teacher. In Colucci-Gray, Das, Gray, Robson and Spratt’s (2013) study on teacher action-researchers, the participants understood the value of seeking the perspective of the students, as this could result in the development of improved learning experiences for the students. Student participation was also a very strong ideal within my practice, as student voice was sought to help inform all teaching aspects within the classroom. In my research, student voice informed learning experiences by providing feedback on different progressions of learning that were attempted in lessons. The following student comment is representative of some of the student perspectives evidenced during this study.

**Steven:** *I like the, ahm, that sheet* (electronegativity development sheet) *cos it built on, like, what we already done with atomic radius and ionisation energy and then it just felt like, kinda like a natural extension, instead of doing something completely new.* (Co-gen)

Student feedback also gave the teacher the opportunity to informally assess the learning within the lessons. The students provided in-class information about the suitability of the progression of the lesson, the impact of the activity and the success or not of any explanations given in class. It was important that the students recognised that their opinions and feedback were being
acknowledged by the teacher. This was stated in Colucci-Gray et., al.'s (2013) study, as they mentioned that the participation of the students, both in the activity and the acceptance of their views, contributed to the democratic influence of action research methodology and the inclusion of student voice.

During the implementation of a newly sequenced unit of learning, the feedback from the students in the class provided important indications that the designed progressive links were relevant. The student feedback allowed for the development of student-centered lessons, that generated relevant progressions.

Victor: I like how some of the things we do tie into, eh, everyday life. So, it's in a way more relatable, so you can kind of understand where things are coming from and where it might be used. (Co-gen)

This evidence of student feedback influencing the teachers’ development was not a common topic in science education literature. Literature recognised the gap that exists between what the teacher communicates and what the student perceives (Schultze & Nilsson, 2018), but generally the focus of research was on how the teacher could help the student, not how the student could help the teacher. In a study by Bergqvist (2012), one of the findings stated that despite teachers being able to identify the difficulties the students experienced, specifically within chemistry, the same teacher possessed limited teaching strategies for the promotion of students’ conceptual development. The identification of issues between teachers and students is very prevalent in science education literature, although the development of research strategies that involve the students, as more than data-sources, seem to be limited. There was limited acknowledgement in educational literature of the students’ role in promoting the teacher’s development. Research focused solely on the teachers’ impact on the student is a narrowed practice, and demonstrates that it is only the teacher that impacts the student. It is important to recognise the students influence on the teacher and this can provide a strong and important impact on teacher’s practice, as found in this research. The following reflection extract is an example of me interacting with students informally as they were working on an activity. This informal discussion with students highlighted an issue with the progression of the activity. On reflection I looked for ways to provide better guidance when introducing atomic trends.
Student impact on teacher practice is beginning to emerge in educational literature (e.g. Schultz & Nilsson, 2018) and will provide valuable information in relation to processes which aid student learning, as explained and demonstrated by the students themselves. This was also evidenced within this study and can contribute to this emerging body of literature.

**Practice became more reflective**

Engagement in this study, through an action research methodology and immersion in educational research literature on social constructivism, resulted in my practice becoming more reflective. A study by Colucci-Gray, et al (2013), reported on the experiences of several primary and secondary teachers who were involved in action research projects in Scotland. The study explored the impact of teacher action research on knowledge, professional practice and the generation of reflections in the participating teachers. It was found that the teacher action-researchers became more skilled at reflecting on and assessing the actions of their practice on their students (Colucci-Gray, et. al., 2013). This development came from the teachers becoming more aware of their own practice and the nature of their knowledge developing (Colucci-Gray, et. al., 2013). In my research study, as a teacher action-researcher, my study supported the findings of Colucci-Gray, et. al. (2013). I found that my reflective development had a significant impact on my practice. This development of reflective practice also improved my assessment of how my actions impacted on the students. I became more conscious of student responses in the classroom during activities and tasks, and the greater recognition of the student contributed to a more skilled reflective practice. The development of active reflective practices impacted action taken in class, as it was now informed by: theoretical knowledge, a growing awareness of how knowledge was developed (experience) and contributions from the students, evidenced in the following reflective piece written during the study.
From reflecting on lessons, students’ activities and engagement levels, a distinction has been seen between ‘student active’ and ‘student centered’. From my reflections, I have found that as well as lessons being organised to optimize learning, I have recognised that just because students are active, does not automatically equate to them developing understanding. (Teacher reflection).

The reflective informing of planned actions developed and ultimately changed my practice. This impact of reflection on teachers practice was also evidenced in a study on primary level teachers participating in an inquiry-based professional development programme (Capps & Crawford, 2013b). The researchers of this programme were initially focused on the views and implementation of an inquiry-based approach into the participating teachers’ classrooms. Through their analysis of teacher interviews it emerged that supporting the teachers in reflecting on previous behaviours in teaching and the new knowledge gained during the professional development could enhance knowledge and support teacher change (Capps & Crawford, 2013b). This study supports the important role of reflection in supporting teacher change (Capps & Crawford, 2013b). Even though Colucci-Gray, et., al. (2013) and Capps and Crawford’s (2013b) studies were developed in different ways and contained different foci; impact of action-research on teachers and impact of an inquiry professional development programme on teachers’ practice, reflection still emerged as a powerful factor that supported teachers. In my study, reflection on previous behaviours and new knowledge led to the re-evaluation of behaviours and ideas in my practice. Reflection was a powerful action in my study and one that supported the change in my practice. These studies provided strong evidence of the importance of developing teacher reflection when implementing programmes that require a change in teachers’ practice.

**Improved relationships**

Engagement with the student is articulated in Noddings (Noddings, 1984, as cited in Goldstein, 1999) research and a pertinent concept was called “language of care” (p. 661). Noddings (2012) discussed the concept that when a teacher asked a question, she was receiving not just the response but also the student.
There was an emotional connection and an involvement of care established. So whether the student was correct or not, the teacher probed gently for clarification and interpretation, not seeking the answer but the involvement of the student in the learning relationship. This emotive and holistic engagement with the student was a form of professional learning as outlined by Colucci-Gray, et al (2013). The authors outlined that the professional learning of teachers was impacted by engagement in the attempt to understand the students own learning experiences through a student-centered methodology (Colucci-Gray et al, 2013). In this study, the professional learning of the teacher was impacted by their attempt to understand the students’ learning experiences. This was supported by the use of more social practices in the classroom and engagement with student-centered methodologies. The following teacher reflection is demonstrative of this impact on teaching practice.

*One illuminating moment for me was when I looked at the terms-sheet one night and could not understand what one of the students had written → to me it made no sense... →... I told him I found the term he used difficult to understand, could he explain it to me. He did → and it made sense when he explained it, just didn’t have it written. (Teacher reflection)*

In this reflection, I acknowledged the need to discuss with my students their understanding during lessons. Discussions like this were very illuminating for me as a teacher, as more accurate assessments in relation to the progression of learning, from the perspective of the student, could be made. As well as developing my professional learning, this also helped to motivate the students, as they recognised that their voice was listened to in class.

Action research involved a community within the classroom; the teacher and the students (Colucci-Gray, et al, 2013). Participation in community by the involvement and acknowledgement of both parties' opinions and ideas, generated changes in the relationship that might normally exist in a typical classroom. The relationship in this study, between me and the students, was positive. There was an understanding in, both directions, between the teacher and students that both were working together for the improvement of learning in the classroom. This finding was evident of the democratic practices within action research, the increasing reflective nature of the teacher and the acknowledgement of the importance of student voice in a social constructivist
classroom. The concept of educational action research, creating a community that can ultimately change relationships, was promoted in a theoretical research paper that proposed a theoretical framework for educational communities of inquiry, and looked specifically at relationships and tensions within communities (Cassidy, Christie, Coutts, Dunn, Sinclair, Skinner & Wilson, 2008). Another study, Kim (2013) looked at five teachers experience of carrying out action research in their classrooms and the development of their practice. An unexpected outcome for the teachers was an improvement in their relationship with their students. Improved relations was promoted by the development of community in this study where the teachers were working with the students as a “unit” and teachers were gaining an understanding of their students (Kim, 2013, p. 390). Improved interactions with students created a more positive atmosphere in the classroom. Braun and Crumpler (2004) also observed in their study that an engagement by a teacher with a reflective practice led to an improvement in interpersonal relationships. The evidence from these two papers is supported in this study.

**Difficulty: Practice took more time**

The final impact on my teaching practice was time. Engagement with a social constructivist methodology in Ireland required a significant portion of time for the practical development of activities and lessons, that were more active and student-centered. I feel that the time put into the development of those approaches and learning activities was positive, although the initial outlay of time could be a barrier for other teachers. Rees, Pardo and Parker (2013) stated that when teachers were involved in the creation and development of their own tools for use within their own classroom, those were the tools the teachers found the most useful. This was in relation to pre-service teachers implementing inquiry into lower secondary level. There was support for this finding in my study also. Gordon (2009) analysed different studies that looked at constructivist teaching in America and highlighted successful implementations of the approach. In this section, Gordon analyses the use of activities to promote social constructivist teaching. A social constructivist activity included the use of concepts as tools and incorporated more emphasis on a students’ ability to interpret, apply and make sense of ideas within the science environment (Gordon, 2009). Gordon (2009) also stated that genuine learning involved
active, not passive students, and that they needed to be involved in the
construction of their own interpretations of the subject matter. Effective activities
and teaching must challenge students. They need to demonstrate in-depth
understanding, apply the subject matter and be held to high standards (Gordon,
2009). This understanding of constructivist activities for the student, must
involve a teacher who is active in their facilitation of the development of
understanding (Gordon, 2009). Students need to be supported to achieve the
high standard of learning that is proposed within a social constructivist
approach. This understanding guided the development of social constructivist
resources in my study. Time was spent developing resources, due to the lack
of activities that promoted the application of concepts for students in Ireland.
The majority of activities that applied the students learning, in a constructivist
manner, during this study were self-designed. The development of those
resources and the time required generated a positive response by the students
within the study and the resources in this study are still in use in my current
practice.

The development of activities that promoted the students’ use of
concepts also benefitted from the incorporation of social learning, sequencing
of learning and the use of open questions to promote learning. The development
of an activity that required the student to apply a scientific concept in isolation
of why or how they could do that, could make the activity very difficult for the
student. Constructivist processes support the application of a concept by
providing socio-cultural links for the students learning. Students need to be
supported in how to learn, how to communicate and how to ask relevant
questions. The development of the student to apply a scientific concept was an
aim of this research, and led to a reconceptualisation of practice, away from a
traditional approach. The reconceptualisation of a teacher’s approach, away
from traditional, due to social constructivist pedagogical approach is not seen
often in literature. Many studies accessed during this research that focused on
teacher change were American in context and focused on the implementation
of inquiry-based practices rather than constructivist practices (e.g. Lotter,
Harwood & Bonner, 2007; Crawford, 2007; Blanchard, Southerland & Granger,
2008). Fewer studies again existed of a teacher, rather than a researcher,
implementing a social constructivist approach into their practice in Ireland.
4.6 Conclusion

In conclusion, teacher’s practice overall was positively impacted by engagement with a social constructivist methodology. I developed from this process both professionally and personally. My teaching practice developed from a mainly traditional style to the incorporation of more open and social approaches and appreciation for the vital active involvement of the student. The active involvement of the student also provided better opportunities for formative assessment within the classroom. The development of reflection, impacted practice by promoting more effective interactions with students and aided a conceptual change in relation to my understanding of both science and learning. Overall, the inclusion of social constructivist methodologies resulted in a positive and active learning environment in my chemistry classroom.
Chapter 5: Impact on Student Engagement

(Findings and discussion 2)

5.1 Introduction

In this chapter, the research sub-question is “how did the social constructivist methodologies and practice affect student engagement?” From implementation of the methodology, it was found that there was an increase in student engagement in chemistry, when compared to the researchers previous teaching practice. Students were actively and positively engaging with activities and importantly their own learning in chemistry. The learning strategies used in the social constructivist methodology, also generated more interactions between the teacher and the students. This chapter discusses the student response to the social constructivist methodology that was implemented during the study. The first section of this chapter details the development of engagement and change in attitude of two students in the study. Following from that is the general response from the students in the class, to the actions taken during the study. Finally, the discussion of how social constructivist methodologies affected student engagement is presented. Again, student engagement in this study is viewed as the students active and positive engagement in learning activities, and their development towards more autonomous learning behaviours.

5.2 Student change in engagement and attitude

This section traces the changes in engagement and attitude of two of the students who were involved in this study, both as class members and co-generative dialogue (co-gen) participants. A factor in the decision to include these particular students in this narrative was due to their involvement in the co-gen dialogues. The two students also represented the variety of student and ability that existed within the research classroom. The students response to social constructivist methodologies highlighted the versatility and flexibility of
the approach for students. The narrative is based upon the collection of student artefacts of completed classwork and homework, data from the co-gens, teacher reflections and field notes that were recorded during the study. The students real names are not included in any part of this thesis and pseudonyms are used instead to differentiate between the students’ comments.

5.2.1 5th year chemistry student – Kevin

Kevin was one of the students who initially volunteered to take part in the co-gen with me at lunch times. As previously stated, from the students who volunteered to take part in the co-gen, I decided that a representative sample of four students would be chosen, and that they should represent the different ability levels that were present in the class (see appendix 15 for rationale based on average grades). Kevin was chosen, from that average, as he was representative of the lower spectrum of results and from classroom observations, he was finding the subject of chemistry difficult.

Kevin was an interesting student, and from the beginning of the study he was appearing in my lesson reflections, when other students were not. His difficulty with the subject content and his behaviour in dealing with it was challenging at times. He was initially reluctant to accept help, and when I prompted him towards a more accurate understanding of the concept in question, he would say things like; “oh yeah, I know that” (see appendix 16 for Kevin’s excerpts). Kevin found instruction difficult. The following example is of one of the initial activities completed during the enculturation and co-operative learning unit. Figure 5.1 shows the equipment that was used during the activity, and a picture of the teacher’s model. The activity was called the Model Tube Activity (Warren, 2001), and students were required to create a working model of the tube that the teacher was demonstrating. The students all received the working model, but the edges of the roll were covered so that they could not look inside. The students then had to observe the movement of the strings and hypothesise what was happening inside the tube. They were given a roll of their own with two strings, and had to attempt to replicate the working model, by observation of the outside of the model alone.
The aim of this lesson was to convey to students that scientists are often utilising indirect observation techniques in the development of new information and models. The model tube activity (Warren, 2001) was used to support the students understanding of how models were developed and used in science. Questions to promote learning for this activity included; "What are the benefits and limitations of scientific models?" (see appendix 17 - lesson plan). In Kevin’s answers, he narrowed his focus to the atom, rather than the use of models in general in science. Another question was “what were the difficulties or frustrations in replicating the model?”. The general response of the class to this question was the frustration felt when they either could not figure out how to build the model, or if they managed to build a model, they could not tell if they were correct. However, Kevin’s answer demonstrated his tendency towards concrete levels of thinking, rather than abstraction of thought. One of the difficulties he put forward was; “trying to get the string through both holes without the string fraying” (see appendix 18 for picture). I could understand where his thinking was coming from; he placed the frustration in replication of the model with the model in his hand. Those examples demonstrated that Kevin’s abstraction of thought needed development and support, but also that chemistry could prove to be a difficult subject for him.

As the weeks progressed Kevin generally worked well in class but had difficulty with some of the terminology and concepts that were being developed.
I noted examples of the difficulties in my lesson reflections, along with other students.

*Some students are also having trouble with the amount of new terms and are getting confused.* (Teacher reflection)

Conceptual difficulties were formatively assessed using *key term sheets* (see appendix 19 for example). The terms on the sheet were discussed in class, supported by peer learning, and the students’ combined understanding could be utilised to provide the written term on the sheet. I then collected the term sheet at the end of class, from every student, and analysed each of them at home. This provided me the opportunity of monitoring the learning in class and ensuring that chemical ideas were progressing along developmentally appropriate paths. If there was a term sheet with inaccuracy or I was unsure of the meaning the students were trying to convey, I could ask those students to explain their reasoning the following day. I found that when I engaged with the students in this way, they rectified their own conceptual gaps of their writing. Through communication with me and explaining their thought process, students generally recognised where they missed a piece of information in their written work. Kevin did not show evidence of this self-correcting conceptual understanding when he was asked to explain what his ideas were discussing. The analysis of the term sheets demonstrated Kevin’s difficulty with the abstraction of thought necessary for some concepts within chemistry. He misinterpreted terms, wrote understandings directly form the book and when asked to explain what was written in his own words, could not. I tried to support his development by prompting and explaining where necessary, although Kevin tried to deflect that help by saying quickly, that *he knew it now*. In those initial few months Kevin found it difficult to admit that he was having a difficulty with the subject and did not ask for help.

Most of the other student groups worked well in their pairs, although in my lesson reflections I observed that Kevin and his partner seemed to have difficulty communicating with each other. Kevin also had the habit of talking more to the student beside him, rather than his own partner. Kevin and his partner were situated in the back row of the laboratory with four other students, who Kevin was friendlier with then his partner. The off-task behaviour of that row of students was recorded in some of my lesson reflections.
What I have noticed, is that the lads with their partners now, there are a few small issues. There is one group/pair, that is not working → one is weak with a confidence issue so can’t admit that to himself (would impact on his self-image) and the other is finding the subject difficult due to an issue with English. I have noticed that they are the only group that is not engaging properly with shared listening resulting in them not discussing, because they are both unsure. (Teacher Reflection)

A turning point for Kevin came when I moved the partners in the class around. At this stage I knew there was an issue with Kevin and his partner, as his partner had asked me if he could swap who he was sitting beside. When I mentioned about moving partners at the end of that class, Kevin came up to me and asked if he could go with one of the students whom he had listened to during the radioactivity poster presentations. In the reshuffle of seats, Kevin was put sitting beside the student he had requested and another student of high ability was on the other side of him. He also ended up in the front row, as his new partner had requested at stay at the top of the room. There was a difference immediately. Kevin was no longer engaged in off-topic discussions and was not trying to figure things out on his own, distracting others when it became too difficult. He was engaged in his task with his new partner and was asking questions, something he did not do with his previous partner. Kevin mentions, on numerous occasions across all three co-gens, the importance of the pair work, as he called it. Kevin’s comments about this in the co-gens demonstrated a learning experience for him and an engagement into a subject that he was having difficulties with, and one which he might soon have disengaged with. The following are a few of the comments Kevin made about peer learning;

*I found that the type of person, like the calibre of person in the subject helped me loads... I found, as soon as I moved up to the front, I wasn’t even understanding much more of you, but like with the two lads, I was like, ha, this is so much easier. It helped me loads... I’ve realised that it’s more beneficial if I choose someone that I will actually learn with. (Co-gen)*

An interesting point from Kevin’s second statement, was that the teacher did not make that much of a difference in terms of increasing his understanding. The condition that was created within the classroom was deemed more beneficial. Kevin and his new partner engaged in co-operative and educative
discussions through a peer learning process. Off-task behaviours that were previously evident in Kevin’s behaviour stopped when positive engagement with another student in learning occurred. Kevin mentioned in the second co-gen also, the importance for him of partner work;

_I think the partner... like it’s increased in value more now... it’s so much easier to like turn around to the partner – would you explain this, instead of interrupting you._ (Co-gen)

Kevin made another very important acknowledgement about his own learning during the second co-gen. I do not think this realisation would have happened for him without the peer learning. His relationship with teachers seemed to have an asymmetrical power balance to it, and he seemed to always want to appear like he knew what was happening, and was very slow to ask questions. He seemed more comfortable with asking a peer for help than he did me, at least during the start of the study.

_I’m a lot more comfortable with admitting, like what I got wrong now. Ahm, I’m not really good for like admitting ‘oh yeah I got that wrong...’ but I’m a lot more open about it now. So, I think that’s after standing to me quite an amount._ (Co-gen)

Later, in the same conversation during the second co-gen, Kevin made a reference to his learning experiences before 5th year chemistry, specifically in mathematics. He recounts that he was very poor at maths, but acknowledged that he did not ask a question in mathematics for his junior certificate term. He stated during the co-gen that he developed a different way of learning;

_If I’d had chemistry in like 3rd year, the way it’s taught this year, I think I would have been able (to) apply the way of learning... if I had the incentive to ask questions and have a bit of self-learning about it, I think I would have done much better._ (Co-gen)

Kevin was an interesting student to observe. I must acknowledge that even though Kevin’s positive engagement in the subject increased, he still experienced difficulties with the complexity of the content within chemistry. However, Kevin did not experience a withdrawal from the subject, which can often be a default option for weaker students when the subject becomes too
difficult and there is inadequate support. An interesting point highlighted by this case, was that the support needed, did not have to be exclusively in the form of a teacher. Indeed, it is very difficult to provide the correct support to every single student, each with their individual learning needs across a wide spectrum of ability. Engagement with the social constructivist methodology encouraged the teacher to develop an understanding of the social construction of knowledge. Social constructivist methodologies in teaching promoted that further and can be developed to encourage co-operative and educative communication between students. Students could then act as support for each other, with the teacher an additional layer of support. The network for support increased dramatically with the implementation of the social constructivist methodology.

5.2.2 5th year chemistry student – Michael

The differential factor between Michael and Kevin was ability. Michael was another student who volunteered to participate in the co-gen during the study. He was chosen as the representative of the higher ability students. Michael consistently achieved the highest grades in the class. He would not face the same challenges as Kevin, although he had his own unique challenges to overcome. Michael did not appear in my lesson reflections, as I tended to note incidents that were not what I expected or made me think about what or how I was doing something. As a very bright and quite student, Michael dutifully completed any work set and did not engage in off-task behaviour. Michael also did not usually ask a question during a task. If Michael had not been a member of the co-gen group, I do not think I would have got to develop a relationship stronger than correcting his tests and saying well done.

Michael was very intelligent, although he had, subconsciously maybe, appropriated the role of a traditional student in the education system. I must acknowledge, while I had not taught Kevin before, I previously taught Michael. I was Michael’s science teacher for junior certificate, but I could not admit to knowing him particularly well. What I recalled from junior certificate was his huge capacity to learn, and in a test, he could give the information back nearly word-for-word. His traditional focus came through when he discussed exam questions during the co-gen discussions. He was uncomfortable with uncertainty and needed some sort of structure to alleviate that at times;
I found it sometimes hard to know what they’re asking?...
I had a look... at the marking schemes, can sometimes help me just to see, what’s actually needed (Co-gen)

During teaching, I would always emphasise the practice of understanding chemistry, as opposed to learning information off. A traditional mindset could focus on the exam, and the importance of the exam appears to be recollection of information rather than application of information. With the exam as the main priority for a traditionally positioned student, the development of contextualised learning experiences with emphasis on application might appear contrary to their goals. I had to support this type of learning for Michael through examples. He needed to experience the benefit of understanding a topic for application in other areas. As the course began to develop, Michael’s thinking also began to change, and an appreciation for understanding began to develop;

I like the order (of the topics) actually that we did the chapters as well. It seems to make sense. Like I know at (the) start, I remember we were going... (with his hand in the air makes zig-zag movements) bits and pieces out of them. But if you look... I felt like it made much more sense doing it that way than following how the book done it (Co-gen)

As a student who tended to work on his own at junior certificate, Michael engaged fully with peer learning practices within 5th year chemistry. At the start of the year he was with a good friend with whom he worked effectively and this could have helped that process develop. In fact, they worked so well together that when I asked them to change partners after Christmas of the study year, Michael and his partner were the only two not to change. Michael himself acknowledged how helpful the pair work was and discussed the contextualised differences between a teacher and student. He mentioned that it can be hard listening to the teacher, as the teacher appears to know everything already, but that the student beside him might be able to explain something a bit differently that could help his understanding, more than what the teacher was explaining.

When asked in the co-gen if they had gained anything from participation in the chemistry class, Michael’s answer was both revealing and rewarding to hear.
I noticed that I’m able to think outside the box a bit more. Like I know when I was in my junior cert I was always kinda like, ‘sure if you don’t know it just learn it off, it’s grand’. Whereas now, I’ll take more time to understand it. Because if you understand something it’s so much easier. I remember the stuff we’ve done at the start of the year, and I haven’t done it since, because I understand it, and it all makes sense. Whereas it you weren’t t understand it and you were just trying to learn stuff off, like it does go pretty quickly and you’ve to keep learning it off. (Co-gen)

This way of thinking became embedded for Michael and he approached learning with a different viewpoint. Evidence of the change in Michael’s thinking came from Michael himself at the end of 6th year. Figure 5.2 is the card I received from Michael at the end of 6th year.

![Figure 5.2 Michael’s card](image-url)
Discussion of exemplar student response

Two distinct students were represented in this section, through reflections and their own comments. Both of their experiences represented a change in engagement and attitude towards chemistry and towards their own learning. It is important to point out that different aspects of the social constructivist methodologies impacted the different students in different ways. Social constructivist teaching methodologies offered a flexible and varied approach to creating more student-centered learning opportunities. The learning opportunities afforded to the students changed both their thinking in a positive manner. Michael saw the benefit of learning to understand the material in front of him and he then saw that he could apply that information to a very high standard, more than if he learnt the information off. Kevin began to appreciate the importance of asking questions and that the class was a supportive environment in which to ask questions. He benefited hugely from working with a more capable student and was willing to ask and listen to his peer, more than he was initially willing to listen to the teacher.

However, limitations that could occur in the enactment of this approach, would include student personalities. Students need to be able to work together positively, however if there are personalities that find it difficult to work together, that poses a challenging problem for the teacher. For many students in this study, this was their first experience with each other in the classroom. The students were starting off on a clean slate. Issues could occur if there were pre-existing issues within a class group, and this might place social restrictions on what could be achieved. I found the early intervention of introducing dialogue for a specific purpose to be extremely helpful for pre-empting issues that might arise in the class. However, I still had to remain cognizant of how social interactions were progressing, to ensure that dialogue was as productive as possible.
5.3 Student response to the use of social constructivist developed methods in class

In this section, the general response of the students within the class is discussed. The general response is generated from field notes during lessons, informal discussions with students and insights gained during the co-generative dialogues (co-gen). Student findings on each learning strategy is outlined as are the impacts of the strategy. The effect of social constructivist practices on student engagement is discussed at the end of the chapter.

5.3.1 Introduction of a new learning unit incorporating scientific enculturation

Development of this learning unit aimed to mediate a social constructivist understanding of science to the students, through scientific enculturation and support throughout the lessons. Driver, Asoko, Leach, Mortimer and Scott (1994) acknowledged that the introduction of new cultural tools for students would require the teacher to provide support to help them make sense and integrate those new constructs. In science education literature, it was discussed that a key social constructivist role for the chemistry teacher would be the mediation of scientific knowledge for learners (Driver, et. al., 1994). This mediation could include a social constructivist developed learning unit and resources which aimed to facilitate the understanding of scientific knowledge for learners.

This section details the response of the students to the introduction and development of the enculturation learning unit. The response outlines are; the students employed productive dialogue with each other during the enculturation lessons and students developed an understanding of the social constructivist nature of chemistry.
Response 1: Students employed productive dialogue with each other during lessons

Much of the evidence of the students’ willingness to communicate in class came from the teacher’s reflections and field notes during the enculturation unit of learning. This evidence was supported by the students later in the co-generative dialogues. Students readily discussed ideas with each other during the unit and were engaged with the activities they were asked to complete. An example of the readiness of students to engage surface in the first lesson of the new learning unit. An example topic of the Olympics was chosen (these had taken place in the Summer of 2017) and the students discussed how and where chemistry could be linked to the Olympic games. This proved quite successful and was mentioned in my reflection of the lesson;

Worked very well in the groups and all had different ideas, these ideas linked well with aspects of chemistry (Teacher reflection)

When students were given the opportunity, through activities in the enculturation unit, they engaged in communication that was focused on the task. Teacher reflections throughout the entire unit of enculturation were very positive the majority of the time. Noteworthy points included; occurrence of good discussions, that students were engaged with the activities and questions, they developed of working relationships and engaged in on-task dialogue. Students, in general, engaged positively with dialogue as a method of learning and the new learning unit helped to develop this practice in the classroom.

Response 2: Student developed towards an understanding of the nature of chemistry

An example of the students’ growing understanding of the nature of chemistry from a social constructivist position, occurred during a concluding activity in the new learning unit. The activity involved the students choosing what they thought were the top three skills that could help a chemist in their work. The students wrote their ideas down on a post-it and stuck them to one of the whiteboards in the class. The activity highlighted the range of skills that could help chemists, and that each student pairs picked slightly different skills, based on what they thought was important. This highlighted that development in the sciences
requires multiple skills and outlooks. An experience which highlighted the students’ development towards an understanding of the nature of science was the appearance of a blank post-it. When I asked that student pair to explain why their post-it was blank, their answer demonstrated a development in their way of thinking about science;

\[\text{Sometimes in chemistry you will come up with a blank, but then you need to use the skills on the board to overcome that.} \] (Field note)

These students exemplified discussions that were occurring regarding the evolving nature of chemistry, and that human ingenuity was a vital part of dealing with issues when they presented themselves in science. This demonstrated the students’ developing understanding of the social and evolutionary nature of science and chemistry.

5.3.2 Change of the sequencing of learning

Student response to changes in the sequencing of learning during the study was a vital component of learning for the teacher. A consideration of the progressive links between content and in relation to instruction was supported by Vygotsky (1997) in developing a students’ higher psychological functions. Davydov (1998) also supported the considered development of formal learning interactions to aid psychological development. In a research paper by Leach and Scott (2002), they discussed the consideration of logic within a science lesson, and the impact that can have on the learning effort of the student. In the same paper, it was outlined that it was not just the sequence of teaching activities that was effective, but the teacher’s role in staging the teaching activities in a social classroom context. This theoretical research paper acknowledged the impact sequencing of learning can have on learning within a social environment (Leach & Scott, 2002). The main student response to the change of sequence of learning was that students found the progressive logical development of content helpful.
Response 1: Progressive logical development was helpful for the students

In co-generative dialogues, students stated that they preferred the sequence of learning that was followed in class, as opposed to the sequence within the textbook. The following excerpt is from one of the students during the second co-generative dialogue (co-gen).

Michael: I like the order actually that we done the chapters as well (Kevin: yeah & Victor nodded his head in agreement). It seems to make sense... I prefer, felt like it made much more sense doing it that way then following how the book done it. (Co-gen)

The unit on chemical bonding also underwent changes in sequencing. (See appendix 20 for developmental student worksheet) Planning and considered reflective time was implemented into the development of a new and more progressive sequence of learning, compared with previous years. This included the completion of research into chemical bonding pedagogy and the difficulties that could arise. The learning load of the student was considered, and logical and clear links were sought within the topic. In both the text-book and the curriculum, the traditional format for bonding began with ionic, then presented covalent bonding and then introduced electronegativity, and all were presented in separate chapters. In this study, ionic bonding, covalent bonding and electronegativity were combined into one unit in the plan. The sequence of learning was also reversed from the curriculum and the text-book, to begin with electronegativity, then covalent and lastly ionic. Starting with the electrostatic framework through electronegativity and orbitals, a progressive relationship could be set up, beginning with covalent and moving towards ionic. This helped to develop a more logical and meaningful understanding of bonding for the students. The students could see a spectrum of bonding from sharing electrons equally to the unequal sharing to no sharing, rather than distinct ideas of bonding, which was what ionic and covalent bonding could appear as for students (Dhindsa & Treagust, 2014). The students discussed their reflections on the unit of bonding during the first co-gen.

Steven: I like the, ahm, that sheet (electronegativity development sheet) cos it built on, like, what we already done with atomic radius and ionisation energy and then it just felt like, kinda like a natural extension, instead of doing something completely new.
Teacher: ok...
Victor: Yeah, each chapter is kinda looped together and so... (Co-gen)

Teacher: What do you think about the spectrum there. That idea of going from covalent to ionic... (pause) (Figure 5.3)
Kevin: I think it’s a lot easier to learn. Like if I started on one side and had to come back and like learn about new things, then link it in, I would have found it more confusing. But like cos we learned it in like, a steady pattern, I think it was much better that way. (Co-gen)

![Figure 5.3 Spectrum of bonding used during lessons](image)

Progressive logical development of concepts within topics, was evidentially helpful for the students. The development of a logical sequence of concepts in these lessons promoted learning in the class. The students were provided with the opportunity to engage in learning that was developmental and that offered the chance of achievement, as one area of learning should support the next. This finding was generated from the compilation of reflections after lessons where there was considered implementation of sequencing in relation to information, tasks and questions. These findings supported that if the sequence of information was developmental the students built on the progressive topics within the lessons. This sense of achievement within a lesson further promoted the students’ engagement.
5.3.3 Peer learning

There was a strong student response to peer learning. The students mentioned the process frequently during the co-generative dialogues. Due to this response, an equally strong impact was then felt on teacher practice. Resultant of student feedback; social learning was incorporated into all lessons and activities, where possible. Peer learning, as a method of social learning was supported in literature (for example; Vygotsky, 1997). It was found that peer learning promoted the students' active engagement and involvement in their learning. It also took the teacher out of the role of expert and demonstrated to students that their peer was a valuable resource in the classroom. This study showed that students found it easier to discuss ideas with one another, as they shared similar experiences and therefore better understood each other’s difficulties. This finding was supported in a co-teaching study by Schultze and Nelson (2018). The main response of students to the method was that they found the peer a source of support during lessons.

Response 1: Provided the students with support during their learning

The peer learning acted as a support system for the students. When students were unsure of an aspect in class, they could turn to their partner and they felt comfortable to ask for their help or to get them to explain an idea. As the year progressed they felt more and more comfortable with this process of learning and support. This comfort with the process was built up developmentally during the study. The students themselves did not recognise the importance and help the process was providing until later in the year, when it was well embedded in practice. In discussion during the second co-gen, the students stated that the peer learning process was helpful for themselves and their fellow classmates and that it supported their learning. They felt it was an element of learning that benefitted the class as a whole.

Kevin: I think the partner like ... increased in value more now... If you like influenced, how necessary partner work was at the start of the year, for the incoming 5th yrs. Then by the time they come to like half way and Christmas tests, they should be able to help each other with like notes and that. (Co-gen)
During the co-generative dialogues, the students mentioned on numerous occasions, how helpful they found peer learning in the classroom. A few exemplar comments included:

**Michael:** *I think that the pair work we do really helps* (Co-gen)

**Steven:** *... with both my partners, that ahm I've had in the year, it's just, it's good to get a better, like, understanding.* (Co-gen)

**Victor:** *Yeah, I like Steven's ah.. idea where group work, has been very helpful. I don't think, ah, I would have like done as well in the test say, if I didn't have someone that could like help me out.* (Co-gen)

Students acknowledged the benefit of learning from their peers and mentioned that they are an added resource within the class.

**Michael:** *I like as well that ... the class is really, I don't know if it's because it's chemistry and I don't know, it's kinda associated with ... being a tough subject and stuff, but it's ... like smart and helpful class so like, sometimes... there might be something really simple that you don't understand, and you don't want to ask you ... but, it's sometimes just easier to ask someone beside you and, even like, there's just little things that might, ahm, stick better.* (Co-gen)

This evidence from Michael is demonstrative of the difficulties that students can face, if it is one voice explaining all the time. There are contextual differences between students and teachers, that should be acknowledged. Students can relate to each other a bit better than they can relate to a teacher, due to greater similarity in their contextual backgrounds, compared to a teacher's context.

### 5.3.4 Student response to the increased use of open questioning

The use of open questioning led to students asking more content related questions about their activities. The open style of questioning used by the teacher promoted and developed the students thinking regarding the task. In
many activities, that engaged the students (generally active and involving social aspects), the student questions asked were content related rather than task focused. This is evidenced in a weekly reflection where some of the questions asked by the students were noted.

I found the students were asking questions relating to the tasks...

They asked very good, probing questions, some of them, showing me that they were trying to process the difficult information; “Is the nucleus in the centre of those orbitals/ why don’t the electrons come near it if they can be found anywhere in there/ are the 2s and 3s orbitals becoming bigger than the previous s orbital in space?” (Teacher reflection)

This reflection demonstrated that the majority of the students were actively engaging with the information presented to them and attempting to generate an understanding. The open questioning allowed for a support structure for the students. If the students engaged in their learning, then an open questioning practice could be a supportive framework, attempting to guide the students thinking and in turn learning. The questions could provoke a thought, which unaided might not have formed.

An example from the study to demonstrate students’ development of learning was seen in the shapes of molecules and VSEPR (Valence Shell Electron Pair Repulsion) theory activity. The development of the shapes of molecules and the students’ engagement with the open questions posed and activities, led to opportunities where conceptual understanding was promoted. The development of understanding was observed in some of the students’ astute assessments and further questions. In the initial part of this unit, a homework sheet was given to the students as an introduction to the concept of the valence shell electron pair repulsion theory (VSEPR Theory). This sheet was a progression from atomic structure, bonding and orbital overlap diagrams. The introduction to the VSEPR theory was through simple bonding atoms and the use of a 2D format. This sheet also demonstrated the importance of logical sequencing of information to ensure, that one idea helped to support another. The class then progressed to physically building the molecules (see appendix 21 for picture). This topic paved the way for understanding in intermolecular forces and students were highly capable of identifying shapes and using the orbital/configuration idea to predict bonding and lone pairs. The students’
development of understanding on the topic of bonding was evidenced through an interesting student question regarding the bonding that can happen around a carbon atom. The student asked why carbon had a valency of four electrons that could take part in bonding. The student had the s, p configuration of carbon written in front of him (1s$^2$,2s$^2$,2p$^2$) and asked;

How can there be a bonding pair if the 2s orbital is full (in carbon)? (Teacher reflection).

The student’s question demonstrated the development of their own conceptual understanding, which evidenced their active engagement with the learning materials. The student linked his orbital understanding of carbon to the Lewis Dot structure and saw an anomaly. The student was applying the concept in question. There was also evidence (see figure 5.4) in the end-of-lesson evaluative activity, of students gaining understanding with the VSEPR theory and intermolecular forces.

Figure 5.4 Students’ happy with post it’s from the evaluative activity.
5.3.5 Student response to problem-based activities and the application of concepts as tools

The development of activities that promoted the students’ use of concepts benefitted from the inclusion of social learning, progressive sequencing of content and the use of open questions to promote thinking and learning. Constructivist processes support the students learning through the application of a concept that contains socio-cultural links to everyday experiences and big science ideas. Students application of concepts can be promoted through supporting their learning and the development of productive dialogues that seek to ask questions and gain clarity.

Two responses are discussed in the next section. The two responses are; students became engaged with their learning through application activities and students became active in their own learning in chemistry.

Response 1: Students developed an engagement with their learning, by applying what they were learning

There was evidence throughout the study that problem-based social activities promoted the involvement of students in discussions, provided development for dialogue and encouraged collaborative learning. Problem-based discussions also attempted to link real-world chemistry with the classroom, providing relevance for the students. Students not only engaged with their learning when they were using the concepts, in certain cases they appreciated the impact application could have on their learning. In the first example, the students were developing their understanding of bonding, linking orbitals and electronegativity with covalent bonding. A new bonding progression unit was designed for this study (appendix 20). During the bonding lessons, I inputted electronegativity information onto the bonding spectrum diagram (figure 5.3) as it was encountered in class. Electronegativity values on the bonding spectrum introduced the students to the Pauling scale as a method to approximate electronegativity difference between bonding atoms. The explanation and application of this scale seemed to impact the students understanding, as mentioned in my reflection of the lesson.
I think the students, some anyway, might have experienced a bit of a light bulb moment when I was explaining how useful a tool this scale was → that we now could take any two elements in the world, and if they (the students) were asked to predict the type of bonding between them, they could. I think they really did appreciate how powerful a tool this is as there were a few ‘ahs’ and ‘ohs’ in the class.

(Teacher reflection)

Another example of the application of a concept impacting student understanding occurred during the gas laws unit. In this unit, Boyle’s Law was introduced graphically first and then an activity to further understanding was completed by the students. From their observations of the investigation, the students then had to apply their results to make sense of the graphical representation of Boyle’s Law that was on the board. The investigation required the students to put a marshmallow into a plastic syringe and create a seal, by holding their finger over the opening of the syringe. The students could then increase and decrease the pressure on the marshmallow inside by moving the plunger up and down.

The investigation (marshmallows & syringe for Boyle’s Law) went very well. Nearly better than I thought, as I had never done it before – I don’t know why. The students were engaged and there was a lot of ‘ooohs’ and ‘aaaahs’ which was interesting. They could clearly see the volume of the marshmallow changing and compared the syringed marshmallow to a beginner one. (Teacher reflection)

These incidents are examples that show students were engaged when given the opportunity to apply their learning. When the students engaged in challenges that could promote their concept development, the majority of the students in this study rose to the challenge and some exceeded it. These findings provide evidence that students are willing to engage with their learning, if their learning involves them and they can see the relevance of the activity.
Response 2: Development of active learners

The evidence of the students’ active collaboration with each other was from field notes during classes and comparison with previous years. The experiments during this study were carried out in pairs, even if that was not normal practice in previous years. In the student pairs, the responsibility to talk, plan, think, discuss and generally do, was halved; no one person took on everything. Activity levels were observed in a reflection after an experiment that measured the relative molecular mass of a volatile liquid.

After the introduction and problem solving of some of the practicalities of the experiment → the students were off! And for the 1st time, my students did this experiment in their pairs. Which was a lot of equipment and a lot of Bunsen burners! But it worked quite well, they discussed what they had to do in pairs and I had much less instruction to give during the experiment than other years. (Teacher reflection)

In this example, as with most experiments during the study, the students worked collaboratively and actively together. During the study, no group fell behind due to non-engagement, and a sole student was not left with most of the work, as every pair shouldered their responsibility for the task. There was, generally, a very high level of experimental work and organisation from the students this year. Another example of this high standard of work and active involvement is seen in a reflection on a lesson involving an electroplating investigation.

... Students were very neat and organised, their work space and results table were very good ... They worked extremely well during the electroplating activity and swapped their objects and metals around themselves. They asked very good questions and made good observations → why was the solid not sticking to the metal evenly? Got the students to explain what was happening during the experiment. They worked very well at that. (Teacher Reflection)

The students worked extremely well throughout all the experiments. The students themselves have also mentioned that the experiments have helped understanding, particularly those that relate to everyday life.
Victor: I like how some of the things we do tie into, eh, everyday life. So, it's in a way more relatable, so you can kind of understand where things are coming from and where it might be used. (Co-gen)

There is a need within experiments to keep the focus on the development of understanding, rather than an experiment being an activity the student simply completes. If the activity is favoured over understanding, then the student could struggle to link the concept to the purpose of the experiment. Students need to be active in their engagement with their learning as much as the activity.

5.4 Discussion - How did the social constructivist methodologies and practice affect student engagement

5.4.1 Introduction

The change in teacher’s practice through social constructivist methodologies positively impacted student engagement in this study. Student engagement in this study was understood as the students active and positive involvement in their own learning. Development of social constructivist designed learning approaches gradually incorporated the students into their own learning over time. The strategies enacted in the classroom sought to break down cultural constraints that could impact an Irish classroom, namely a traditional teaching culture dominated by assessment. The approaches used in this study promoted dialogue and students were active in the classroom and productive in tasks and investigations. The next section expands on the concepts of social dialogue and the application of knowledge.

5.4.2 Social dialogue

Providing a more social element to learning had one of the biggest impacts on the students and their engagement in chemistry, in this study. A method used in this study which provided opportunities for social dialogue among students
was peer learning. Peer learning as a method, was the result of extensive reading of the theories and work of Lev Vygotsky (for example; Vygotsky, 1997 & Veresov, 2005). The development of peer learning was underpinned by a Vygotskian theory, which outlines that knowledge is socially constructed. Through this social construction of knowledge, the individual can then engage in an internal reflection of the idea/concept (Vygotsky, 1997). The understanding that social interactions were important for student learning impacted strongly on my practice. Indeed it determined how activities and learning progressions would be carried out in the classroom. The planning for lessons always included, as best as possible, a social element that involved the students discussing with each other.

Decided to completely change this lesson, based on the experience that new material takes time to embed, and instead of putting more new info on the students, decided to do pair and explain work (Peer learning) on the investigations done in Wed’s class. (Teacher Reflection)

Peer learning was the term used to describe times in the class when the students had to discuss ideas, answer questions or develop and carry out an investigation, with their peer. In this study, it was found that peer learning promoted students to become active in their learning.

Students were very active and engaged on all tasks throughout the classes. The shared listening through the week worked very well, from my point of view students were on task and I got feedback every night on their thinking about a certain topic (Teacher reflection)

The active and social construction of knowledge was encouraged in this study through dialogue processes. When students worked together they were engaging in the co-construction of each other’s, and their own learning, and this demonstrated a high degree of interpersonal skills and interactions (Goldstein, 1999).

The interpersonal relationship was important to the success of the method, and in this study, students mentioned the peer work as providing a support for their learning and that they felt comfortable asking their peer a
question.

Victor: ... group work, has been very helpful. I don't think, ah, I would have like done as well in the test say, if I didn't have someone that could like help me out. (Co-gen)

This supportive social relationship was also mentioned by other students in the following two studies. Emdin (2007) was a researcher who was teaching in a New York based high-school and introduced co-generative dialogues into his practice. The use of co-generative dialogue (co-gens) was to create social spaces where discussions and exchange of social capital could take place between the teacher and students. During these co-gens, students expressed what was important for them to experience success in chemistry. A theme that emerged from the students was that it was important for them to understand the chemical concept enough to be able to explain it to their peers and then to be able to use the concept in real life (Emdin, 2007). Interestingly, co-gens were also utilised in this study in an Irish context, and despite cultural differences between the students, the theme of learning from others, supporting each other’s learning and applying chemistry to the real world was also evident in this study. Student voice and social dialogue informed the learning strategies in the classroom.

Social relationships and interactions between students helping to facilitate learning was also supported in the social constructivist research work of Dwyer (2010). Dwyer applied social constructivist approaches to a learning environment, although not in the same manner as my study. Dwyer was the researcher in her work and developed a social constructivist programme for teachers to implement in a disadvantaged primary school in Ireland to develop literacy levels (Dwyer, 2010). Despite the different contexts, the teachers in Dwyer’s (2010) study also commented that the students were constructing knowledge in groups and were supporting each other in the tasks during class.

Another impact of social dialogue in the classroom was evidenced in how the traditional role of the teacher began to change. Along with the development of a more social practice and interaction with students, my pedagogical knowledge was also impacted during the study. This impact was also evident in science education research relating to co-teaching in a recent study by Schultze and Nilsson (2018). In Schultze and Nilsson’s (2018) study
on co-teaching, an experienced chemistry teacher co-taught with two senior secondary students as the co-teachers, to a junior secondary science class, in Finland. The impact on the experienced chemistry teacher’s pedagogical knowledge and how that changed through discussions with the student co-teachers was monitored. In the paper, the authors stated that the student co-teachers mediated understanding between the teacher and the students, bridging the gap between the different frames of reference for the teacher and the students (Schultze & Nilsson, 2018). Students found it easier to develop understanding from one another, due to students sharing similar experiences and from this, gaining a better understanding of each other’s difficulties (Wells, 1999, as cited in Schultze and Nilsson, 2018). Although my study was not on co-teaching, there was support for the finding of different frames of reference and the mediation of information between teacher and student in my research. Students in my study expressed their occasional difficulty with always listening to the teacher and not always understanding what was said in class. However, the students found they could support each other, and become a resource for each other within the class during the study. The following comment, made by a student during one of the co-gens, demonstrated that students and teachers have different frames of reference and that mediation in the form of questions (to the teacher and to other students) could help further understanding.

**Steven:** *I think it’s important that like the students know, that they need to ask questions cos I think however you explain it, there’s going to be something you miss out on... and it’s easy to, as a teacher, I’d say it’s easy to miss out on something cos like you already know, what you’re saying so you can easily miss something that you know but the student doesn’t so it’s important they can ask the questions* (Co-Gen)

As a group the students could work together to mediate and develop the information the teacher was discussing. Another impact of the students supporting each other’s learning, that was evidenced in Schultze and Nilsson’s (2018) paper, was that the teachers increased their understanding of the difficulties the students experienced in class. As the teacher engaged with the student groups through discussions, the students highlighted difficulties they faced in their understanding that they were working on, and that the teacher might not have previously acknowledged or realised. It was found in this study,
that as the students began to gain support from other students and not solely
the teacher, the traditional role of the teacher also began to change. The teacher
began to take more of a facilitator role, providing support to students as they
worked on tasks to promote their understanding. The facilitator role was
furthered through the development of social constructivist resources and
instructional approaches taken during the lessons.

The mention of comfort and support between students, demonstrated
very clearly both the social and affective involvement in learning, as outlined by
Vygotsky (Vygotsky, 1997). The concept of the unity of affect and intellect is
supported by many theorists (e.g. Gajdamaschko, 2005) and a shortcoming of
some research studies has been the lack of reference to emotions and leaving
the affective nature of the teaching and learning experience unexplored
(Goldstein, 1999). From this study, there seems to be very little literature on the
impact of teaching on student engagement, and how, through the involvement
of the students, learning strategies could be improved, to promote students
ability towards autonomous learning. Literature accessed through this study
focused on student achievement and attitude and a few on interest, but the
interest of the student was generally judged from a questionnaire rather than
discussion or involvement with the students themselves. This study provides
evidence of the valuable impact the students had on the development of the
social constructivist methodology in this study.

5.4.3 Student engagement led to active learners

The activities that were documented as on-task (i.e. students were positively
and actively engaging in the activity) in my reflections were activities that
included peer learning and the application of a concept through problem-based
activities. There was support for those on-task activities within the students’ co-
generative dialogues, as those activities were more frequently mentioned by the
students themselves, and from the full class group in various evaluation
activities at the end of topics. The engagement of the students with their own
learning was mentioned by the students themselves during a co-gen.

Victor: our chemistry class is so much more engaging. So,
there’s kinda more of a motivation to kinda learn. (Co-gen)
With the increased use of peer learning in classroom activities, students began to develop productive social interactions that could promote their understanding of the topic in question. As the students progressed with this method of learning, I walked around the class as the discussions were happening, and the students did not engage with me, as they were discussing with each other. They engaged with me on the occasion when they were both stuck, and then they had a relevant content focused question to ask.

Throughout the study, students began to recognise the importance of being actively involved in tasks and developing a collaborative relationship with their partner.

*Kevin: I’ve realised that it’s more beneficial if I choose someone that I will actually learn with. (Co-gen)*

Recognition of the importance of the peer was one of the keys to success for this process and had a positive impact on teaching in the classroom. The students’ ability to recognise the importance of developing a collaborative relationship with their partner, demonstrated high-level communication skills, support for the other person, a willingness to shoulder the work that might be involved and actively engage with the material being covered in class.

From reflection of students’ activities and engagement levels, a distinction was observed between students partaking in activities and students actively involved in their own learning. My understanding of students solely completing an activity was when an activity was given to a student, but the learning intentions or purpose of the activity was not made clear, and no adaptations occurred to try and support the student in their learning. Students were not supported in the generation of the link between the activity and the understanding of the content. Students in this sense were engaged in *busy time*, rather than genuine learning and development. My understanding of a student actively involved in their learning, was that the student was at the centre of the learning and that the learning was designed and adapted for the student in the attempt to promote understanding in the best way possible. The development of this line of thinking, active vs centered, was realised over the course of this research study and from engagement in critical reflection and in critically reflective discussions with peers and my academic supervisor.
Teaching in a social constructivist manner entailed the promotion of experiences where the students became active participants in their learning process (Gordon, 2009). However, Gordon (2009) maintained that social constructivism was often misinterpreted. When a teacher conceptually engaged with constructivism, their teaching could produce very positive impacts. Unfortunately poor results and ineffective teaching and learning was evidenced if social constructivism was misconstrued or misused (Gordon, 2009). This demonstrates the importance of teachers questioning and developing an understanding into how they view learning and how that in turn impacts their pedagogical practice and the activities the students engage with.

5.5 Conclusion

Social constructivist methodologies impacted student engagement positively in this study. This approach developed more social practices in the classroom which had a strong effect of both the teacher and the student. Engagement levels in this study are viewed as positive by the researcher when compared to her previous practice and how previous students participated in their learning. Positivity of engagement in this study was evidenced through student actions such as: students being active, both physically and mentally, participation in on-topic discussions, asking conceptual orientated questions rather than task orientated questions and limited issues relating to homework or behaviour. In my previous practice, students could be described as passive, relative to the students in this study, more task orientated instructions were needed and there were issues re. homework and slight increase in behaviour issues. Social dialogue, in-class peer and teacher support and activities that developed the application of knowledge, supported (promoted) the engagement levels of students and from this active student participation in their own learning was observed.
Chapter 6: Prevalence of social constructivism in chemistry curriculums and comparison with the Irish curriculum

6.1 Introduction

The research sub-question that outlines this chapter's discussion is; “how does the current chemistry curriculum relate to social constructivist methodologies?”. This chapter involved the analysis of the content within chemistry curriculums across different contexts. Theses curriculums and contexts were chosen due to their similarity in social and economic backgrounds to Ireland, and also the syllabus topics in the different countries were very similar to the Irish syllabus. The content in the curriculums was analysed for direct and indirect mention of social constructivist theoretical aspects. Other theoretical aspects in relation to curriculum development were also included in the content analysis. The frequency of the different curriculum theories and occurrence of social constructivism were compiled for each chemistry curriculum and used as a method of comparison between different curriculums. Curriculum can have an impact on both teacher practice and student engagement. In the previous two chapters, evidence was put forward of the positive impact a social constructivist pedagogical approach could have on both teacher practice and student engagement. If a social constructivist approach is not mentioned explicitly within the curriculum, it could be more difficult for a teacher to engage with the process. This chapter discusses the extent to which social constructivism is referenced in curriculums. A comparison between the current chemistry curriculum and the draft chemistry curriculum (no date of implementation at the time of writing) is discussed, as it is relevant to the discussion on curricular reform for senior cycle education in Ireland. The chapter then widens the discussion to European and Australian chemistry curriculums, and includes a comparison between the curriculums and their representation of social constructivist methodologies.

The attempt to gain a national understanding of knowledge, particularly knowledge in relation to science, is a hotly contested area that has generated debate from philosophical, political, economic and sociological positions (Hopkins, Barker & Bolstad, 2005). Social constructivist themes are implicitly
represented in curriculums in Ireland, through various aims that included the mention of active methods of learning for the construction of knowledge (DES, 2016b). Other methods within a social constructivist position included; social interaction through discussion/debates, the role of language (communication) (Vygotsky, 1997) and the use of reflection during learning activities (Burgh & Nichols, 2012). The social constructivist position was evident through the recognition of science as a collaborative human endeavour, that was impacted by culture, society and history, and was testable and tentative (Lederman, 1999). The tentative nature of science could be exemplified in curricula, by their treatment of the scientific modelling process. An important social constructivist position for scientific models was the recognition of their inherent social and developmental aspect. From a social constructivist position a scientific model was a human construct applied to a natural phenomenon (Driver, Asoko, Leach, Mortimer & Scott, 1994). Therefore, in curricula, it was not just that scientific modelling was mentioned, but how it was interpreted. In the analysis of this chapter, I initially noted whether scientific modelling was mentioned in each curriculum’s rationales or aims, and then if the concept was presented as dynamic, i.e. developmental and subject to change. This contrasted with the mention of a static scientific model, i.e. no mention of developments and implicitly presented as the final model (Adbo & Taber, 2009). In the content analysis of different curricula, scientific modelling was an aspect of social constructivism that was looked for in the rationales, aims and assessments of the documents. Other areas that were used in the analysis of curriculum documents, included the mention of further studies or careers, developing interest in chemistry for the student and the development of lifelong learning.

Theoretical aspects other than social constructivist methodologies included; inquiry processes, Blooms taxonomy and mention of the scientific method (Jenkins, 2007). In Ireland, an inquiry-based approach was promoted as a method to actively engage students with material and concepts in science (DES, 2016b). Indeed, in science curriculum development across Europe, there was a priority placed on inquiry-based teaching approaches (Roccard, et. al., 2007). Also, many of the learning outcomes from the curriculum were classified according to Bloom’s taxonomy (Paul, 1985) specifically; knowledge, comprehension, application, analysis, synthesis and evaluation. The epistemic and pedagogical rationale for learning outcomes are evidenced through an explicit reference to Bloom’s taxonomy (O’Brien & Brancialeone, 2011). Table
6.1 is a key for the theoretical aspects that were looked for in the Irish and other curricula for the analysis of content.

Table 6.1 Shorthand for the different theoretical aspects

<table>
<thead>
<tr>
<th>Shorthand Symbol</th>
<th>Theoretical Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Learning</td>
<td>Active Learning, learning relevant to the student, creativity</td>
</tr>
<tr>
<td>Social Learning</td>
<td>Social Learning (debates/discussions)</td>
</tr>
<tr>
<td>Role of Lan.</td>
<td>Role of Language (ways of communicating)</td>
</tr>
<tr>
<td>Use of reflection</td>
<td>Use of reflection during learning activities</td>
</tr>
<tr>
<td>Human endeavour</td>
<td>Human endeavour (collaborative)</td>
</tr>
<tr>
<td>Socio-cultural Im.</td>
<td>Impact of culture, social and historical and reference to ethics and morals in relation to science</td>
</tr>
<tr>
<td>T &amp; T</td>
<td>Science is both testable and tentative</td>
</tr>
<tr>
<td>S.M. – Dynamic</td>
<td>Scientific modelling – dynamic</td>
</tr>
<tr>
<td>S.M. – Static</td>
<td>Scientific modelling - static</td>
</tr>
<tr>
<td>Further studies</td>
<td>Further Studies</td>
</tr>
<tr>
<td>Dev. Interest</td>
<td>Developing interest or motivation in chemistry</td>
</tr>
<tr>
<td>Lifelong Learning</td>
<td>Promotion of lifelong learning in the aims</td>
</tr>
<tr>
<td>Inquiry</td>
<td>Inquiry processes, posing questions, hypothesis, lab skills, reading data, refining, problem-solving</td>
</tr>
<tr>
<td>Bloom’s Tax</td>
<td>Bloom’s Taxonomy</td>
</tr>
<tr>
<td>Scientific Method</td>
<td>Scientific method</td>
</tr>
</tbody>
</table>

Table 6.1 details the theoretical aspects, both social constructivist and others, there were employed in the development of curricula and implicitly and explicitly stated throughout.

6.2 Irish Chemistry Curriculum

As discussed in previous chapters, Ireland, at the time of writing, is experiencing significant educational change, from policy to practice. The most recent and extensive change included the development and implementation of a new junior cycle programme at the lower level of post-primary education. The introduction of new curricula throughout all subjects began on a phased basis in 2014 (NCCA, 2011b). This curricular change is in contrast with extremely slow movement at the senior level of post-primary schools, particularly with the
sciences. However, a consultation document was produced by the National Council for Curriculum and Assessment (NCCA, 2012) in relation to developments for the senior cycle science. The consultation document echo’s many of the new junior cycle science aims, including; a focus towards an inquiry-based approach, emphasis on discussion, debate, critical thinking and problem solving, inclusion of a research activity and open ended investigation, outcomes based syllabus with the aim to develop skills, e.g. self-learn and the inclusion and development of the key skills from junior cycle (NCCA, 2012). While the consultation process is promising, the draft syllabus for chemistry was published in 2011, and there has been no development since then. This study was framed by the current chemistry curriculum in Ireland, which was first published in 1999 (NCCA, 1999).

The curriculum document began with the aims and principles of leaving certificate programmes in general before the specific aims of chemistry were stated. A general aim of senior cycle education was holistic in nature, and included the;

*Development of all aspects of the individual, including aesthetic, creative, critical, cultural, emotional, expressive, intellectual, for personal and home life, for working life, for living in the community and for leisure* (NCCA, 1999, preamble)

This holistic aim was educative in nature, and included the development of the student. The other aims for senior education programmes included; preparation for the requirements of further education or employment, the students’ role as an active and “enterprising” citizens, provide continuity with the junior cycle programme, emphasise the importance of self-directed learning, spirit of inquiry, critical thinking, problem solving and lifelong learning (NCCA, 1999, p. 1). Those aims were general in nature, linked to programmes rather than the development of actions to realise the aims through a contextualised subject. The next section of the curriculum document, contained a brief preamble about the general aim for science education. The aim also revealed an economic focus, which seemed to be an important part of policy in the development of this curriculum. The aim discussed the need for senior cycle education to be reflective of the changing needs of the students. This aim now has an ironic nature to it, since the curriculum itself had not changed in nearly twenty years. With the curriculum not changing, the responsibility of adapting to the students’ needs fell to the
teacher, but who in turn was bound by an outdated and over-crowded curriculum (Murphy, 2015). The aim for general science also mentioned the reflection of; “the growing significance of science for strategic development in Ireland” (NCCA, 1999, preamble). In relation to the social constructivist methodologies identified in this study and the general aims stated in the chemistry curriculum, very weak social constructivist aspects were evidenced in the Irish curriculum. An active construction of knowledge developed within a context was not stated, instead the aims presented de-contextualised aspirations, that contained an economic influence. The holistic development of the student was important and stated, but the aims were not placed within a context, be that subject or activity, and did not expand on methods that could aid the development of the student. The second aim also did not refer to any context in relation to how the curriculum would cater for the changing needs of the students.

After the preamble, in most of the other curriculum documents assessed in this chapter, a rationale or general aim of chemistry would be specifically outlined. However, in the Irish document, after the general aim for science, no statement on the nature of chemistry or a cultural or context understanding of the impact of chemistry was given. The lack of a socio-cultural representation of chemistry and no mention of the nature of chemistry as a science was further evidence that not even implicit representations of social constructivist methodologies existed in curriculum. If they were not mentioned in the curriculum their demonstration in practice would be dependent on the teachers own philosophy of education. However, it was found that teachers could possess a naïve understanding of a philosophy of education, including a naïve view of the nature of chemistry (El-Khalick & Lederman, 2000). There are many complex factors that could contribute to this naïve view of the nature of chemistry, one example is assessment. It was found that some secondary science teachers, due to the weighting placed on assessment, selectively skipped some curriculum aspects in favour of content-focused learning approaches, as they were deemed more important for the student (Hopkins, Barker & Bolstad, 2005). Assessment had influenced those teachers understanding of the nature of chemistry rather than a theory of learning influencing nature of chemistry.
Table 6.2 represents a content analysis of the rationale, aims and assessment of the current Irish chemistry curriculum. The table includes the social constructivist methodologies identified in this chapter (table 6.1) and other curricular influences. The social constructivist methodologies appear in the top part of the table, and the other curricular influences are separated by a row containing purple dots. This was to aid the visualisation of social constructivist methodologies throughout the different curricula. The extended content analysis of the curricula can be found in appendix 22.

Table 6.2 Content analysis of the Irish chemistry curriculum

<table>
<thead>
<tr>
<th>Irish Chemistry Curriculum (NCCA, 1999)</th>
<th>Theoretical Aspect</th>
<th>Rationale</th>
<th>Aims</th>
<th>Assessment</th>
</tr>
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<td>Active Learning</td>
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<tr>
<td>Social Learning</td>
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<td>Role of Lan.</td>
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<td>Use of reflection</td>
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<tr>
<td>Socio-cultural Im.</td>
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<td>✓</td>
<td>✓</td>
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<tr>
<td>S.M. – Dynamic</td>
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<tr>
<td>S.M. – Static</td>
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<tr>
<td>Further Studies</td>
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<td>Lifelong Learning</td>
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<td>✓</td>
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</table>

Key: Table 6.2

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓</td>
<td>Indication that a theoretical aspect was found and/or mentioned. It is not indicative of the number of times an aspect was found and/or mentioned.</td>
</tr>
</tbody>
</table>

In table 6.2 there are no theoretical aspects marked in the rationale column, but that is due to the absence of a rationale. However, as mentioned, the lack of a rationale and understanding of the nature of chemistry, along with the general
aims, pointed to little influence of social constructivist methodologies. Table 6.2 demonstrates that social constructivist methodologies, as understood in this study, had little impact on the curricular design or development of this chemistry curriculum. This curriculum design was guided by a science, technology and society (STS) approach (Eivers & Kennedy, 2006), and this can be seen through the inclusion of societal themes in the preamble and within the aims of the course. Inquiry was promoted through the advocated use of investigations during lessons, although this aim was not developed through to the assessment. Inquiry processes and the impact of social, historical and cultural aspects on science were the only social constructivist aspects (as identified in this study) found in the aims of the Irish chemistry curriculum. There was also no mention of active learning possibilities, which included creativity, that could be promoted through the learning of chemistry, either by direct statement or by the mention of developing new materials or products (NCCA, 1999). An area that was mentioned in the syllabus aims was the development of appreciation for the "scientific method" (NCCA, 1999, p. 2). It was stated in science literature and in published education research articles that the scientific method is a myth and has been resoundingly debunked (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). The idea that scientists followed a single set of procedures and arrived at knowledge was an oversimplification of the scientific process that was, unfortunately, also represented in many chemistry textbooks. Endorsement of a scientific method was also contrary to an understanding of science from a social constructivist perspective. Jenkins (2007) put forward the argument for the abandonment of all reference to a scientific method within a curriculum. He explained that any attempt to reduce such a creative, flexible and diverse way of thinking and analysis through science, to a stepwise exercise could not develop creative and diverse thinkers. The omission of active learning, including creativity, within a national rationale, created a situation where once omitted, those aims could become very difficult to interpret and develop. If they become difficult to develop, the probability could lead to the limited engagement and practice of those aims. In some cases, those aims might not be developed at all, because they were not there. A teacher could develop the aims of active learning in their classroom, although evidence has shown that assessment can drive curriculum and teachers views on learning have been impacted by an assessment-focused education culture (Murchan, 2018).
Curricula stated understanding of a scientific model could reveal a theoretical position, explicitly or implicitly. In the Irish curriculum, there was no mention of either a dynamic or static conception of a scientific model. In the curriculum, there was no reference to models in the subjects aims, therefore no understanding of what a scientific model entailed. The only reference to the word model was seen in the subject content information section of the curriculum. The reference to chemical models was reduced to one term, “use of models” appearing numerous times as an activity within the document (for example; NCCA, 1999 p. 49). The term appeared in conjunction with depth of treatment. For example; the depth of treatment for the overall topic “tetrahedral carbon” was “saturated organic compounds” and the activity was “use of models, as appropriate” (NCCA, 1999, p. 54). There was nothing else written in the activity section bar that short sentence. As stated there was no initial understanding of what a scientific model was in the aims of the curriculum and there was no functional contextual link between identified subject content and the term use of models. An issue identified in chemistry education research was the simplified and unproblematic representation of the models of chemical concepts in textbooks (Adbo & Taber, 2009), which could demonstrate the misrepresentation, or lack of representation, of the nature of chemistry within school courses. Chemistry education research literature argued that chemical models were important and central to the understanding and development of chemistry (Taber, 2010). However, there were issues with the use and implementation of chemical models in classrooms. The scientific model used in classrooms, could be presented as the true and final version of the knowledge or concept in question. If this was the case, then the uncertainty and social discussions involved in the development of the creation of the model would be lacking in the explanations (Erduran, 2001). The use of chemical models in an over-simplified manner, was not reflective of their formation, which in turn did not reflect the nature of chemistry from a social constructivist position. Even with the difficulties of the representation of chemical models, often they might not be used at all in classes, with teachers instead relying on verbal explanations and textbook pictures to convey a chemical concept (Barthlow & Watson, 2014). A possible hypothesis for the simple use of models in classrooms could be due to the lack of a functional reference to models in the chemistry curriculum. This could be true in the Irish context.
6.3 Issues with curriculum

Absent from the Irish curriculum was any understanding of the nature of chemistry, a rationale or a philosophical understanding of the science. The exclusion of a rationale or the contextualised placement of chemistry as science has ramifications for the understanding of the subject from both teachers and students’ perspective. Jenkins (2007) pointed out that school science faced several challenges, one of those being the development of teaching strategies that allowed for the accommodation of active learning through creativity and imagination, as well as development of logic and understanding. When the curriculum failed to mention active learning, creativity or the development of new materials, a narrowing of the possibility of chemistry as an exciting school science occurred. Students’ own curiosity and desire to discover could be hampered due to the lack of creativity within present day teaching methods, content and activities (Niaz, 2010). This again highlights the significant impact teachers’ practice could have on student engagement, in this case, a negative impact was felt when the students’ curiosity was not fostered through active learning opportunities.

To further this point, Erduran (2009) put forward the argument that to focus on subject matter, solely cognitive pursuits, was to narrow the practice of chemistry teaching and learning. A further narrowing could be attributed to the assessment format in Ireland. The assessment for chemistry was a summative written exam, lasting three hours and one hundred percent of the marks for students were attained in the final exam (DES, 2016b). The chemistry curriculum, assessed in this manner, was focused on instructional, cognitive aims, rather than the holistic and creative development of the student. This emphasised the narrowing of practice that occurred within chemistry in Ireland (Murchan, 2018). There was no practical element to assessment in chemistry, which could have resulted in the inquiry processes, that could be developed through investigations, being overlooked (Kennedy, 2013). The summative examination placed emphasis on cognitive aspects that could be recalled, rather than skills that were developed. Any development of skills in relation to laboratory work, were difficult to assess in a written examination. The curriculum as it stood provided difficulties for the implementation of a teaching approach that promoted active student learning. The assessment was acknowledged as
a high-stakes summative exam that could favour more traditional methods of
teaching (Goos, 2004). Traditional teaching styles favoured a cognitive focus of
knowledge and the transmission of that knowledge. In the curriculum, there was
no aim promoting creativity, no mention of scientific models and a lack of
contextual links between the curricula aims and the subject content, all of which
could be attributed to the absence of a rationale of chemistry and no working
understanding of the nature of chemistry. Social constructivist methodologies
had very little influence and connection with the present chemistry curriculum
(NCCA, 1999). Also, the present curriculum (NCCA, 1999) is out-of-date, while
a draft syllabus was developed in 2011, to date, it has not been implemented.
That draft syllabus will be discussed later in this chapter. However, the out-of-
date curriculum could have impacted on students' interest levels, and was also
over-crowded in terms of content. The over-crowding of the curriculum provided
very little opportunity for investigative work, or any extended work into a topic.
Those issues were indicative of issues teachers encountered in senior cycle
chemistry in Ireland. However, as previously presented, even when curriculum
and assessment was changed in Ireland, it had a limited impact on teachers' practice. Another area that needed further consideration was the effect of
teaching culture in Ireland on the implementation of change. Development of
curriculum alone will not impact teachers' practice, an engagement between the
two processes, curricular change and teachers’ practice needs to be developed
and nurtured.

6.4 Other chemistry curricula

To begin this analysis, there is a discussion of how and if chemistry as a science
was represented in the curricula. A representation of chemistry as a science
could state an acknowledgement and understanding of a nature of chemistry.
Table 6.3 is a key that signifies the number that each country’s curriculum was
assigned for use in the comparison tables that follow.
Table 6.3 Key for numbers in table 6.4, 6.5 & 6.6

<table>
<thead>
<tr>
<th>Number</th>
<th>County and Curriculum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ireland – Leaving certificate chemistry (NCCA, 1999)</td>
</tr>
<tr>
<td>2</td>
<td>Northern Ireland – A Level (CCEA, GCE, 2007)</td>
</tr>
<tr>
<td>3</td>
<td>England – A Level (AQA, 2015)</td>
</tr>
<tr>
<td>4</td>
<td>England – A Level (CIE, 2014)</td>
</tr>
<tr>
<td>5</td>
<td>England – A Level (Edexcel, 2015)</td>
</tr>
<tr>
<td>6</td>
<td>England – A – Level (OCR, 2014)</td>
</tr>
<tr>
<td>7</td>
<td>Scotland – (SQA, 2015)</td>
</tr>
<tr>
<td>8</td>
<td>Wales – A Level (WJEC GCE, 2015)</td>
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<td>9</td>
<td>Australia (ACARA, 2015)</td>
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<tr>
<td>11</td>
<td>International Baccalaureate (2014)</td>
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</table>

Table 6.4 shows that five of the eleven curricula included in this analysis, made no reference to a representation of chemistry as a science in their rationale. The holistic nature of the syllabus itself was mentioned and the aim for the learners, but no cultural or context specific understanding of chemistry was put forward. Creativity was chosen as the theoretical aspect to highlight that an understanding of the nature of chemistry could lead to a greater insight into how chemistry could be practiced as a science, both in school and beyond. The other reason that creativity was chosen, was due to the high prominence the skill has been given in the new junior cycle framework in Ireland, appearing as one of the eight key skills in the programme (DES, 2015). The countries that did not put forward an understanding of chemistry as a science were; Ireland, England (Assessment and Qualifications Alliance, AQA), England (Edexcel), England (Oxford Cambridge and RSA, OCR) and Wales. The other six curricula offered similar understandings of chemistry as a science.

Table 6.4 Inclusion of a representation of chemistry in the different curricula

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<tr>
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</tr>
<tr>
<td>✗</td>
<td>Not present within the country’s rationale</td>
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</table>

What was interesting from the different countries’ explanations was that the curriculum that gave a representation of chemistry within the rationale, except for Northern Ireland, also mentioned the creative nature of chemistry. This was either done by direct statement, or by mentioning the possibility of the development of new materials or products. The countries that did not offer a representation of chemistry, did not mention creativity in any form, nor is creativity mentioned in their syllabi aims. In the following section the curriculums representation of chemistry is discussed and highlights how the acknowledgement of the nature of chemistry opened the subject up to creativity and innovation.

Different curriculums put forward different explanations and descriptions of chemistry as a science. However, all curriculum descriptions contained common themes of chemistry as described in chemistry education literature. Chemistry was described as the link science between the micro-world of atoms that comprised matter and the macro physical world (SQA [Scottish Qualifications Authority], 2015). It was also seen as the link between the understanding of the chemical processes of matter which could lead to an understanding of biological and physical systems (ACARA [Australian Curriculum, Assessment and Reporting Authority], 2015). The understanding of chemical interactions informing advancements in the physical and biological worlds was also mentioned in the International Baccalaureate (IB) (IB, 2014). The idea of chemistry as interconnecting science opened its capability to the generation of exciting developments within all sectors of society (FNBE [Finnish National Board of Education], 2003). The curriculums above all articulated an understanding of chemistry as a science. They also included different possibilities that were inherent in the subject and developed aspects that were mentioned within chemistry education research.

The understanding of chemistry as a science in the national curriculums was mirrored in research papers on chemistry in education – as the study of matter and explanations of patterns and interactions (Erduran, 2001; Adbo & Taber, 2014). Within chemistry education research, chemistry was understood
as particle matter at sub-microscopic scale and in an abstract level as the creation of models, often through qualitative means (Erduran, 2001). Chemistry was equated to the science of matter (Erduran, 2001), including the observation of the properties of matter at a phenomenological level and sub-microscopic level. The observation of those properties of matter could then be developed into a series of models (Adbo & Taber, 2014). The centrality of particle models in chemistry, and the fundamental link to any kind of advanced study, has led to particle ideas being given high prominence in many science curriculums (Franco & Taber, 2009). The creation and use of those models was an abstract theoretical structure and elemental to the understanding of modern chemistry (Adbo & Taber, 2014). It was also mentioned, that chemists’ contribution to their science, was in the formulation, often qualitative, of models to explain patterns in data collected about nature and matter (Erduran, 2001). Therefore, the creation of models within chemistry, was an important theoretical point for chemistry education researchers. In chemistry, the promotion of the centrality of matter and models, as a means to link the physical and biological systems, in the creation of novel ways of solving issues within the world, could only be viewed as a creative and innovative science that offers possibilities. A statement of the understanding of the nature of chemistry, with the acknowledgement of its implications on the world, could impact how science was presented and practiced in the classroom. However, it is not enough to say that the subject is creative and exciting, students must experience that through their learning. This requires an understanding of the nature of chemistry at a level that impacts practice and thought.

The analysis of the Irish curriculum in relation to social constructivist methodologies was situated within the culture of education in Ireland. The analysis of numerous other curriculums, as they occurred across numerous other educational contexts could not be framed or analysed in the same manner. The analysis of the different social constructivist methodologies, as identified by this study, could offer a first level reading, essentially a comparison of frequency with which social constructivist methodologies were mentioned across the different curriculums rationales and aims. Table 6.5 and table 6.6 represent the comparison of the different counties rationales and aims within each of their upper secondary school chemistry curriculums.
Table 6.5 Comparison of different countries rationales

<table>
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<tr>
<th>Theoretical Aspect</th>
<th>1</th>
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<th>3</th>
<th>4</th>
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Table 6.6 Comparison of different countries aims

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199
Table 6.5 and 6.6 evaluate how social constructivist methodologies, if present, were represented throughout the different curriculums. This evaluation of social constructivist methodologies could provide a preliminary guide to the theoretical and philosophical position of learning in a curriculum. What was apparent, at a frequency level, was that social constructivist approaches were more frequently mentioned in the rationales of countries outside of the European Union, apart from Finland. There was also an increase in frequency of social constructivist methodologies from the rationale to the aims. This could suggest that social constructivism was being interpreted as a method, rather than a methodology. An example was the English AQA exam board A-level (No. 3). In their rationale, one social constructivist approach was mentioned and that was active learning. However, active learning has a wide pedagogical understanding. In the aims, the frequency of social constructivist methodologies mentioned increased to six. Active learning was not mentioned as an aim within the curriculum, despite being mentioned in the rationale. Also, it was the only curriculum document that conveyed the idea of a static scientific model. The majority of the other curriculums, did not mention a scientific model at all. Wales, Australia, Finland and the International Baccalaureate all mentioned a dynamic representation of scientific modelling either within their rationale or their aims. As previously stated, a lack of reference to scientific models in the curriculum could lead to difficulties in the classroom with teachers relying on text-books as their source of information. Models represented through text-books were usually simplified and could be presented as the final form (Adbo & Taber, 2009). With this presentation, the arguments, discussions and evaluations underlying the development of those chemical models were absent (Erduran, 2001). No mention of the scientific model in a curriculum could also demonstrate a limited understanding with developing a nature of chemistry. It also signifies a lack of use of social constructivist methodologies. The development of scientifically literate students, which is an aim of the DES in Ireland (DES, 2016b) could become quite difficult if they are unaware of how the knowledge in chemistry was generated. The bypassing of the social constructions involved in the development of concepts in science could lead to rote-learning of content, often de-contextualised, rather than the promotion of ideas to be understood.
In terms of the aims within the different curriculums, inquiry processes and Bloom’s taxonomy were the strongest theoretical aspects across all curriculum documents. Interestingly, the use of reflection and social learning did not appear as aims in any of the countries curriculums. Use of reflection also did not appear in any of the countries rationales, and only two countries included social learning as part of their rationale, England (CIE) and the International Baccalaureate. However, social learning in terms of a method for student activities, was discussed later in the documents of many of the curriculums, e.g. use of group work or collaborative work in investigations. The minimal reference to social learning across all the countries rationales and aims was interesting. The adoption of a social constructivist methodology would have implications on a teachers’ practice. To accept a social constructivist position implies that learning would involve the social construction of knowledge and social engagement with the world around you. With acceptance of this position, pedagogy would also have to take a social position. The construction of knowledge does not happen in isolation or by sheer observation, it is the interplay between ideas and social interactions. With social learning having very little representation in the different countries rationales, and no representation in any of the countries aims, it could be concluded that social learning was not interpreted as a pedagogical approach, rather group work was an instrument that a teacher could use in their practice. This contrasts with social learning, from social constructivist position, that would inform practice, rather than being an add-on to practice.

6.5 Assessment

As stated previously, many of the learning outcomes, or as they are called in the curriculums, assessment objectives, were classified according to Bloom’s taxonomy (O’Brien & Brancaleone, 2011). Table 6.7 provides evidence of the classification of the objectives according to Bloom’s taxonomy.
Table 6.7 Comparison of different countries assessment focus

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The assessment objectives within the curriculums were framed by the terms; knowledge and understanding, apply, analyse and evaluate. The only exception to all the countries’ curriculum objectives being framed by Bloom’s taxonomy was Finland. In the Finnish Core Curricula document, the role of assessment was the provision of feedback to the students on their progress, and that the course assessment should be diverse and not based solely on written exams (Finnish National Board of Education (FNBE), 2003). Assessment also included continuous observation of the students’ progress and the students’ own self-assessment (FNBE, 2003). Finland’s assessment approach was the exception within this analysis, as it was the only country that did not have a centralised approach to assessment. A centralised approach in the other countries usually involved an examination board that designed the assessment and that was then distributed out to schools. Assessment in Finland was determined by the teacher of the subject, and the final assessment for the student was decided by the principal and the student’s teachers. The student also received information about the assessment criteria involved and would receive feedback throughout completion of the subject (FNBE, 2003). Bloom’s taxonomy may exist within
certain aspects of assessment in Finland, although the assessment objectives were not exclusively classified by Bloom’s taxonomy.

Inquiry processes for assessment were evident in curriculums that contained a practical assessment. The curriculums that did not have a practical assessment, going towards a percentage of their summative exam, did not contain inquiry processes within their assessment. All curriculums mentioned the importance of developing investigation and laboratory proficiencies and using those to develop problem-solving and communication skills. Indeed, inquiry processes was a stated aim within all the curriculums. However, when the practical was not assessed, the aim of inquiry was not translated to the assessment objectives. This can also be seen in the aims that promote a social constructivist methodology, but the assessment objectives being reduced to classification under Bloom’s taxonomy. A further complicating factor was assessment for accreditation in upper secondary level education, which has been found to narrow practice to outcomes rather than processes. Although the development of processes in policy and in the rationales of curriculums is stated (O’Brien & Brancaleone, 2011), the outcomes of assessment are prioritised (DES, 2016b). The development of the processes of active and social learning, creativity, development of scientific models, should be evident in assessment objectives, so that those skills and ways of thinking do not become side-lined in a class overshadowed by assessment.

6.6 Comparison between current curriculum and draft curriculum

Table 6.8 demonstrates the difference between the current chemistry curriculum and the draft chemistry curriculum. The draft curriculum was developed as a progression programme from the junior cycle in lower secondary education school in Ireland. It is important to point out that the document from the NCCA (2011a) is a draft and is therefore subject to change. At the time of writing, there was no updated draft of a chemistry curriculum produced, despite the consultation process being completed.
Table 6.8 Comparison between the current curriculum and possible new curriculum

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One of the biggest difference between the two curriculums, was the inclusion of a rationale and understanding of chemistry in the draft curriculum. The representation of the nature of chemistry included a lot more themes relating to social constructivist methodologies than the current curriculum. This indicates that curricular change is being influenced more by a social constructivist position. However, despite the inclusion of varied theoretical aspects in relation to learning, the assessment, even with development in curricular design, is classified to Bloom’s taxonomy and other processes of learning are not assessed.

Nature of science as a curricular change was introduced in Ireland in 2016 with the introduction of the new science specification at junior cycle. There was evidence in other countries of difficulty in the practice of nature of science and in some cases its absence altogether from classrooms. An issue with the uptake of nature of science had, in some cases, experienced similar issues as inquiry teaching in Ireland. It was found that the initial attempts to implement nature of
science aspects to the curriculum encountered two main issues; teachers’ inadequate views about nature of science and confusion in relation to the philosophical stance that was implicit in many curriculums (Hopkins, Barker & Bolstad, 2005). It can be difficult to understand something that is implied, and much of the curriculums in this analysis have also demonstrated an implicit nature to the philosophical understanding of chemistry. This was further supported in the work of O’Brien and Brancaleone (2011) when they commented that the lack of critique into the question of learning “what it is and how it works” (O’Brien, 2006, cited in O’Brien & Brancaleone, 2011, p. 10) can lead to issues for the theoretical foundations of a learning outcomes approach.

6.7 Conclusion – social constructivism within curricula

In summary, the current Irish chemistry curriculum is the oldest curriculum of those analysed in this study. It also contains little to no reference to a social constructivist methodology, either implicitly or explicitly. Social constructivism is more frequently mentioned, in an explicit nature, in the curriculums outside of the European Union, the only expectation to this within the EU is Finland. Interestingly, Finland contains the most explicit mention of social constructivism and is the only curriculum whose assessment metric is not solely based on Bloom’s taxonomy, but also mentions social constructivist approaches within their assessment. All other curriculums assessment metric was based of Bloom’s Taxonomy. If a country had a practical investigation that went towards a percentage of the final summative exam, then inquiry processes were also assessed. A contributing constraining influence on the EU countries could be the Bologna process (O’Brien & Brancaleone, 2011). This process has set in motion the key skills approach that is evident in lower secondary education in Ireland and developing into senior level. The key skills approach has merits, however the certification at sets levels across countries seems to have confined assessment (O’Brien & Brancaleone, 2011).

From the analysis, it was concluded that social constructivism was at best implicitly mentioned in curriculums, bar Ireland. Social constructivist approaches, e.g. active/social learning, appeared within the curriculums as a
method to add onto practice, rather than a methodology that could inform practice. The assessment is acknowledged as a major driving force of the curriculum (Murchan, 2018) and in the cases analysed here, does not support the practice of a social constructivist methodology. That includes the active participation of the students, development of collaborative relationships, communication in the classroom and another area not mentioned in any curriculum was the reflection of the student on their own learning. Aspects could have been mentioned later in the curriculum. However, this usually lead to the understanding of the approach as an instrument to use, rather than inform practice.

From an Irish position, the introduction of a social constructivist curriculum approach would require very significant cultural changes. The lack of a social constructivist position and the constraining factors of assessment and traditional teaching in Ireland, suggest that the explicit introduction of social constructivist methodologies would be quite difficult. The cultural barriers are significant, even if the development of learning within the approach is positive. The cultural influences surrounding education in Ireland cannot be ignored, but they should be acknowledged and this acknowledgement should be encouraged and develop into national discussions on learning, so that Irish education can develop something that benefits all.
Chapter 7: General Discussion

7.1 Introduction

This chapter outlines the social constructivist methodologies which had a positive impact on teaching practice and student engagement. It also discusses the potential impact of this methodology on future pedagogical practice in chemistry in Ireland. The discussion is structured around three main areas; the impact of the methodology (proof of concept), the methodology’s implication for pedagogy and the potential impact it could have on curriculum in Ireland. The limitations of the study are discussed, along with possible future research areas and the study’s conclusions and contributions to theory are presented. Finally, the findings and implications of this research provide practical applications for the development of a social constructivist pedagogy and theoretical implications that could inform the development of a revised senior cycle chemistry curriculum in Ireland.

7.1.1 General discussion: Impact of social constructivist methodologies on teaching practice and student engagement

There are very few research studies in Ireland that have applied social constructivist methodologies to teaching practice, especially in senior second level chemistry education. The findings in this study support the use of social constructivist methodologies in Ireland as a method to promote teacher conceptual change towards more social methods of teaching and support more active student learners. Indeed, the underrepresentation of social constructivist research in Ireland, contrasts with a growing engagement with the approach in America and Australia. Constructivist methodologies such as; student voice (Laux, 2018), collaborative environments through productive dialogue (Gillies, 2017) and engagement of students through co-generative dialogues (Emdin, 2007), were applied in both American and Australian contexts, and produced positive implications for education. These aspects of social constructivism were also evidenced in this study and included the recognition of the importance of student voice to the teaching and learning process and the development of an active and collaborative classroom through productive social dialogue. The
positive aspects of social constructivism experienced in this study occurred in an Irish educational context, in which a more traditional culture of teaching existed. The development of productive dialogue and student voice was promoted through the use of co-generative dialogues during this study. Communication methods for the students were also continually supported and results of this included students engaging in supported discussions with one another during activities. Students supporting each other’s learning was also evidenced in a research study developed by Wegerif, Mercer and Dawes (1999). The study found that the use of communication methods involving group discussion improved group reasoning (Wegerif, Mercer & Dawes, 1999). Students in social activities, through productive dialogue, began to co-construct knowledge. This process was supported by the teacher, to promote the students thinking and conceptual understanding on the concept of the lesson. These findings are further evidence of the positive impact social constructivism had on my teaching practice, and demonstrates its potential to impact other teachers’ practices and policy regarding pedagogy.

In Ireland, most studies that addressed social constructivist methodologies were conducted within primary education (e.g. Dwyer, 2010; Kennedy, 2008). There is a gap in literature in relation to the impact of social constructivist approaches in senior second level education. In Ireland, this gap in literature could be associated with strong cultural factors that have impeded engagement with this approach to teaching and learning. Examples of the cultural factors that could inhibit engagement with social constructivist methodologies include; over-crowed curriculums (Murphy, 2015), the high volume of subject content causing a teaching for coverage approach (Dadds, 2001), lack of continuous professional development (CPD) that develops theoretical as well as practical understanding (Martin, 2006), and the constraining factor of assessment (Murchan, 2018). These factors have also contributed to a tendency towards traditional teaching practices in Ireland (Oldham, 2001), which would be openly challenged by a social constructivist approach to education. However, a movement away from traditional teaching methods, towards more student-centered learning that promotes active and engaged learners, is stated in national education and science policy in Ireland, as well as internationally within educational literature (NCCA, 2009; DES, 2016b; Murphy, 2015). At a senior level in secondary education, students are about to enter the world beyond school and should be developing skills and
attitudes that will help them towards future learning and growth. The development of a lifelong learner is a stated aim within national policy for senior cycle education (NCCA, 2009). Another stated aim within the recent STEM reports was that high-quality education should encompass high levels of student engagement, enjoyment and excellent performance in STEM subjects (DES, 2016b). Within educational research literature, the development of the student as an active life-long learner, developing 21st century skills relevant to today’s world, is also promoted (Murphy, Varley & Veale, 2012; Murphy, 2015). Student engagement is a stated educational aim within national policy in Ireland and the findings of my study provide evidence of increased student engagement in chemistry using social constructivist methodologies. This research also provides a possible methodology for other researchers to develop understandings relating to social constructivism in other subject areas in senior secondary level education.

The findings of this study have the potential to develop practical applications of social constructivism to pedagogical practice. Social constructivism also has the capacity to be developed into a curriculum model for use within the revised chemistry curriculum. However, for social constructivism to be implemented successfully within curriculum in Ireland, significant changes to the curriculum and to assessment would have to occur. Along with changes to curriculum and assessment, teachers would also need to be supported by extended professional development. This extended support would be necessary to help teachers’ conceptual engagement with the curriculum model as an approach to pedagogy, rather than individualised methods of teaching. The adoption of social constructivism as a stated curriculum method could help to progress Ireland’s aim of developing active and engaged learners. However, it would require a significant shift in teaching culture in Ireland.

The following section outlines, in more detail, how the findings from the research study could be expanded in Ireland. The section is divided into three main areas; proof of concept, implications for pedagogy and the potential impact of social constructivism on curriculum development in Ireland.
7.2 Proof of Concept

7.2.1 Introduction

The social constructivist methodology developed and used in this research yielded, overall, positive results. An endorsement of the methodology was evidenced in my findings. The findings included; teacher conceptual change (supported by reflection); more social methods to teaching practice; active, collaborative and supportive students and student engagement with learning promoting their own conceptual development. An important finding also recognised in this study, was the students impact on the teachers practice. In Driver, Asoko, Leach, Mortimer and Scott’s (1994) theoretical paper on the construction of scientific knowledge, they discussed that teaching from a social constructivist perspective was as much a learning process for the teacher as it was for the student. This study’s initial goal was to improve learning within a chemistry classroom for students. Importantly, the students, in their feedback, comments, informal discussions and co-gens throughout this study, equally supported the teacher in her learning. The positive developments towards teaching practice evidenced in this study dovetail a growing body of evidence supporting the concept of social constructivist methodologies being implemented into education (for example: Dwyer, 2010; Kennedy, 2008; Goos, 2004; Gordon, 2009, Roth & Bowen, 1993).

Enablers and barriers encountered during the implementation of social constructivism in an Irish context are discussed and strategies put forward that could help the implementation of social constructivist methodologies into pedagogy on a larger scale. The design of relevant continuous professional development (CPD) could be a strategy that could help the implementation of social constructivism for teachers and is outlined. Future research into other aspects of the broad theoretical construct of social constructivism is considered.
7.2.2 Positive impacts of the social constructivist methodology used in this research

A unifying factor that supported the successful implementation of the following strategies was the inclusion and acknowledgment of student participation and voice. Student voice is an extremely important aspect of social constructivism, and one that supports the social constructivist methodology. I found that an engagement with students and acknowledgment of their feedback and questions during class, prompted me to re-evaluate my teaching practices, which led to improved relations and practices within the class, also the improved engagement of the students with activities. Teaching practices were informed and developed with the aid of the students perspective on learning. In a social constructivist classroom, the involvement of the student is vital to enable the co-construction of knowledge, both for the student and the teacher. This was also recognised in educational literature when Osborne, Simon and Collins (2003) stated that an emphasis was needed in identifying what makes teaching effective from the perspective of the student. My study presents a contribution to this developing body of knowledge. The inclusion of the student and their voice is supported in a variety of studies. In a theoretical review of literature, Laux (2018) concluded that student voice led to a feeling of empowerment for the students, as they were constructing their own meaning and experiencing achievement. Student voice is powerful educational aim, and can become a reality when developed within social, reflective and democratic processes. An ever-present reality of classrooms is the complexity inherent in social interactions, therefore the involvement of the student in their learning, is a vital approach to help the teacher navigate processes within classrooms, which help to support and promote learning. Teachers’ recognition that the student has a pivotal role in the implementation of social constructivist methodologies is vital for a positive engagement with the approach.

The introduction of the scientific enculturation unit (see appendix 23 for outline of unit), incorporating sociocultural factors, had a strong impact on my personal belief and understanding of science and learning, ultimately changing my approach to teaching. Thompson and Zeuli (1999) suggested that real change in learning led to changes in beliefs and habits of practice. The authors put forward the argument that if students were to learn, they must first think. They described thinking as actively solving problems, resolving dissonances.
leading to the creation of understanding in the mind of the thinker (Thompson & Zeuli, 1999). A change of practice for a teacher, therefore, must come from learning which develops from active thinking and engagement with the change (Thompson & Zeuli, 1999). In this study, I created an enculturation unit that developed my thinking through active involvement, and generated learning that progressed my beliefs through practice and reflection. Development of teacher learning also involved engagement and feedback with the students in the class, and this was an important and vital aspect of social constructivism. Teacher development of an enculturation unit, including acknowledgement of student feedback during the unit, could be a beneficial initial introduction to social constructivism.

The inclusion of social interactions to develop the social construction of knowledge, changed my role as teacher. Through the social construction of knowledge, I was no longer the expert, disseminating information, I became more of a facilitator and supported students in their construction of knowledge. This impact was also acknowledged in research by Dwyer (2010). She looked at student learning using online and other digital resources, in disadvantaged primary schools in Ireland. Her focus was on the development of cooperative learning and the classroom behaviours between students and teachers as they learned to use the online resources (Dwyer, 2010). Dwyer’s study demonstrated that the role of the teacher changed throughout the study, with the teacher becoming more of a facilitator, as the students began to rely more on each other during online learning. Dwyer (2010) provided evidence that peer collaboration led to the social construction of knowledge and that this was promoted by the development of cooperative relationships between students (Dwyer, 2010). Despite differences between Dwyer’s study and my own, social interactions in both contexts impacted both the teacher and student. Dwyer’s study was set in a primary school and involved her as researcher observing teaching during designed lessons. In my study, the research approach was a teacher-designed self-study on the impact of changing my own practices in an upper secondary school context. Despite these differences, both Dwyer’s and my own study provide evidence of the powerful impact social interactions have on the development of active and collaborative student environments. The generation of the active student was supported by the teacher taking on the facilitator role and allowing the student autonomy over their own learning, something which is difficult to achieve through a more traditional practice. Evidence of the impact
of social interactions across studies of different education contexts suggests that social constructivism has the potential to be impactful in a variety of educational settings and across different topics.

Just as social interactions challenged my traditional role as teacher, the interactions also moved the students out of their traditional passive roles. It was found, in research that looked specifically at teaching methodologies, that passive, non-engagement, student learning was partly connected to a traditional style of teaching (Loughran, Berry & Mulhall, 2012). PEEL (Project for Enhancing Effective Learning) was a movement in education that was set up to directly respond to teachers concern about students' passive learning (Loughran, Berry & Mulhall, 2012). The issue of passive learners was evident in education for a long period of time and PEEL sought to challenge students passive learning habits to develop more active learners. The group viewed teaching as more than the delivery of information and PEEL recognised the challenge teachers faced in the genuine confrontation and progression past traditional practices teaching, to implement change in their practice (Loughran, Berry & Mulhall, 2012). Activities that produced the highest student engagement during this study involved challenges and puzzle like tasks. In a literature based research paper by Gash (2014), he concluded that there was no guarantee that learning that challenged students into more complex representations would happen solely due to increased social interactions. The teachers' development of the lesson and activities had to ensure that challenges existed within the learning (Gash, 2014). Student interaction can support conceptual development, but the learning experiences need to be designed by the teacher to appropriately challenge for the development of the student. Students responded to a challenging task, although the element of social interactions provided support for the student in their learning. Students could ask their peer questions, or seek clarification at a point that was most supportive to them. The peer-as-teacher and supportive peer as problems arose, was evidenced in my study when students explained ideas to each other, or helped each other solve issues relating to investigations. Students were no longer passive in their learning, they were willing to take responsibility and be active in their role as learners.

As knowledge is understood to be socially constructed, another element that was taken into consideration was the presentation of the pedagogical
chemical content to the students. This involved the development of a unit of work in chemistry containing progressive and logical connections that would build and support the students conceptual understanding rather than present disparate aspects of information. The difficulty students experienced when attempting to understand disparate pieces of information was acknowledged by Gordon (2009). In his theoretical essay paper, he analysed different studies that used constructivist methods of teaching. In one example, he discusses research involving a case study of a lower secondary school maths teacher who implemented constructivist changes to her practice. Unsure as to how the change was impacting her students, she asked for their response and got mixed reviews. The students recognised the importance of working independently or in groups, and the importance of problem-solving and thinking for themselves, but they expressed that they were also confused and did not receive enough support during explanations (Gordon, 2009). The teacher recognised that her constructivist approach had not been helpful for many students and that they were experiencing difficulties in making connections between concepts. The teacher adapted her teaching approach to provide support when it was necessary (Gordon, 2009). The importance of progressive connections within content coupled with support for the learning was highlighted in this example and evidence of this was found in my research study. The progression of curricular material in my research was informed by the pedagogical content knowledge of the teacher and feedback from the students. The students provided in-class information about whether the sequence of information they were working with was progressive and logical to them. The social constructivist concept of knowledge being constructed through social interactions, led to more informed progression paths for content and aided the development of lessons and resources.

These aspects of social constructivism had positive impacts on my teaching practice. They included; the students perspective in the development of teaching methodologies, the development of a scientific enculturation learning unit and its impact on teacher engagement with social constructivism, increased social interactions that promoted change in the traditional role of both the teacher and the student and the importance of progressive pedagogical content that supported student learning. The impact of student participation enabled successful implementation of those aspects of social constructivism. Acknowledgement of student voice and participation by the teacher in this study
involved; listening, accepting, acknowledging and acting upon what the student communicated. Acting on what the student voiced was evident in my study when student feedback was used to inform and develop teaching practice.

7.2.3 Barriers to the implementation of social constructivist methodologies

Some aspects of social constructivism were more difficult to implement in an Irish chemistry classroom. One of the biggest barriers that was experienced during this study, was time. The social constructivist aspect of social construction and mediation of knowledge required more time than traditional teaching. The chemistry curriculum in Ireland is currently overcrowded and the volume of subject content favours a more traditional approach to teaching. This generally includes the dissemination of information rather than an engagement with learning. Due to this cultural and constraining factor surrounding teaching, the use of social constructivist methods took more time, initially than traditional teaching. This could be an issue for some teachers, as they might not be able to reconcile taking more time and covering less material in the current curriculum context. Even though time was an issue, the students’ development and understanding of concepts was at a high level. I found that introductory lessons in new topics took longer, but in the application of concept activities students moved through them quite quickly, so time was gained there. The level of understanding they reached allowed the majority to progress quickly through near the end of the topic. Another method I used to accommodate for the issue of time, was having a digital classroom where all notes and class presentations were located and students had access to that. Students did not take down any notes during lessons.

Another aspect that could be a barrier to constructivist implementation in Ireland, was the level of support and time the student needed in the development of socially constructed knowledge. The use of social constructivism and the development of skills for learning rather than the replication of information, required that the student was supported in this learning. The level of support sometimes was quite high, as students had not experienced the development of these skills before. In a mainly traditional teaching culture, students were more familiar with the transmission of
information. This resulted in the students becoming very uncertain when they were being asked to decipher or apply information without direct instruction from the teacher. The time given to support the students in this way of learning was hugely productive later in the course as they applied their skills and understanding to new contexts and needed less and less support. The uncertainty students felt when completing unknown activities was evidenced in a study by Roth and Bowen's (1993). Their study involved students completing open-inquiry ecology investigations with very little guidance from the researcher, who taught this unit of work in their school context. During the student interviews in this research study, some students mentioned that they did not feel that got the amount of support they would have liked, and stated that the teacher should have come around a bit more. However, near the end of the ten-week study Roth and Bowen (1993) observed that once the students gained confidence in the approach they became more independent and developed positive attitudes to their work. The outlay of time initially, produced very positive results later in both studies. However, this initial time outlay and how best to support the student could be a barrier for some teachers.

Increased social management of the classroom could also be a difficulty in the implementation of the social constructivist methodology. The increased social management was due to greater social opportunities. During this study, the teacher had to learn effective management methods to monitor the high frequency of interactions that were occurring. This monitoring was to ensure that the interactions were positive and productive between students throughout the class. This could be a barrier to the implementation of social constructivist approaches for teachers, particularly if the teachers’ teaching style is quite didactic and traditional. The increase of social interactions and student talking in the class might be too far away from their conception and belief of teaching. A method that helped me to implement more social interactions and ensure that discussions were on-topic, was to get the students to work in pairs. In pairs, I found it was more difficult for them to go off-task, they had no one else to talk to and it was obvious when one was not working. For the majority of the study the students worked in pairs, including during experiments.

Another issue to the implementation of social constructivist methodologies is the lack of support or CPD opportunities available for teachers. In my context during this study, I was completing a doctorate of
education and had support and access to an academic supervisor. However, an issue I experienced was the completion of the research and the management of the development of resources and methods while working full-time. While I lacked time, other teachers would not have access to the same support I had during this research. It is widely acknowledged in educational literature that the development of teachers’ practice requires relevant and on-going support (Crawford, 2007; Lotter, Harwood & Bonner, 2007). The main aspect of change that was very strong in literature studies, was the impact of the teachers own belief system and their understanding in relation to science. The development of any CPD to support social constructivist methodologies must take into consideration the belief system of the teachers involved and their understanding of science. Some teachers might be more favourable to social constructivism than others, but just like in a classroom, the level of support that is required should be evaluated.

A further difficulty encountered with the social constructivist approach used in this study, was the movement between the conceptual understanding of a meta-theory, to the development of practical approaches in the classroom. This study provides evidence that practical social constructivist methodologies are possible. It is acknowledged that social constructivism is a wide-ranging theory and ontological position, and this study is not aiming to narrow the theory, rather highlight the aspects of the theory that were positive for development in the context of the teacher’s practice, in this study.

The barriers encountered during the implementation of the social constructivist methodologies included; increased time, how to best provide support to students and increased social management. Due to these barriers, teachers would require on-going support as issues can continually arise throughout the implementation of the approach. The current CPD model in Ireland, including the once-off nature of the support, would be an ineffective model to use to help the integration of social constructivist methodologies. If teachers are not supported as issues arise in the classroom, they are likely to revert to their previous practice, as issues might be less likely to occur there. This understanding that teachers need experience over time with their learning, for engagement with the practice to occur was identified by Ratcliffe and Millar (2009). Their study involved the implementation of the nature of science pilot trials in England over a period of two years. They found that despite support
available, it took some teachers a full teaching cycle (one year) before their practice began to modify (Ratcliffe & Millar, 2009).

Despite the barriers that could arise in the implementation of social constructivist methodologies, the positive impacts of the approach outweigh the difficulties. The findings of the study demonstrate; the capacity of the teacher to change practice, the development of active and engaged students and over-all the evidence of improved social relationships, particularly between the teacher and the students. The next section details the impact a social constructivist pedagogical approach could have on teacher practice and student engagement in Ireland.

7.3 Implications for pedagogy: both teachers’ practice and student engagement

One of the major implications of a teacher engaging in social constructivist methodologies, is the resultant movement away from traditional teaching styles. Engagement with social constructivism promotes the social construction of knowledge. Teachers engagement with social constructivist understandings of learning impacts their beliefs surrounding teaching. This change in belief system results in less traditional methods of teaching being used as it no longer supports how the teacher views the construction of knowledge. This section focuses on the change in relationship between teachers’ practice and student engagement that is possible through the adoption of a social constructivist approach to pedagogy. The impact of social constructivism on the interaction between national curriculum and teachers practice will be outlined in the next section.

Planning for teaching using a social constructivist methodology can lead to the development a more student-centered methodology, which can impact pedagogical content knowledge (PCK). Implementation of a social constructivist methodology moves teachers’ away from a more traditional style of teaching, to a more social and interactive form of teaching. Engagement with this approach can change the relationship between teachers’ practice and student engagement (figure 7.1). This engagement with social constructivism is
possible for the teacher if they are supported in their learning. The culture of education and the impact of assessment cannot be changed easily, although greater understanding surrounding social constructivist theories can result in teachers realising that the cultural impacts on education are socially developed and therefore contestable. They are not fixed aspects of education that must be adhered to, rather constructs that currently hold social importance.

The change in the relationship between teachers' practice and student engagement which occurred during this study is represented by the differences between figures 7.1 and 7.2. The main difference highlighted in this section is the inclusion of a double-headed arrow between teachers' practice and student engagement in figure 7.2. This is in comparison with a single arrow head in figure 7.1. Figure 7.1 represents the relationship between teacher's practice and student engagement in a traditional teaching context. In figure 7.1, the direction of influence (the red arrow) from the teacher's practice to student engagement represents the powerful role that a mainly traditionalist teaching style can have on student engagement. The impact appears to move in one-direction, from the teacher to the student, with no inclusion of student voice. The lack of inclusion of the student and the single direction represents a transmissive and didactic style of teaching. Wherea, figure 7.2 represents the change to the relationship due to the implementation of a social constructivist methodology. In figure 7.2 there is a double-headed arrow between teachers' practice and student engagement. The double-headed arrow represents a two-way relationship between teachers and students, demonstrating that learning is occurring in both directions. Figure 7.2 is a visual representation of the implication for pedagogy that could be developed from the findings in this research study.
Figure 7.1 Representation of the relationships between curriculum, teachers’ practice and student engagement.

Key
- Green square = Main conceptual area
- Grey square = Influencing factors impacting on conceptual areas
- Red arrow = Indicates impact of one conceptual area on another, including direction and extent of impact (thicker arrow - greater impact)
- Black zigzag = Barrier

Figure 7.2 Representation of the implication of a social constructivist pedagogy on teacher’s practice and student engagement
Figure 7.3 is a closer look at the two-way (interconnecting) interaction between teacher’s practice and student engagement. This represents the change due to engagement with the social constructivist methodology in teaching practice. The use of a social constructivist methodology increased social interactions and productive communication with students that promoted the inclusion of student voice in lessons. There are two concepts that have impacted the development of the inter-relationship between teachers and students. Social constructivist methodologies, helped to develop a student-centered pedagogical approach and mediated knowledge between the teacher and the student. This again required engagement between the teacher and the student for this to be successful. Therefore, co-operation and collaboration encompasses the development of more democratic processes within the classroom and during activities. This more democratic process also allows for genuine inclusion of the student and their voice in their learning.

**Figure 7.3 Mediation of knowledge between teacher’s practice and student engagement**

Teacher’s engagement with learning can support the development of their teaching practice. In research it has been stated that the quality of learning experiences, provided through the teachers’ practice, impacts on student engagement (Osborne, Simon & Tytler, 2009; Bolyard & Moyer-Packenham, 2008). The development of a social constructivist practice had a positive impact on the teacher, resulting in positive implications for student engagement and student learning. During this study, the implementation of a social constructivist approach supported the development of positive, productive, collaborative and active students. In science education literature, it was discussed that the development of a more collaborative and cooperative learning approach, with
the inclusion of the students, could engage students to become more active in their learning (Murphy, 2015). Minner, Levy and Century (2010) further supported Murphy’s (2015) findings when they stated that improved levels of engagement from the students, promoted and in some cases furthered their understanding of concepts. This study recognises the importance of developing social, active and collaborative learning environments to promote conceptual understanding.

Acknowledging the use of mediated knowledge between teachers and students, it is important to note that they both have different cultural contexts and frames of reference, and those differences could have an impact on a meaningful mediation process if not recognised. This was evidenced in Emdin’s (2007) research as he identified cultural misalignments between teachers and students that were impacting on the learning within the chemistry classroom. Through his engagement with co-gens, Emdin, the other chemistry teachers and the students could express the differences in their understanding of interactions within the classroom (Emdin, 2007). This, more equitable, discussion promoted the co-construction of teaching approaches and reconceptualised success measures within the classroom, between the teachers and the students (Emdin, 2007). Schultze and Nilsson (2018) also noted that differences in contexts existed between teachers and students. In their study on co-teaching, they found that the student co-teachers mediated understanding between the teacher and the junior science students, and that the students had a powerful impact on the pedagogical knowledge of the chemistry teacher (Schultze & Nilsson, 2018). This is again demonstrative of the value and importance the inclusion of students in the classroom.

With the aid of the co-gen in my study, teaching strategies were discussed and informed by students and then implemented during the study. An extremely powerful outcome from co-generative dialogue, that was found in research and supported in this study, was the students realisation that their ideas were not only listened to, but that the teacher put their ideas into action in the classroom, with positive effects (Martin, 2006). Co-generative dialogue as a method to promote the mediation of knowledge, was not a once-off event, as it needed to be developed over time and could be different for every group that it might be completed with. However, if managed correctly, co-generative dialogue could
provide a platform for teachers to better understand their students and how to motivate them, and help the subject become more comprehensible, linking student understanding with teaching strategies to promote student learning (Schultze & Nilsson, 2018). Bergqvist (2012) also provides evidence of previous research limitation regarding educational studies involving teachers and students. Bergqvist’s (2012) thesis investigated how school textbooks and teachers present models of chemical bonding to students in upper secondary schools in Sweden. In the analysis of her work, she presented an interesting finding, that although teachers could point out the difficulties students had experienced while learning chemistry, the same teachers had limited teaching strategies to try and promote the students’ conceptual development (Bergqvist, 2012). The methodology developed in this study provides supportive evidence of strategies that can support pedagogical change with the aim of developing students conceptual development, from the perspective of the students. Pedagogical change for the promotion of engaged and active students includes the mediation of knowledge between the teacher and the student. This mediation could take into consideration the different sociocultural backgrounds, contexts and positions within the classroom and aim to develop a bridge for understanding, facilitated by co-generative dialogues. Reflective practices also aided this change for the teacher, as it provided a space in which to critically reflect about actions taken and information gleaned from the students. Reflection was also required to ensure that the mediated knowledge was benefiting both the student and the teacher, and not reinforcing the teachers concept of teaching. These processes were guided by the social constructivist methodology of the study, to incorporate social construction of knowledge between all members of the community of learning in the classroom.

This study supports social constructivist theory’s positive impact on education and goes a step further to provide practical applications for the classroom. The overall finding of the effect of the social constructivist methodology on the students in this research, was that students became engaged and active in their own learning, providing opportunities for further conceptual development in chemistry. Aims stated within the recent Irish STEM report included; the development of engaged students and excellent performance in STEM subjects (DES, 2016b). The development and implementation of a social constructivist approach, during this study, promoted the engagement levels of students. Due to increased engagement levels of the
students, there were further opportunities to progress conceptual understanding. From these findings, this study could provide evidence to support and promote the use of social constructivism as an approach for the development of chemistry pedagogy in Ireland, as it addresses aims contained within the national report on STEM subjects.

7.4 Impact on curriculum development in Ireland

Social constructivist methodologies positively impacted both teacher practice and student engagement. The development of a professional learning model to support teachers’ implementation of a social constructivist approach to teaching was outlined. However, if social constructivism was to be introduced as a curriculum model, educational cultural factors would play a part in whether that implementation would be viable. In this section, Ireland’s lack of reference to a coherent methodology and inefficient CPD is discussed. Assessment also has a strong impact on the possibility of developing social constructivism as a curriculum model.

Curriculum change in recent history in Ireland has not experienced success in terms of the transfer of the ideals of curriculum to the practice of teaching. In figure 7.4 this is represented as a disconnect between curriculum and teachers’ practice. Contributing factors to this disconnect include the absence of a clearly stated methodology, resulting in no clear rationale to guide the learning in the curriculum, the lack of relevant CPD available to teachers in Ireland and the lack of change in assessment to reflect the inclusion of skills within the curriculum. From engagement with this research, I developed recognition of the differences between the enactment of social constructivism and the forced adoption of inquiry-based learning in science classrooms. In studies on social constructivist methodologies, the approach impacted pedagogy on a wide scale, impacting both the teacher and the student. While, in studies on inquiry learning, it was acknowledged that the approach had become narrowed to investigations due to the practical nature of the classroom environment (Minner, Levy & Century, 2010). It was evidenced that inquiry was not being developed as an approach to learning, rather a method that was added onto a teachers’ normal practice (Loughran, Berry & Mulhall, 2012).
pedagogical change was not being developed. To avoid a narrowing of social constructivism, as a curriculum model, the clear and stated rationale of social constructivist methodologies along with extended support for teachers is needed. This could progress the development of active learners and ensure a coherent pedagogical impact rather than the addition of a method to existing pedagogy.

This section discusses some of the obstacles within educational culture in Ireland that can hamper engagement with educational change. Research that considered educational change relating to teaching and learning for science, mentioned that post-primary science curriculums in Ireland were over-crowded and favoured factual-information rather than conceptual learning. The same research connected students’ disengagement from science with an obsolete curriculum along with other school and cultural factors (Murphy, 2015). Other school and cultural factors can also be seen in figure 7.4 and they include a traditionalist culture of teaching and a high stakes summative examination in Ireland. These factors have a strong influence on teachers’ practice. The combination of a less than relevant curriculum with a traditional culture of teaching, driven by a high-stakes assessment, has impacted on student engagement. This study is demonstrative of the substantial effort required for teachers to change their practice from what has become normalised in their context.

Figure 7.4 represents that curriculum change in Ireland experiences a disconnect with teachers practice, as teachers’ practice is more strongly influenced by culture and assessment than curriculum changes. If curriculum aimed at promoting a change in the culture of teaching is to succeed, then the disconnect that is currently being experienced, needs to be addressed.
Figure 7.4 and figure 7.5 represent the potential difference between no social constructivist methodology (fig. 7.4) and the introduction of social constructivist methodology (fig. 7.5) curriculum model in Ireland. Figure 7.4 shows a small arrow going from curriculum towards teachers’ practice, which represents the weak influence curriculum, to this point, has had on teachers’ practice. Figure 7.5 represents the impact that a social constructivist methodology could have on the relationship between curriculum and practice.
Figure 7.5 Representation for the implication of social constructivism on teachers’ practice and curriculum

Figure 7.6 provides a closer look at the relationship and impacts on curriculum and teachers’ practice.

Figure 7.6 Relationship between teachers’ practice and curriculum

In figure 7.6, there are two terms that represent the areas where policy and curriculum could begin to positively impact practice. In maths education reform research, it was stated that social constructivist perspectives on learning could provide a theoretical rationale for curricular change (Goos, 2004). This statement supports the inclusion of social constructivism in figure 7.6, as a clear methodology that could provide a clear rationale for change that can develop teachers’ practice. Support for social constructivism as a theoretical rationale for curriculum change also came from my study. In my study, social
constructivism impacted teacher’s practice. As a methodology, the inclusion of social constructivism in curriculum change could promote genuine development and change in teachers’ practice. Goos’ (2004) study was an examination of teaching and learning practices of a senior maths teacher, using a constructivist framework, in a maths class over two years. Goos (2004) acknowledged that the involvement of senior secondary classes was significant, as the high-volume content in the curriculum and high-stakes assessment might favour a more traditional approach to teaching at this level (Goos, 2004). Despite this constraint, the teacher in Goos’ (2004) study continued to develop his constructivist approach with positive outcomes. Students began completing tasks with less and less support and asking questions and assisting their peers, often by-passing the teacher (Goos, 2004). In my study the same constraining factors influence the presence of traditional style teaching in Ireland, yet I still developed my practice and moved it away from a traditional approach. This provides significant support to social constructivism as a curriculum model. As an approach to change pedagogy, without curriculum change, it had an impact even surrounded by constraining factors. If social constructivism was supported as a curriculum model, the outcomes for learning and education could make the change worthwhile.

Continuous professional development (CPD) is included here, as progressive CPD models could support and be inclusive of the teacher and provide the opportunity for them to implement change in the classroom and experience support. Time also needs to be given to teachers so that they can positively engage with the process. For policy or curriculum to make an impact, the teacher needs to be involved in the practice and gain experiences with the change. A disconnect occurs for teachers if they are asked to interpret and implement educational theories in the absence of both practical and emotional experience and they are also not given the time needed to critically reflect on the experience. Without these supports and experiences the ability to implement theory and change into daily practice becomes limited (Martin, 2006). Martin (2006), in a theoretical paper on constructivist methods for teachers and researchers, recognised that without practical understanding, theoretical understanding cannot be developed. Often education research (or DES directives) advocate that teachers should implement change based solely on theoretical ideas (Marin, 2006). Teachers need time and practice, like their students, to gain practical experience to begin to develop understanding
(Martin, 2006). CPD in its current form supports teachers' developments in gaining a practical understanding of the change in question, although that is not sufficient to develop theoretical understandings (Martin, 2006). Development of teachers’ beliefs is acknowledged as one of the key factors for the implementation of change in classrooms. Therefore, development of theoretical understanding as well as practical, should be a fundamental component of CPD models supporting the implementation of social constructivism as a curricular method.

Development of the curriculum itself would require a reduction in the volume of content, so that extended investigations and deeper understanding of a topic could be gained, rather than surface information. The curriculum would also have to maintain relevance, so an option or flexibility to research or investigate emerging ideas in chemistry could be accommodated. Finally, the inclusion of scientific enculturation within the curriculum, as a method to promote social constructivism and the development of understanding and positioning of sociocultural influences, could provide more opportunities for learning for both students and teachers.

7.5 This study's contribution to the development of a social constructivist pedagogical approach to chemistry

7.5.1 Professional Learning Model

From the findings of this study and engagement with literature in teacher professional development, a social constructivist professional learning model is presented. As the enculturation unit had such a strong influence in my study, the design of the professional learning model is based around the design of the enculturation unit. The overall aim of the professional learning unit is the enculturation of teachers into social constructivist understandings of learning and of science. Engaging teachers in the design and development of a scientific enculturation learning unit can help develop their own understanding of the impact sociocultural influences have on science and ideas in science generally. The development of this unit of work can also include discussions on historic and societal developments of scientific concepts. This could be supported
through debates on famous scientific myths and why they prevail (e.g. Newton and the falling apple). Exploration of different theories of learning can aid the teachers thinking in terms of their own understanding of learning. This initial programme could be a method to embed the conceptual areas of social constructivism including; the social construction of knowledge, sociocultural influences on science and learning and the importance of a clear and progressive sequence of content that aids understanding. The teachers would be involved in their learning, through the supported design of their unit, which could lead to a change in habits.

Structures of CPD that could support the implementation of social constructivism into teaching practice are presented. The professional learning model for social constructivism proposes that teachers should be supported in the design of content or approaches, but the practice of those approaches should happen in the classroom. An extended CPD programme where support can be provided to teachers over time is needed. This support can provide space for the design and discussion of ideas, including discussions on why a certain method might be used. The teacher can then bring their idea back to their school context and carry out the designed approach in their classroom. The teacher then returns to the community of learners in the CPD group, all with their own experiences and then engages in discussions on what happened in the classroom. These discussions are then supported by the facilitator of the group and any solutions or ideas can be shared. These discussions also provide a reflective aspect for the teacher on their own practice, and support the social construction of knowledge. This contextualises the development of ideas to the classroom practice and makes the CPD more relevant to the teacher. This could support the teacher in their development of social constructivist methodologies and could begin to guide their thinking in more general terms.

In studies about the implementation of inquiry-based learning for both pre-service and in-service teachers in America, there was evidence of strategies that supported teachers in their implementation of inquiry. These strategies could also be used beyond inquiry, to the development of teachers' practices in general. The strategies included; the teacher being involved in the development of tools and approaches for teaching (Rees, Pardo & Parker, 2013), the development of beliefs and teaching cannot happen in isolation of classroom practice (Crawford, 2007) and that teachers needed long-term
science experiences while they were teaching and for this to occur during the academic year (Lotter, Harwood & Bonner, 2007). Active reflection of the teacher’s own practice and beliefs was also recognised as an important component of support for the implementation of change in teachers practice (Capps & Crawford, 2013b). These findings, although discussing inquiry practices, support the proposed model for professional learning outlined in this section. However, the strongest predicator of supporting actual change in teachers practice was the teachers’ belief system and understanding of science. This was stated in the following papers; Rees, Pardo and Parker, 2013; Crawford, 2007; Lotter, Harwood and Bonner, 2007 and realised in my study as an influencing factor in the development of my teacher’s practice.

7.5.2 Development of curriculum resources

Throughout the study the students worked with various curriculum and resource materials that were either created or edited by the teacher. The interactions and opportunities to ask the students questions as they were engaged with the activity provided valuable feedback in terms of the suitability of the resources for the students. This study could provide evidence for the development of further chemistry resources that could compliment a social constructivist methodology. These resources could be designed specifically for leaving certificate chemistry and promote the application of concepts within the curriculum. The process developed in this study could be a framework for the design and development of these resources. There are very little chemistry resources that provide opportunities for students to engage actively in their own learning and apply their learning in Ireland.

7.6 Future research

The implementation of social constructivism in this discussion has focused on chemistry. An interesting area of future research could be the implementation of social constructivism into other senior cycle subjects. The impact and development of social constructivist approaches in other subjects could produce methods that could further inform chemistry. It could also provide further evidence for the use of social constructivism as a curriculum model. There is
very little evidence of social constructivist research studies in senior second level education in Ireland, but also internationally. The viability of implementing an overall social constructivist approach to senior cycle in Ireland could be possible, but dependent on further research into other subject areas.

As stated, social constructivism is a wide-ranging theoretical construct. Another interesting area of further study could be the development of aspects of social constructivism that were not developed during this study. In this study, aspects of the theory were chosen, based on their ability to be developed in an Irish chemistry classroom. Other areas that could be developed into practice, and maybe in other subjects include; role play (Gordon, 2009), co-teaching with students (Roth & Tobin, 2004; Schultze & Nilsson, 2018), and a greater focus on scientific literacy, spoken and written and the development of knowledge (Roth, 2014).

The implementation of a social constructivist approach to teachers’ practice can develop a student-centered methodology and impact the teachers pedagogical content knowledge (PCK). This impact on PCK could be another very interesting area of future research. In a social constructivist methodology, social interactions between and with students is promoted and the progression of content knowledge in chemistry. It has been emphasised in theoretical science education research that a teacher must develop a comprehensive understanding of chemical subject matter knowledge in a constructivist classroom (Gordon, 2009). This deep level of understanding is needed to be able to support the student at their point in learning, and understand conceptual difficulties that could arise when talking with students (Windschitl, 1999). The development of curriculum resources and lessons, and feedback from the student can further inform PCK in chemistry. A comprehensive study of conceptual alternatives and social impacts on students understanding of chemistry could be developed in an Irish context. There are conceptual difficulties highlighted by certain reports (e.g. SEC, 2013), although an in-depth study into factors that impact student understanding in chemistry in Ireland has not been developed.

Change in teaching in Ireland has traditionally taken a top-down approach, through the introduction of new curriculums, or new approaches being rolled-out to schools. An interesting area of study, could be the effect of
investing in support structures that provide teachers with experience of different pedagogical approaches and support their development of learning. From this study, it was recognised that a social constructivist approach to pedagogy moved the teacher away from the traditional teaching approach. If more teachers were engaged in different teaching methods, the introduction of curriculums advocating for that change might be smoother. If investment went into supporting teachers rather than enforcing teachers, there could be a very different vista on education in Ireland.

7.7 Limitations

The introduction of a social constructivist, student-centered methodology into a mainly traditional culture of teaching presented some difficulties, and time was the biggest limiting factor. To develop the social construction of knowledge, students needed time to interact with ideas, before they could begin to internalise and use them. Previously, in my practice, due to the curriculum’s high proportion of subject content, learning for understanding was set aside in favour of coverage of content. The social constructivist approach in this study gave more time for understanding, although the high volume of content remained the same. This impacted on the timing of the course in the final year. The viability of this approach in schools could be dependent on the volume of content that remains on the course. However, despite pressures of time, and the same high volume of content, the focus on learning for understanding in this study did not impact negatively on the students. In fact, the standard of answers and ability to interpret examination questions was high for the majority of the class. Time also featured as an issue in the initial development of the resources in this study. The development of the resources that supported the student to apply the concept in question, had to be researched or developed from scratch by the teacher. This initial outlay of time was rewarded by the engagement of the students with the activities in question, and the promotion of their conceptual development.

Peer learning as part of social learning was a key aspect of the social constructivist approach, although it too presented a few difficulties. The management of the social aspect of the classroom, taking into consideration the
diverse range of personalities was an aspect of the study I had not fully accounted for. When swapping the partners for peer learning, a tension existed between me assigning partners, or letting the students choose their own partners. During the study, I utilised both approaches. I acknowledged that I would change partners sooner, if I felt that a pair were not engaging positively. This relates back the social management aspect of the classroom. In this social environment, the teachers’ interpersonal skills and emotional intelligence was tested.

Due to time constraints during the academic year, I was only able to complete three co-generative dialogues. Going forward with this research, I would try to ensure that at least one co-gen was completed in each action-research cycle of the academic year.

As a researcher, I chose which aspects of social constructivism to pursue in relation to the suitability of the context. The decision was taken due to cultural and social factors that impact education in Ireland. The position of choice was both a benefit, as the approach was customised to my classroom environment and a limitation as certain aspects were not engaged with that could also be beneficial. One factor that had an influence on the aspects chosen was the assessment of senior cycle chemistry. This was already highlighted as a possible reason for the lack of social constructivist research into that area of education, and it did present confining boundaries on my research. One of the more difficult aspects of developing social constructivist practices within this setting, was the balance between supporting students in their generation of knowledge and understanding and preparing them for their summative exam. The summative exam requires the students to know a large volume of content and the exam questions generally required exact and repetitive terminology. These two processes appeared to be in opposition with each other at times during the year. Student orientated and designed investigations and research were also difficult to incorporate, as the students had prescribed experiments that they had to complete as they were included in the summative examination. Therefore, the curriculum itself was another factor which impacted on which social constructivist approaches could be engaged with. However, despite the restrictive factor of the assessment and the curriculum, social constructivist approaches were applied to senior education in Ireland, with positive results. I am also aware that more open practices in relation to investigations could
promote the social constructivist approach further. This could be looked at in future research.

7.8 Conclusions

It was seen that a social constructivist approach aided the development of a more student-centered methodology and impacted the development of teacher conceptual change including pedagogical content knowledge. Through this study, the contributions to theory on developing student engagement in chemistry lessons, were; the importance of the inclusion of student voice in the process of learning, support for the social constructivist practices of increased social interactions and opportunities for the students to apply their learning. The contribution to policy includes the support for; teacher engagement with courses that develop their theory of learning through supportive CPD and a clear methodology to provide a clear rationale for teaching and learning. This could provide a more coherent message and could positively impact the implementation of a change in curriculum.

Contributions to theory

- Social constructivism as a pedagogical approach promoted student-centered teaching practices and developed the teachers’ practice. The findings of the study support a proof of concept of social constructivism.

- Social constructivism could be developed into a pedagogical approach in Ireland, that could incorporate social interactions, collaborative work and challenging and appropriate activities to promote active student engagement in chemistry.

- Social constructivism has the potential to be developed as a curriculum approach, although there are social, cultural and educative factors that, presently could hinder the development of that curriculum model. Changes required would include; change in focus of the assessment, less subject content in the curriculum, assess skills and knowledge and
a supportive system of CPD that placed teachers at the centre and which included extended CPD over time with access to curriculum resources.

This study supports and provides evidence for the inclusion of social constructivism as a clearly stated curriculum approach in the new chemistry curriculum. Social constructivism supports the ideals laid out in the senior cycle framework (NCCA, 2009). Implications of the explicit introduction of social constructivist methodologies into the chemistry curriculum include; reduction in the volume of content, assessment to reflect the skills and knowledge aimed to be developed and relevance in terms of topics for the students. Social constructivism can promote teacher practice away from traditional styles. However, the promotion of teacher practice needs to be suitably supported. This study provides a professional learning model for the introduction and implementation of social constructivist methodologies in teachers’ practice and advocates for on-going supportive models. The evidence from the study also provides a framework for the development of exemplar curriculum materials, and could support teachers in the development of their own contextually relevant activities and resources for chemistry. This study supports social constructivism as a methodology for pedagogical practice and contains support structures for its implementation into teachers’ practice. The study also supports social constructivism as a potential curricular approach in chemistry, whilst acknowledging the challenges that approach could present.
References


Dwyer, B. (2010). *Scaffolding internet reading: a study of a disadvantaged school community in Ireland*. (PhD), University of Nottingham, UK.


Appendices

Appendix 1

1. **Thematic Analysis - Transcribed data and coding margin**

   1.1 **Thematic analysis - Initial codes and method**
Appendix 2

Thematic Analysis - More formal themes

<table>
<thead>
<tr>
<th>Proponents of reflection</th>
<th>Impacts of reflection on teaching</th>
<th>Summary Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Students and teachers</td>
<td></td>
</tr>
<tr>
<td>Social learning</td>
<td>On task collaboration</td>
<td></td>
</tr>
<tr>
<td>Assessment</td>
<td>Questions developed over time</td>
<td></td>
</tr>
<tr>
<td>Reflection</td>
<td>Recognised need for more help</td>
<td></td>
</tr>
</tbody>
</table>

Examples of Progress (2 for each)

- Example: social
  - Results of their changes

Incorporate the culture of the school into teaching and learning methods.
Appendix 3

Ethical approval from the Ethics Committee
Appendix 4

Example of teacher reflection during the study

Cycle One Week Nine

Reflection week 24th – 27th Oct (29/10/16)

This week was looking at particle wave duality and quantum function.
This is an area I have an internal struggle with every year.
The wave particle duality leads to the electron behaving very
differently to anything the students have ever come across before ->
so I find trying to contextualise this for the students difficult.
I also struggle with the amount of quantum physics I should
introduce to them.
It might be needed as background information to help them
understand atomic configurations -> but then who really understands
quantum physics when they hear it for the 1st time?
I find I can lose students here, at this point.
They find it too strange and mind blowing.
Some really do not like the idea of something that everybody is
struggling with.
The unknown is not something students link with school.
They expect the known.
They find this very hard, challenging and a philosophical puzzle.
One student came up after class this week and asked -> “If electrons
are not always particles, how are there solid things?”
It was a brilliant question and one I had no answer for (not a
satisfactory one anyway).
Sometimes I think I have my students leaving class more confused
than when they came in.
Part of me thinks this could be a good thing -> challenge their
assumptions and hopefully broaden their thinking.
But there is a fine line between that and confusing them to the point
of them turning away.
The buildup of the atomic orbitals and s and p configurations was
more logical (when they blocked out all the illlogical maybe) but this
was also taught like I would have taught the topic previously ->
didactic instructions and students practice examples after instruction
and teacher example.
They asked very good, probing questions, some of them, showing
me that they were trying to process the difficult information; “Is the
nucleus in the centre of those orbitals/ why don’t the electrons come
near it if they can be found anywhere in there/ are the 2s and 3s
orbitals becoming bigger than the previous s orbital in space?”
(examples).
For midterm work – I gave them an investigation they had to carry
out themselves on the trends in the periodic table using the Royal
Society of Chemistry periodic table app.
Will be very interested to see how students deal with the
investigation and subsequent questions.
At the start of this week, I put up the scientific timeline in the class, and referred to it a couple of times during lessons, but also pointed out that it was incomplete and we will be adding to it. Now there was no student input to this initial timeline, I suppose I wanted something tangible up 1st and then the students can add to it. Well that approach might have worked. When talking about wave particle duality, I had the previous day mentioned a few scientists involved, one student said, “Ms., you know were missing Louie De Broglie from the timeline?” I said I was and that I will add him to it and said good observation. The student then said, “Ms., when you put him up, will you please put up a picture of broccoli as him? Every time I see broccoli now I think of Louie De Broglie”.

Other students started laughing and agreed that they would like Louie De Broglie represented as broccoli! And then the ideas of Walter White from breaking bad being used to represent Heisenberg and a cat in a box to represent Schrodinger were thought of. I will do this as it has context for the students and they might feel like their voice is being listened to. But it is definitely a timeline of symbols that will only make sense to this class group. It has been developed within the culture of this classroom environment.

End of cycle one reflection
Free form reflection at end of cycle one (6/11/16)
I have given this part of my reflection on inquiry cycle one the title – free form. This is because I hope to write organically what I thought, what I am feeling now and what I hope to bring forward from this. I will inform the reflection more with questions from Larrivee’s model and also themes emerging from the reflections written throughout cycle one. What I Thought
My initial research question and the foci of my investigation was scientific reasoning and how it might be improved in the chemistry classroom. I looked at the skills and processes involved in scientific reasoning (from PISA and literature; communicating results, scientific argument, drawing conclusions, creating models and making interpretations) and decided to look specifically at these processes before I started the chemistry curriculum.

Students are perceived to be weak in these areas – so I thought I would focus on some of these processes 1st and develop the students thinking in these areas, all the while linking back to where this fits into science.
We spent nearly 2 weeks working through certain activities to try and get the students to recognize, appreciate and develop some of the processes. From what I saw, I think this effort was worthwhile. However, I do feel I can develop this further and would be cautious of leaving it standing as a once off. I hope to link activities we did at the start into inquiry within the course as well. Either by referring back – model activity linking with atom model change and why, and re-doing some of the activities but with a focus this time on chemistry. For example, as homework they could develop chemistry inquiry cubes for junior cycle classes and get them to explain their reasoning back to me. I think for true ‘success’ of this initial block the thinking and skills involved have to be re-addressed and embedded throughout the year and continuously referred to.

**Lesson plans**

I found the lesson plan format and how to conceive and use it very difficult. The initial plan I used was an inquiry framework got from the Discover Sensors website, a science foundation Ireland initiative to promote inquiry learning in STEM subjects. I used this framework to design my units and assess the learning outcomes of each unit. For this it was quite useful. However, I also used it as my lesson plan format for 3 lessons, which accounted for one week. I found the setting of questions for each class and questions to probe understanding and think about their own learning – good ideas, but difficult to work on a class by class basis. I found in class, the questions could change based on the context of the lesson, and how the lesson developed with regard to the class. What was written was not always asked. This was partly because they changed slightly during the class based on questions the students were asking and because I found referencing a page for my plan quite strange again. I felt at the start, I was thrown off the flow of the lesson. I think that now because after 9 years of majority of the time not using specific lesson plans it was a little alien to me. I like my classes to flow quite organically based on the interactions with the students, but have an overall plan of the unit in my head. The other reason I think I found the 1st plan difficult was because on some days the plan was 3 pages in length and I would get lost, try and find my place and could skip over something. I missed the homework once even though it was written down. There was too much writing on the plan to try and follow in class.
The 2nd lesson plan format, was trying to build from the previous – so I put all the key information I needed on one page.
I thought one page was important, as it was easier to see all the information during the class.
I liked the style of the plan – but again found the key questions a bit difficult.
This style of plan for each individual lesson lasted for another week (3 lessons).
One of the reasons this format got changed was due to the volume of work it was putting on me and I began to feel quite stressed and a bit snowed under.
I thought the amount of data I would generate over an academic year with all the individual lesson plans and knew I could not maintain it.
So on the 3rd week came the third incarnation of the lesson plan and it is the one that was continued with until the end of October.
This lesson plan took a weekly format with the learning outcomes to be achieved that day in class the focus of the lesson.
The how the lesson was to be developed and homework to be given.
This format I found much easier to work with and easier to follow in class itself.
I could also be getting more used to having a plan in front of me in class and it is actually helping the flow of the classes now, instead of hindering it.
There is probably a couple of things that could be worked on with this format.
Key questions that might need to be asked or key ideas to be probed could be included in the plan.
I could make the plan go onto 2 pages, back and front, so on any given day, I am still looking at one page, it will just give a bit more detail.
I think I might need this, as I over-planned a lot of the lessons using the weekly format, and if I plan more specifically I might reduce that problem, some amount.
What I am feeling now
From completing the 1st inquiry cycle I feel there is a lot I can bring forward from it.
It was illuminating for me personally, as when I started this inquiry I felt blind.
I was not sure where I was going with this, was what I was doing right, am I looking at the right things, doing the right thing, recording the right stuff, etc., etc.
Lots of questions!
From the 1st cycle I have learnt that this is a process.
I am learning, just as my students are learning (hopefully) and they are actually going to inform my process and thinking so much.
I have started on a journey and I have now taken the 1st step.
I still don’t know where it will bring me or what that will look like, but
not have a little more light and a little less fear.

**To Bring Forward**

In the lessons at times I felt my structuring and style of questions
were a bit complicated and not thought through enough – maybe
with more room to plan in the lesson format and a focus on what the
learning outcome is for the class and questions I should ask to help
achieve that – I might improve this aspect.

Felt it was a weakness personally in some of my lessons, generally
the lessons that contained quite complicated information.
In the activities the students complete, particularly if they are
meaning making activities, I need to get them to discuss their
reasoning more and then have something that they have to write
their reasoning down on.

Did this at the start, but not much after that.

Keep a focus on the skills/processes of scientific reasoning.

Ask why more!

Homework – puzzle based.

Homework was good in cycle one, try to keep that up.

Another idea for homework is them creating resources for junior
certs based on atoms, periodic table, elements, bonding, etc.

Another idea is to give them PISA questions to attempt for
homework (or optional) and see how they handle the reasoning
portion of those questions.

Reflection – Not to be so negative on myself.

Identify positives within the week (everything wasn’t bad) and explain
why I think they are positives.

Also identify what could be improved on and why and importantly –
what didn’t work, according to what I thought.

Simple but good format for reflection.

Keep this information for co-gens as well.

Would be interesting to see if what I thought was successful was
successful for the students also.

And the same with failure.

The Unknown – I have said in a few reflections that the students do
not like the unknown – the culture of school and maybe home leans
to the known.

I would like to try to de-demonize the unknown for them a little bit –
not to confuse them, but to let them know that the unknown is not a
bad thing.

It is in fact something that should excite the curiosity within them and
understand that science only moves forward because of the
unknown.

Keep filling in the timeline

Will have the four student white boards after midterm – develop
ideas as to how we will use them
### Lesson plan - Unit 1: Lesson 2

<table>
<thead>
<tr>
<th>Unit 1</th>
<th>Lesson 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>31/8/16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop an understanding that a scientific process does not always follow a set path.</td>
</tr>
<tr>
<td>There are many skills involved in the scientific process.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Questions to set the class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do you think discoveries in chemistry/science have always followed the same set of rules/path? Why or why not?</td>
</tr>
<tr>
<td>2. What type of skills would a scientist need in today’s world?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>(To be completed before class)</td>
</tr>
</tbody>
</table>

**Scientific Process Skills**

Do you think discoveries in chemistry/science have always followed the same set of rules/path? Why or why not?

Questions to drive learning
- Use different pictures of equipment, people and information to develop students thinking. (Worked well –> all students had completed this exercise from the previous night and the pictures showed their interests.)
- Give examples in biology, chemistry and physics as thoughts that not everything can follow the same path. (All agreed that no fixed set of rules could have been followed to make the discoveries in their pictures.)

Questions to probe understanding (In class)

[This activity, discussing the idea of scientific discoveries and a fixed path with their pictures as a stimulus worked very well. The students discussed this in pairs and had good discussions; I had to interrupt them to sum up the activity.]

Questions to get students to think about their own learning
I kept lots of space between the questions and typed words, one so I could see clearly what the next thing was, and two, that I could write in observations relevant to each part if there was any.

<table>
<thead>
<tr>
<th>Q 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(To be completed before class)</td>
</tr>
</tbody>
</table>

What type of skills would a scientist need in today’s world?

Questions to drive learning
- What do they know from junior cert?
  - A mind map was developed on the board of all the skills the students had thought of for homework.

Questions to probe understanding
- If they say observation – what is the difference between observation and inference?
- Are further skills needed in each main skill mentioned – what could these be within investigation for example?

Went in the opposite direction in class -> Started with all the skills the students thought a scientist needed. Then on another board, while the students were grouping similar skills, I wrote up some of the scientific processes that research has mentioned. I asked them to look at their groups of skills and see could they fall, in some way, with what was on my board.
Appendix 6

Lesson plan - Unit 1: Lesson 4
### Activity Two

**Mystery Box – Looking at indirect observation and modeling**

*Activity was slightly rushed at the end*

**Questions to drive learning**
- You have to find out as much as you can about the object inside the box.
- What else could help you understand what is in the box better?
- Could you make use of an empty box?
- When they open the box, there are some things that they could not have deduced, e.g. colour – knowledge about anything depends on the quality of our evidence.

I noticed that before I gave the second or third question above, students themselves were picking up objects and moving them and weighing them in their hands to compare against what was in the mystery box.

The Mystery Boxes that were given to the students to explore.

### Questions to probe understanding
- **Draw a diagram of what they think is in the box**
- **Explain to the students** that they have just created a model
- **Is the model complete?** Are their limitations to the model they have made?
- **Is the model useful?** [Need to expand more on this question]

→ Students drew their models and majority deciphered the shape as spherical.

### Questions to get students to think about their own learning
- **For homework** – students must try to come up with two examples of where scientists have faced situations like the mystery box.

I knew I had set homework, but when I was looking at this just before class, I didn’t see this section. Should probably have a stand-alone homework section in this plan. The students did not get this task for homework.
Appendix 8

Lesson Plan – Unit one: Lesson 3

<table>
<thead>
<tr>
<th>Learning Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop recognition of patterns from given data</td>
</tr>
<tr>
<td>Develop problem solving skills through activities in the class</td>
</tr>
<tr>
<td>Make predictions based on given evidence and patterns</td>
</tr>
</tbody>
</table>

Questions to set the class

1. What type of skills do we use when we have to investigate something?

Q 1

Questions to drive learning

- What skills and processes that we discussed yesterday would have to be used when starting an investigation?  
  *(Will get them to answer on the student sheet)*
- What strategies could we put in place when we are investigating?  
  *(Careful observations and not to input inferences too early…)*
- How does working in a team impact on investigation? *(Didn’t ask – forgot)*

Questions to probe understanding

- After the inquiry cube activity – are there further insights into investigations that they now know or have learnt *(Didn’t ask directly)*

Questions to get students to think about their own learning

- What have they learnt from the cube activity that they did not know before? *(Didn’t ask)*

Activity 1

Inquiry Cubes

*(took a long time to complete for some groups, and very little time for others)*

- Students must work out the missing number in each cube
- Record observations, patterns found and explain how they got their answers

<table>
<thead>
<tr>
<th>Cube</th>
<th>Answer</th>
<th>Possible pattern</th>
</tr>
</thead>
</table>
| 1    | 6      | Consecutive numbers 1–6  
Or opposite sides of the cubes add up to 7  
Or numbers are arranged in the same pattern as found on a dice |
| 2    | 8      | Opposite sides of the cube add up to 10 |
| 3    | 36     | The numbers on the cube are the squares of numbers 1–6 |
Questions to drive learning

- **What type of patterns did you find with the cubes?**
  Students found patterns and saw that some people saw the same thing differently -> they got to the same conclusion a different way

- **Did everybody in the class find the same pattern?**

- **Where does creativity come into science?**
  I lead this -> some students did answer, but I lead it by saying what happens when we don’t know an answer. What does a scientist do in that instance?

Questions to get students to think about their own learning

- **Students create their own cube and give the solution and their reasoning**
  Students’ cubes were very good and interesting. They had decided a pattern and started writing in numbers to the flat blank cube, and only then realized that where they put the number was important -> but they did see it when practically working on the cube.

<table>
<thead>
<tr>
<th>Activity 2</th>
<th>More complex inquiry cube</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“Will do this – trialed it with the 6th years and worked very well”</td>
</tr>
<tr>
<td></td>
<td>Solve the more complex cube and write their answer on the board</td>
</tr>
<tr>
<td></td>
<td>Students compare other groups answers with theirs and inquire about methods used and patterns found</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Homework</th>
<th>Work given in relation to the next class – focus on evaluation of evidence and communication of findings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>+ Mario Molina pack (Including information, articles, and student worksheet) – Given out</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Notes</th>
<th>Reflection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not quite sure how the lesson went -&gt; not sure how I felt afterwards, it wasn’t as positive a feeling as I had after yesterday’s lesson. Not quite sure why -&gt; it was the students’ work and I was not as vocal in the class as yesterday, maybe that had a factor in my own feeling. The students were working well in their own groups, but I didn’t get as much feedback from them as usual. Although on reflection of this class, I did miss a number of questions that were set out for the class. Do I always need feedback – can the students work and learn for themselves? Which of course they can, but am I comfortable with that? I thought I was – maybe I’m not! Some students found the cubes quite difficult and did not feel accomplishment -&gt; could have introduced an initial activity for practice to introduce the concept a bit better. They never got round to the creation of their own cubes. Had definitely over planned, or under estimated how long the cubes would take. I think the learning outcomes were achieved – particularly the recognition of patterns from data.</td>
</tr>
</tbody>
</table>

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Appendix 9

Sample of student co-generative dialogue transcript

06:25 T: Maybe is there anything there that you hadn't thought of, or did somebody write something, that you would think maybe I would do that or actually no... I actually didn't like that.
06:33 M: One thing Vlad has there at the very end, is ah... over coming difficulty of a chapter, ahm, by the end of it (Bell goes). Which am, I didn't really think of that, but like, I always remember when your starting a chapter sometimes your doing stuff, and I'm just like - I don't even know what's going on anymore. Oh this is the chapter I'm not gonna like or whatever. But by the end of the chapter, it always kinda fits in and it's actually really nice when you... get to the end and you know it's kinda... in your brain, then.
06:57 T: (Nodding at the student when he was talking) Gonna come together a little bit...
07:01 S: I like the extra experiments, Mark has there. Like the marshmallows and the colours and the skittles when we were doing radioactivity. Just kinda helps. Like the experiments really help normally (T: yeah) and now I feel like the more we do the better I understand it.
07:17 V: Yeah, I like Sammy's ah... idea where's it group work, has been very helpful. I don't think, ah, I wouldn't have done it as well in the test say, if I didn't have someone that could like help me out.
07:31 T: Yeah, and... I have tried to kinda... group work before with other groups... I have to say yer yer, excellent at it. But maybe it's... I'm thinking a little more about it... but it's definitely a class, yer definitely a class that I've found, ye really do work well with the people that you are with, and ahm, I think yer working quite well in the groups... so it's just interesting to hear from ye then that ye are finding that... helpful.
08:07 M: I like as well that like ahm... I feel like the class is really ahm... I don't know if it's cos it's chemistry and and... I don't know... it's kinda associated with, you know, being a tough subject and stuff, but it's a really like... like smart and helpful class so like... sometimes... there might be something really simple that you don't understand, and you don't wanna ask you - cos you're just like - ah come on (me and him both laughing) you should know that...ahm..
08:31 T: I would never say that (jokingly with him)
08:32 M: I know you wouldn't (smiling) but... it's sometimes just easier to ask someone beside ya and... even like... there's just little things that might, ahm, stick better. That with the way they say it, and say you'd say it or something and just think that helps a lot.
19:02 K: (Turning to address me) We're talking about biology.
19:03 T: Oh, that's ok, that's fine. Your making your own notes?
19:06 M: In biology we don't make our own notes, like we take them from the board and I was just saying that I prefer, like, making my own, cos like... you'd be taking it from the board and some stuff... I don't know... there's some stuff that you feel like you need to, your missing stuff and then... I just find like - slideshows in biology like wreck my head. Cos it would be... capital letters missing in stuff... and that just really annoys me now (T: Yeah, agreeing strongly).
19:29 T: No, now that that would annoy me as well. Although I do it every now and again, cos I'm very bad at spelling... but thank God for auto-correct. (laughing) For me. Ahm... so what's the advice for me for my incoming 5th year group? What do ye think?
19:46 S: I like the post-it's notes we filled out - what you were having trouble with and what you liked, at the end of shapes of molecules. Ah... I just thought it cleared stuff up well.
19:57 V: Exam questions are like, I think, a must. So... they help out tremendously.
20:05 T: Do they?
20:05 V: Yeah
20:08 T: Ok...

20:08 M: I like the sheets that you give us, do you know how you give us, I don't know where they are from but, like I find them really helpful sometimes, or most of the time (K: uhm [confirmatory noise]) and am, what Vlad was saying, what he'd think would be good was, do you when your like.. get all the sheets for one topic at the start and just have them kinda all together.. (T: Yes [emphatically said]) cos it might be a hard to keep them.

20:25 T: To keep them actually, ahmm.. together all the time. And some topics are a lot longer than others (K: yeah) and you're getting bits of information (K: here and there) yeah. Actually, that's a good idea, just to have the set of them put together, so there nearly a folder for each topic, on the ones you've worked on. It's a good idea.

20:43 K: Yeah.. and then like you're not losing sheets.. as well.

20:47 M: I like the order actually that we done the chapters as well (K: yeah & V nodded his head in agreement). It seems to make sense.

Like I know I'm, at start, I remember we were going, there was like four chapters and we were kinda going (with his hand, doing zig zag movements) bits and pieces out of them. But then if you look like.. I prefer.. felt like it made much more sense doing it that way then following how the book done it. The one thing I don't like was oxidation and reduction and that that's half finished.

21:07 T: (smiling) Yeah - sorry. (Laughing). (K: nodding his head). But that's ok, I would would totally understand that as well because, ahmm.. I suppose our next chapters titration and we've acids and bases in there but we also have oxidation and reduction. So.. the initial.. I suppose I could keep that information to when we actually do the titrations..
Appendix 10

Ideal Gas Equation Challenge – Activity sheet and information

You are working in an outdoor store during the summer holidays. Your manager mentions that she is not sure about the new shipment of camping gas stoves, as they are coming from a new supplier. Customers have also been complaining about the quality of these stoves and some have returned them. She questions if there is an issue with the quality of the gas within the stoves and is wondering if there is a way to check that the gas inside, is what it says it is.

With your background in chemistry and your ingenuity, you think you might have a way to check this problem for your manager. If you can get the correct equipment – you could use the ideal gas equation to find the relative molecular mass of the gas inside, and check that against the gas that is advertised as inside - Butane (C₄H₁₀)

\[ PV = nRT \]

Data from the day of the experiment

Pressure in the room at time of experiment = 1050hPa
Volume of gas collected = 800cm³
Mass of stove before removal of gas = 457g
Mass of stove after removal of gas = 455g
Temp in the room at time of experiment = 20°C
Resources the students received – pictures of the equipment that could be available for the challenge (appendix 10 contd.)
Appendix 11

Student activity of VSEPR and the building of the common shapes of molecules
James Chadwick

Early Life and Study

James Chadwick was born in Cheshire, England, on 20th October, 1891, the son of John Joseph Chadwick and Anne Mary Knowles. He attended Manchester High School prior to entering Manchester University in 1910; he graduated from the Honour School of Physics in 1913 and spent the next two years under Professor (later Lord) Rutherford in the Physical Laboratory in Manchester, where he worked on various radioactivity problems, gaining his M.Sc. degree in 1915. That same year he was awarded the 1851 Exhibition Scholarship and proceeded to Berlin to work in the Physikalisch Technische Reichsanstalt at Charlottenburg under Professor H. Geiger. Unfortunately for Chadwick, World War I began in 1914, when he was still in Berlin. He was interned in a camp on the west of Berlin until the war ended in 1918.

In 1919, Rutherford, now back at Cambridge having succeeded J.J. Thomson as head of the Cavendish Laboratory, came up with a model that explained why the model didn’t blow up. He saw that the positive charge of the protons must be offset by some type of neutralizing particles, which he called neutrons. The idea was simple and appealing, but not easy to prove. Chadwick, Rutherford’s associate, devoted eleven intensive years to hunting for neutrons before finally succeeding in 1932.

In 1932, Chadwick made a fundamental discovery in the domain of nuclear science: he proved the existence of neutrons - elementary particles devoid of any electrical charge. In contrast with the helium model (alpha 1905) which are charged, and therefore repelled by the considerable electrical forces present in the nuclei of heavy atoms, this new tool in atomic disintegration need not overcome any electric barrier and is capable of penetrating and splitting the nuclei of even the heaviest elements. Chadwick in this way prepared the way towards the fission of uranium 235 and towards the creation of the atomic bomb. For this epoch-making discovery he was awarded the Hughes Medal of the Royal Society in 1932, and subsequently the Nobel Prize for Physics in 1935.

From 1943 to 1946 he worked in the United States as Head of the British Mission attached to the Manhattan Project for the development of the atomic bomb.

Today, most people are happy to accept a slightly modified model of Bohr’s atom, because it can be used to explain the spectra and the reactivity of the elements. The modified model of the Bohr atom includes neutrons, which were discovered by Sir James Chadwick in 1932.
Appendix 13

Questions developed because of student feedback from the atomic development scientist cards

Questions for developing meaning around Dalton and Thomson's discoveries

- Does your prior knowledge of the atom make this activity easier or more difficult?
- Do you think Dalton’s ‘atmosphere of heat’ could be linked with Thomson’s ‘smoke ring’?
- Was Thomson’s ‘smoke ring’ an initial model to work with? Why was it initial?
- What is the difference between Stoney’s naming of a unit of electrical energy and Thomson’s discovery?
- In the cathode ray experiment that Thomson carried out – which field (electric or magnetic) could pull the rays off course?
- Which field (electric or magnetic) could deflect the rays up or down?
- Based on Thomson’s conclusions from the careful observations from his experiment, how did he change Dalton’s model of the atom?
- Do you think Thomson’s model was accepted straight away? Why or why not?

Rutherford

- Using the newest know model of the atom (Thomson’s), arrange what they would look like in a piece of foil – draw out your idea?

- If you were to fire alpha particles (positive particles of considerable mass) through the foil – what do you think would happen? Write down your ideas

- Questions at the end of Rutherford’s card are good meaning questions

Chadwick and Bohr

- Rutherford proposed the existence of neutrons, but why did it take Chadwick another 11 years before he could provide evidence for their existence?
- Why did Chadwick’s discovery of the neutron further the research on atomic fission?
- What was extraordinary about Bohr’s idea?
- Do you think people believed him?
Appendix 14

Term development sheet for trends in the periodic table

Look up both terms and then explain them simply in your own words here:

**Atomic Radius:**

____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

**First Ionisation Energy:**

____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

On the graph paper given, create two graphs using the periodic table app to find the relevant information. For both graphs use the elements across the period, starting from Lithium (3) to Neon (10).

**Graph 1**
Graph atomic number (Li to Ne) on the x-axis against atomic radius on the y-axis

**Graph 2**
Graph atomic number (Li to Ne) on the x-axis against first ionization energy on the y-axis.
Look up both terms and then explain them simply in your own words here:

Atomic Radius:

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

First Ionisation Energy:

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

On the graph paper given, create two graphs using the periodic table app to find the relevant information. For both graphs use the elements across the period, starting from Lithium (3) to Neon (10).

Graph 1
Graph atomic number (Li to Ne) on the x-axis against atomic radius on the y-axis

Graph 2
Graph atomic number (Li to Ne) on the x-axis against first ionization energy on the y-axis.
Appendix 15

*Part of the rationale of choosing students for the co-generative dialogue*

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<tr>
<th>Name</th>
<th>Average of results so far</th>
<th>Grades</th>
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<td>96%</td>
<td>H1</td>
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<td>Ding</td>
<td>80%</td>
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<td>86%</td>
<td>H2</td>
</tr>
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<td>81%</td>
<td>H2</td>
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<td>89%</td>
<td>H2</td>
</tr>
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<td>82%</td>
<td>H2</td>
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<td>H2</td>
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<tr>
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<td>H6</td>
</tr>
<tr>
<td>Daj</td>
<td>36%</td>
<td>H7</td>
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*Will choose 4 students – one from band H1/2, H3, H5 and H6/7.*
Appendix 16

Kevin’s excerpts (S120 during coding)

Reflection, cycle two, week two, 14/11/16

10  Frist ionisation energy across the periodic table (15/11/16)
11  S118 didn’t use the terms required.
12  “steadily increases in difficulty because the screening effect comes
13  into play (due to atomic radius decreasing)” (S120).
14  These two ideas are at odds with each other, which highlights to me
15  that his understanding is missing.
16  But whenever I explain or try to ask him, he just tells me he gets it, “Oh
17  yeah I know that”, or “I know it now”.
18  He won’t admit to himself that he is having difficulty.
19  “The atomic radius affect this because if you removed a negative
20  electron, more positive energy is needed to remove an electron.
21  The nuclear charge must be increased in order to remove an electron”
22  → I don’t understand his thinking here!
23  I need him to explain it to me.
24  “Increases due to increase in number of electrons making the atom
25  more stable. Decreasing atomic radius → stability is influencing
26  strongly, octet framework working here (but must be from junior cycle
27  as I haven’t mentioned it yet in my teaching).
28  Can understand the link he has made between stability and higher
29  energy to remove, but need to get the idea of electrostatic forces into
30  his mind.

Appendix 17

Lesson plane for model tube activity

<table>
<thead>
<tr>
<th>Unit 1</th>
<th>Lesson 4</th>
<th>Learning Outcome: Scientific Process Skills - Model tube activity</th>
<th>Focus: Modeling &amp; evaluation</th>
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<tbody>
<tr>
<td>Learning actions for the lesson:</td>
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<tr>
<td>Introduction (3 minutes)</td>
<td></td>
<td></td>
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<tr>
<td>Body of lesson (20 minutes)</td>
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</table>
| ■ Model Tube activity – task: create a working model of the tube the teacher is holding and moving. Groups to be aware of the scientific process skills involved in this task (3 minutes)
■ Discussion of difficulties and observation of other models (3 minutes)
■ Application of models – the activity they just completed was based on indirect observation. Can the students apply that model they created to an idea outside of the classroom (3 minutes)
■ Don’t get to this |
| Conclusion (3 minutes) |                  |                                                              |                             |
| ■ In the activity the evaluation of data observed lead to the creation of a hypothesis – a (temporary) scientific explanation that can be tested |
| Homework: |                  |                                                              |                             |
| ■ Mario Molina’s work is due tomorrow |
| ■ Students must look again at why they are doing chemistry, why do the like it or are interested, and must emote a picture that |                  |                                                              |                             |
| ■ Students worked well throughout the class |
| ■ Throughout the course, reference to the application of models must be noticed |
| ■ This classes focus ended up being the benefits and limitations of models more so then the evaluation of data – I think! Students sheets might reveal differently |

<table>
<thead>
<tr>
<th>Key Questions</th>
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<tbody>
<tr>
<td>■ What are the benefits of a model?</td>
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<tr>
<td>■ Are there any limitations to a model?</td>
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<tr>
<td>■ Name or draw models you can think of, from junior cert science, that you can remember or ones that don’t make sense to yourself</td>
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<tr>
<td>■ Any other benefits or limitations that occur to them through out the class should be added to the list</td>
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<tr>
<td>■ Draw a rough model (diagram) of inside the tube each time a string is pulled, adopt the hypothesis accordingly</td>
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<tr>
<td>■ What were the difficulties or frustrations in replicating the model</td>
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<tr>
<td>■ Is the statement of a hypothesis correct? Find examples in your model</td>
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<table>
<thead>
<tr>
<th>Strategies used</th>
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<tbody>
<tr>
<td>Class will work in groups of 3 today</td>
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<tr>
<td>In groups list the benefits and limitations of models</td>
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<tr>
<td>Swap their list with other groups to build up a comprehensive list</td>
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<tr>
<td>No group builds models instead of lists</td>
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<tr>
<td>This list will be used throughout the class</td>
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<tr>
<td>Students will draw and discuss their models</td>
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<tr>
<td>Students will record why their working model also demonstrates a hypothesis</td>
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Notes for Self:

<table>
<thead>
<tr>
<th>Learning actions for the lesson:</th>
<th>Key Questions</th>
<th>Strategies used</th>
<th>Notes for Self:</th>
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</thead>
<tbody>
<tr>
<td>Introduction (3 minutes)</td>
<td>■ What are the benefits of a model?</td>
<td>Class will work in groups of 3 today</td>
<td>■ Led the conclusion myself</td>
</tr>
<tr>
<td>■ Model Tube activity – task: create a working model of the tube the teacher is holding and moving. Groups to be aware of the scientific process skills involved in this task (3 minutes)</td>
<td>■ Are there any limitations to a model?</td>
<td>In groups list the benefits and limitations of models</td>
<td>■ Students worked well throughout the class</td>
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<tr>
<td>■ Discussion of difficulties and observation of other models (3 minutes)</td>
<td>■ Name or draw models you can think of, from junior cert science, that you can remember or ones that don’t make sense to yourself</td>
<td>Swap their list with other groups to build up a comprehensive list</td>
<td>Throughout the course, reference to the application of models must be noticed</td>
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<tr>
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<td>■ Any other benefits or limitations that occur to them through out the class should be added to the list</td>
<td>No group builds models instead of lists</td>
<td>This classes focus ended up being the benefits and limitations of models more so then the evaluation of data – I think! Students sheets might reveal differently</td>
</tr>
<tr>
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<td>■ Draw a rough model (diagram) of inside the tube each time a string is pulled, adopt the hypothesis accordingly</td>
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<tr>
<td>■ Students must look again at why they are doing chemistry, why do the like it or are interested, and must emote a picture that</td>
<td>■ What were the difficulties or frustrations in replicating the model</td>
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<td>■ Is the statement of a hypothesis correct? Find examples in your model</td>
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Appendix 18

Picture of Kevin’s answer

Difficulties

Trying to get the string through both holes without the string falling.

Trying to ensure the holes were wide enough to let the string pass through, but slim enough as to ensure the string is not loose.
## Appendix 19

### Chemistry term sheets

#### Chemistry Terms

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</table>
Chemistry Terms

Diagram, or chemical symbol representation of first ionisation energy

General trend of first ionisation energies going across the periodic table and why? (atomic radius, nuclear charge, screening effect)

General trend of first ionisation energies going down the periodic table and why? (atomic radius, nuclear charge, screening effect)
Appendix 20

Student worksheet to introduce and develop the new sequence of bonding

**Atomic Radius** (Explained using nuclear charge and screening effect)

**Ionisation Energy**: minimum energy required to completely remove the most loosely bound electron from a neutral gaseous atom.
Electronegativity: is the relative attraction that an atom in a molecule has for the shared pair of electrons in a covalent bond.

(The ability of an atom in a covalent bond to attract the electrons in the bond to itself is given a special term - electronegativity. The attractive forces at work here are the positive nuclei and the negative electrons)

Could any of the previous terms help you predict the trends in electronegativity across and down the periodic table. Explain your reasoning and draw your trend arrows on the periodic table.
Linus Pauling – The Pauling Scale of Electronegativity

Using your periodic table app, I want you to fill in the electronegativity values for group 1, group 7, period 1, period 2 and period 3 in the table below.

Do these figures support your prediction of the trend of electronegativity within the periodic table

___________________________________________________________

___________________________________________________________

___________________________________________________________

___________________________________________________________

___________________________________________________________

Periodic Table of the Elements
**Atomic Orbitals**

What is an atomic orbital?

<table>
<thead>
<tr>
<th>Orbitals</th>
<th>S orbital</th>
<th>P&lt;sub&gt;x&lt;/sub&gt; Orbital</th>
<th>P&lt;sub&gt;y&lt;/sub&gt; Orbital</th>
<th>P&lt;sub&gt;z&lt;/sub&gt; Orbital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw</td>
<td></td>
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</tbody>
</table>

Draw what might happen if an s and s orbital overlapped
S, p, configurations of atoms

Write the s,p configuration of the following atoms including the arrangement of electrons in the orbitals.

Example:

- Hydrogen:

- Oxygen:

- Nitrogen:

- Carbon:

- Chlorine:

- Sodium:

- Magnesium:
Valence Electrons

The electrons in the highest energy level are called valence electrons. Valence electrons are the electrons located farthest from the nucleus. Valence electrons are always in the highest energy level. The valence electrons are the most important electrons in an atom because they are the electrons that are the most involved in chemical reactions and bonding.

The electron configuration for thallium (No. 81) is:

\[ 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 4p^6, 5s^2, 4d^{10}, 5p^6, 6s^2, 4f^{14}, 5d^{10}, 6p^1 \]

The outermost energy level (not sublevel) is the 6\(^{th}\) energy level. How many total electrons does thallium have in the sixth level? 3, they are in boldfaced type above. Therefore, thallium has 3 valence electrons.

How many valence electrons does oxygen have?

Oxygen: \(1s^2, 2s^2, 2p^4\)

In its outer energy level (the 2\(^{nd}\) level) oxygen has a total of 6 valence electrons (2 in the 2s and 4 in the 2p).

Now, work out the number of valence electrons in the other atoms whose electronic configurations you have written.

Hydrogen: ____________

Nitrogen: ____________

Carbon: ____________

Chlorine: ____________

Sodium: ____________

Magnesium: ____________
Bonding

To help our understanding of bonding, we are going to use the concept of atomic orbitals, their overlap and electronic configurations to explain the sharing of electrons.

And

The concept of electronegativity to predict the position of bonding electrons between two atoms.

![Diagram of bonding types and electronegativity](image.png)
Bonding in Hydrogen – What is happening?

Write the electronic configuration of Hydrogen atom

From your knowledge of electronic configurations and stability of orbitals/sub-energy levels, what does hydrogen look for to stabilize its configuration?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Get the electronegativity value of the Hydrogen atom

Hydrogen atoms have one electron to share → two hydrogen atoms share a pair of electrons. This sharing of a pair of electrons increases the force of attraction between the two atoms and it is defined as a bond.

Draw the type of bond you think might happen between two hydrogen atoms and predict where the pairs of electrons will be between the two atoms

What happens when atoms with different electronegativity form a bond? Attempt the example Hydrogen-Chloride.
Appendix 21

Building of VSEPR Models
Appendix 22

Content Analysis and frequency of curriculum themes mentioned in chemistry curriculums in the different countries looked at in this study

<table>
<thead>
<tr>
<th>Ireland – Leaving Cert Chemistry (1999) [No Practical]</th>
<th>Rationale</th>
<th>Aims</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aim</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educational (science for educated citizens)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Vocational (science for preparing students to fulfill industrial needs)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td><strong>Older approaches</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific method (I have that somewhere)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific literacy (Murphy et al., 2001)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human endeavour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creativity and imagination (Designing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge relevant to the student</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific knowledge is testable and tentative (SC*)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influence of history, society and culture (context)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Ethics and morals</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Inquiry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of various processes and procedures employed in scientific inquiry</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td><strong>Social constructivism (Vygotsky, Driver et al, 1985)</strong></td>
<td></td>
<td></td>
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<tr>
<td>Social interactions (group work/team work)</td>
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<td>Co-construction of knowledge</td>
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</tr>
<tr>
<td>Role of language (discussions and communication)</td>
<td></td>
<td></td>
</tr>
<tr>
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</tr>
<tr>
<td><strong>Bloom's Taxonomy (Bloom et al., 1956)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge, comprehension, application, analysis, evaluation, synthesis</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td><strong>Scientific Modelling (Abdo &amp; Taber, 2014 – I think – need to check)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static (no mention of developmental change)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic (subject to change)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Further studies or mention of careers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lifelong learning</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Developing interest and motivation (in chemistry)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Assessment (p. 3)</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The syllabus will be assessed in relation to its objectives. All material within the syllabus is examinable. Practical work is an integral part of the study of chemistry; it will initially be assessed through the medium of the written examination paper. An element of practical assessment may be included as part of the overall assessment at a later stage (nearly 20 years later, that has not come to pass). Objectives (p. 36) – knowledge, understanding, skills (interpretation of data, rest experimental), competence (explain and identify) and attitude (students should appreciate).
<table>
<thead>
<tr>
<th>Australia (2015) [Practical]</th>
<th>Rationale</th>
<th>Aims</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aim</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educational (science for educated citizens)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Vocational (science for preparing students to fulfill industrial needs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Older approaches</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific method (<em>I have that somewhere</em>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific literacy (<em>Murphy et. al., 2001</em>)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human endeavour (<em>has a strand called this</em>)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Creativity and imagination (Designing)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Knowledge relevant to the student</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific knowledge is testable and tentative</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Influence of history, society and culture</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ethics and morals</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Inquiry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of various processes and procedures employed in scientific inquiry</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td><strong>Social constructivism (Vygotsky, Driver et al, 1985)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social interactions (group work)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Co-construction of knowledge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Role of language (discussions and communication)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Reflection</strong></td>
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<td></td>
</tr>
<tr>
<td><strong>Bloom's Taxonomy (Bloom et. al., 1956)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge, comprehension, application, analysis, evaluation, synthesis</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Scientific Modelling (Abdo &amp; Taber, 2014 — I think — need to check)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static (no mention of developmental change)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic (subject to change)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td><strong>Further studies or mention of careers</strong></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Kind of matches up between rationale and aims, but implicit understanding of social constructivist methodologies in the rationale was not there.

Achievement standards (p. 23)
Success criteria developed for unit 1&2 and a separate criteria for unit 3&4 – grades ranged from A – E
Terms used: analyse & evaluate (A), explain & apply (B), describes & discusses (C), Describes & identifies (D), Identifies & describes (E)

Separate success criteria sheet for inquiry skills – (A), designs, analyses, justifies, evaluates, selects, communicates,
(E) – follow procedure, identify, selects to demonstrate trends, considers, constructs simple, communicates
<table>
<thead>
<tr>
<th>Aim</th>
<th>Rationale</th>
<th>Aims</th>
</tr>
</thead>
<tbody>
<tr>
<td>Educational (science for educated citizens)</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Vocational (science for preparing students to fulfill industrial needs)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Older approaches**

| Scientific method (I have that somewhere) (Technically it says methods) | ✓         |      |
| Scientific literacy (Murphy et al., 2001)                          |           |      |


| Human endeavour                               | ✓         |      |
| Creativity and imagination (Designing)       |           |      |
| Knowledge relevant to the student             | ✓         |      |
| Scientific knowledge is testable and tentative | ✓         |      |
| Influence of history, society and culture    | ✓         |      |
| Ethics and morals                             | ✓         |      |

**Inquiry**

| Importance of various processes and procedures employed in scientific inquiry | ✓         |      |

**Social constructivism (Vygotsky, Driver et al, 1985)**

| Social interactions (group work)                |           |      |
| Co-construction of knowledge                   |           |      |
| Role of language (discussions and communication) | ✓         |      |

**Reflection**

| Blooms Taxonomy (Bloom et al., 1956)            | ✓         |      |
| Knowledge, comprehension, application, analysis, evaluation, synthesis |           |      |

**Scientific Modelling (Abdo & Taber, 2014 – I think – need to check)**

| Static (no mention of developmental change)     | ✓         |      |
| Dynamic (subject to change)                     |           |      |

| Further studies or mention of careers          | ✓         | ✓     |

| Developing interest and motivation (in chemistry) | ✓         |      |

**From the rationale**

These specifications have been written with minimal context. This means that you can select the context and applications that you feel bring the subject alive (p. 5). Lots of aims but minimal rationale. Aims well enough dispersed, but again very little, bar communication, about social constructivism

**Assessment Objectives (p. 67)**

- Knowledge and understanding, apply knowledge and analyse, interpret and evaluate scientific info, including make judgements, and develop and refine practical design.
<table>
<thead>
<tr>
<th>Aim</th>
<th>Rationale</th>
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<tbody>
<tr>
<td>Educational (science for educated citizens)</td>
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</tr>
<tr>
<td>Vocational (science for preparing students to fulfill industrial needs)</td>
<td>✓</td>
</tr>
</tbody>
</table>

### Older approaches

| Scientific method (I have that somewhere) | ✓ |
| Scientific literacy (Murphy et. al., 2001) | ✓ |

### Nature of Science (Abd-El Khalick & Lederman, 2000)

| Human endeavour | ✓ |
| Creativity and imagination (Designing) | ✓ |
| Knowledge relevant to the student | ✓ ✓ |
| Scientific knowledge is testable and tentative (SC*) | ✓ ✓ |
| Influence of history, society and culture (context) | ✓ ✓ (in ref to the syllabus) |
| Ethics and morals | ✓ |

### Inquiry

| Importance of various processes and procedures employed in scientific inquiry | ✓ ✓ |

### Social constructivism (Vygotsky, Driver et al. 1985)

| Social interactions (group work/team work) | ✓ |
| Co-construction of knowledge | ✓ |
| Role of language (discussions and communication) | ✓ |

### Reflection

| Blooms Taxonomy (Blooms et. al., 1956) | Knowledge, comprehension, application, analysis, evaluation, synthesis |
| Scientific Modelling (Abdo & Taber, 2014 – I think – need to check) | Static (no mention of developmental change) |
| Dynamic (subject to change) | |

### Further studies or mention of careers

| ✓ |

### Lifelong learning

| Develop self-motivation and the ability to work in a sustained fashion (p. 12) | ✓ |
| Developing interest and motivation (in chemistry) | ✓ |

### Assessment Objectives (p. 13)

Knowledge with understanding, handling, applying and evaluating and experimental skills and investigations
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Aim</strong></td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Vocational (science for preparing students to fulfill industrial needs)</td>
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<td></td>
</tr>
<tr>
<td><strong>Older approaches</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific method (I have <em>that</em> somewhere) <em>(says methods)</em></td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Scientific literacy <em>(Murphy et. al., 2001)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nature of Science <em>(Abd-El Khalilc &amp; Lederman, 2000)</em></strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human endeavour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creativity and imagination <em>(Designing)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge relevant to the student</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific knowledge is testable and tentative <em>(SC)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influence of history, society and culture <em>(context)</em></td>
<td></td>
<td>√</td>
</tr>
<tr>
<td><strong>Ethics and morals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Inquiry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of various processes and procedures employed in scientific inquiry</td>
<td></td>
<td>√</td>
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<td><strong>Social constructivism <em>(Vygotsky, Driver et al., 1985)</em></strong></td>
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<tr>
<td>Co-construction of knowledge</td>
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<td></td>
</tr>
<tr>
<td>Role of language <em>(discussions and communication)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Reflection</strong></td>
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<td></td>
</tr>
<tr>
<td><strong>Blooms Taxonomy <em>(Bloom et. al., 1956)</em></strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge, comprehension, application, analysis, evaluation, synthesis</td>
<td>√√</td>
<td>√</td>
</tr>
<tr>
<td><strong>Scientific Modelling <em>(Abdo &amp; Taber, 2014 – I think – need to check)</em></strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static <em>(no mention of developmental change)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic <em>(subject to change)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Further studies or mention of careers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lifelong learning</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop self-motivation and the ability to work in a sustained fashion <em>(p. 12)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Developing interest and motivation <em>(in chemistry)</em></td>
<td></td>
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</tr>
</tbody>
</table>

**From rationale**
Provide a basis for school and college accountability measures at age 18 *(p. 3)*

**Assessment (p. 87)**
Knowledge and understanding, application and how science works *(practical?)*
Stretch and challenged questions – using a variety of stems – analyse, evaluate, discuss, compare.
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Aim</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educational (science for educated citizens)</td>
<td>[✓]</td>
<td></td>
</tr>
<tr>
<td>Vocational (science for preparing students to fulfil industrial needs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Older approaches</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific method (I have that somewhere) (says methods)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific literacy (Murphy et al., 2001)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human endeavour</td>
<td>[✓]</td>
<td></td>
</tr>
<tr>
<td>Creativity and imagination (Designing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge relevant to the student</td>
<td>[✓]</td>
<td></td>
</tr>
<tr>
<td>Scientific knowledge is testable and tentative (SC²)</td>
<td>[✓]</td>
<td></td>
</tr>
<tr>
<td><em>Instruction must take into account the fact that human beings observe and analyse reality using all their senses (p. 12)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influence of history, society and culture (context)</td>
<td>[✓]</td>
<td>[✓]</td>
</tr>
<tr>
<td>Ethics and morals</td>
<td>[✓]</td>
<td></td>
</tr>
<tr>
<td><strong>Inquiry</strong></td>
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<tr>
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<tr>
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<td></td>
</tr>
<tr>
<td>Co-construction of knowledge</td>
<td>[✓]</td>
<td></td>
</tr>
<tr>
<td><em>(Students are seen to be the constructors of their own learning, competence and views of the world)</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Role of language (discussions and communication)</td>
<td>[✓]</td>
<td></td>
</tr>
<tr>
<td><strong>Reflection</strong></td>
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<td></td>
</tr>
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<td></td>
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<tr>
<td>Knowledge, comprehension, application, analysis, evaluation, synthesis</td>
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<td></td>
</tr>
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<td>Dynamic (subject to change)</td>
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</tr>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lifelong learning</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper secondary school instruction must support the development of students’ self-knowledge and their positive growth towards adulthood and encourage students towards lifelong learning and continuous self-development (p. 12)</td>
<td>[✓]</td>
<td></td>
</tr>
<tr>
<td>Developing interest and motivation (in chemistry)</td>
<td>[✓]</td>
<td></td>
</tr>
</tbody>
</table>

**Rationale** = was for role of general upper secondary education in general
Scotland (SQA) (2015) [Practical – apx. 20%] | Rationale | Aims
--- | --- | ---
**Aim**
Educational (science for educated citizens) |  |  
Vocational (science for preparing students to fulfill industrial needs) |  |  
**Older approaches**
Scientific method (I have that somewhere) |  |  
Scientific literacy (Murphy et al., 2001) | ✓ |  
**Nature of Science** (Abd-El-Khalick & Lederman, 2000)
Human endeavour |  | ✓  
Creativity and imagination (Designing) | ✓ | ✓  
Knowledge relevant to the student |  | ✓  
Scientific knowledge is testable and tentative (SC*+) |  |  
Influence of history, society and culture (context) | ✓ | ✓  
Ethics and morals | ✓ |  
**Inquiry**
Importance of various processes and procedures employed in scientific inquiry | ✓ | ✓✓✓  
**Social constructivism** (Vygotsky, Driver et al., 1985)
Social interactions (group work/team work) |  |  
Co-construction of knowledge |  |  
Role of language (discussions and communication) |  | ✓  
Reflection |  |  
**Bloom's Taxonomy** (Bloom et al., 1956)
Knowledge, comprehension, application, analysis, evaluation, synthesis | ✓ | ✓✓✓  
**Scientific Modelling** (Abdo & Taber, 2014 – I think – need to check)
Static (no mention of developmental change) |  |  
Dynamic (subject to change) |  |  
Further studies or mention of careers |  |  
**Lifelong learning**
Extend and apply skills of independent/autonomous working in chemistry (p. 3) (aim) | ✓ | ✓  
**Developing interest and motivation** (in chemistry) |  |  

**Assessment**
Extending and applying knowledge, planning and designing (inquiry), selecting information analysing, evaluating, drawing conclusions, communicating and analysing and evaluating (p. 7)
<table>
<thead>
<tr>
<th>England – OCR – A Level (2014) [No Practical]</th>
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<th>Aims</th>
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<tbody>
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<tr>
<td>Scientific method (<em>I have that somewhere</em>) (methods)</td>
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<td></td>
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<tr>
<td>Scientific literacy (Murphy et. al., 2001)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge relevant to the student</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific knowledge is testable and tentative (SC*)</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>(How society makes decisions)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Influence of history, society and culture (context)</td>
<td>√</td>
<td></td>
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<tr>
<td>Ethics and morals</td>
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<td></td>
</tr>
<tr>
<td>Inquiry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of various processes and procedures employed in scientific inquiry (includes problem-solving in this)</td>
<td>√</td>
<td>√</td>
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<tr>
<td>Social constructivism (Vygotsky, Driver et al, 1985)</td>
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<tr>
<td>No5 - Influence of history, society &amp; culture - Understand how society makes decisions about scientific issues and how the sciences contribute to the success of the economy and society (as exemplified in ‘How Science Works’ (HSW)) (p. 2) – this is the impact of society on science. It does not fall into science as a human endeavour as science as a human construct is not discussed, its society’s impact on science that’s mentioned, rather than science developing from society. The scientific issue is taken as a construct, something that’s there. Assessment objectives: knowledge &amp; understanding, apply, analyse, interpret and evaluate (p. 66)</td>
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<td>Northern Ireland – GCE A Level (2007) [Practical]</td>
<td>Rationale</td>
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*Assessment objectives (p. 34)*
Knowledge and understanding, application of knowledge, analyse and evaluate

**Practical**
Inquiry skills and analyse, interpret, explain and evaluate
<table>
<thead>
<tr>
<th>Wales – WJEC GCE A Level (2015) [Practical 10%]</th>
<th>Rationale</th>
<th>Aims</th>
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<tr>
<td><strong>Aim</strong></td>
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</tr>
<tr>
<td>Educational (science for educated citizens)</td>
<td>✓</td>
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</tr>
<tr>
<td><strong>Older approaches</strong></td>
<td></td>
<td>✓</td>
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<tr>
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<td><em>(Evaluate the role of the scientific community in validating new knowledge and ensuring integrity or knowledge is tentative)</em></td>
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<td>Creativity and imagination <em>(Designing)</em></td>
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<tr>
<td>Knowledge relevant to the student</td>
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<td>✓</td>
</tr>
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<tr>
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</tr>
</tbody>
</table>

**Aim**
Understand how society makes decisions about scientific issues *(NoS - tentative)* and how the sciences contribute to the success of the economy and society *(NoS - history)*. **Assessment objectives** – Bloom’s taxonomy *(knowledge, understanding, apply… p.48)*
<table>
<thead>
<tr>
<th>International Baccalaureate (2014) [Practical 20%]</th>
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</table>

**Aim**

Develop an understanding of the relationships between scientific disciplines and their influence on other areas of knowledge (not sure where this fits as an aim)

**Assessment of objectives** - All of the assessment objectives were centered around Bloom's taxonomy; Demonstrate knowledge and understanding, apply, formulate, analyze and evaluate. Then demonstrate the appropriate research, experimental and personal skills necessary to carry out insightful and ethical investigations.
<table>
<thead>
<tr>
<th>Ireland – Draft Syllabus (2011) [Practical 20%]</th>
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Assessment – mainly Bloom’s taxonomy and inquiry
Appendix 23

Outline of lessons included in the scientific enculturation unit

<table>
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<tr>
<th>Lesson</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Introduction</strong> – What does chemistry mean to them? Discussion – Do scientific discoveries always follow the same path? (Examples given to promote thought)</td>
</tr>
<tr>
<td>3</td>
<td><strong>Patterns &amp; problem solving</strong>. Through investigation. Objectives – develop recognition of patterns from given data, develop problem-solving skills through inquiry cube activities, and make predictions based on given evidence and patterns</td>
</tr>
<tr>
<td>4</td>
<td><strong>Modelling and evaluation</strong>. Model Tube activity – develop a working model and discuss difficulties associated with models and observation and application of other models in science</td>
</tr>
<tr>
<td>5</td>
<td><strong>Evaluating evidence</strong>. Evaluating evidence, communication and ethics in science. Mario Molina activity sheet and the responsibility of scientists</td>
</tr>
<tr>
<td>6</td>
<td><strong>Summation activity</strong> – incorporating all scientific processes. Develop an understanding that science will change with time and the development of new technologies. Creation of a chemistry toolkit – skills or ideas they think they might need for studying chemistry</td>
</tr>
</tbody>
</table>