Biology by Inquiry
An Intervention Programme in Irish Post Primary Schools

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DECLARATION

Declaration of Authorship
I hereby certify that this dissertation, Inquiry in Biology: An intervention Programme in Irish Post-Primary Schools is entirely my own work. All quotations from other sources are acknowledged and referenced.

______________________________________________
Emma Ryan
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The publication of ‘Strategy for Science, Technology and Innovation’ (2006) by the Irish Government and of ‘Task Force on the Physical Sciences‘ (2002) recognises the decline in the number of students taking up sciences at both senior cycle and into third level and the dramatic need for a change in how science is being taught in Irish post-primary schools. The OECD report (2006), Evolution of Student Interest in Science and Technology Studies, recommended that teaching should concentrate more on scientific concepts rather than on the retention of information. The central aim of this thesis is to gain an insight into the attitudes and perceptions of qualified science and biology teachers and students towards the use of Inquiry based teaching and learning in the Irish Post-Primary Classroom and investigate the extent to which the principles of scientific inquiry teaching and learning are being practiced in the Senior Cycle Biology classroom from a teacher and student perspective.

Inquiry-based learning requires students to develop scientific process skills and an understanding of the science content while working in a pedagogical manner that combines hands-on activities with student-centred discussion and discovery of concepts. Many educational theorists have listed advantages associated with inquiry-based learning but the principle advantages for students is that they think critically for themselves; providing them with the tools to be lifelong learners and good future scientists.

This research study was divided into three parts, used a mixed method approach and was conducted over a two year period. Part one was the exploratory phase that used science/biology student and biology teacher questionnaires and biology student and teacher interviews to gather data relating to the research questions and aims of this research study. Part two involved the development of inquiry-based teaching resources and led to the development of the Inquiry Based Biology Lesson Student Booklet. These resources were then used in Part three - the Intervention Programme.

Results indicated that the majority of Junior Certificate Science students and Leaving Certificate Biology students are not practicing the true principals of scientific inquiry. Even with all of the associated advantages of inquiry-based learning teachers mentioned limited time, syllabus constraints, pressure to get the course completed and no assessment of inquiry-based methods as problems that hinder them implementing inquiry-based learning into post-primary schools. Pre- and post-lesson questionnaires and pre- and post-lesson interviews were conducted with students who participated in the intervention programme. The results showed students had an increased understanding and knowledge of scientific process skills. A change in their attitudes towards science/biology, an increase in their engagement of science and development of many skills was recorded.

Recommendations arising from this research study included the need for inquiry-based learning to be incorporated into the Junior Certificate Science and Leaving Certificate Biology assessments. Other recommendations include the need to encourage teachers to partake in in-services or Continuous Professional Development on inquiry-based learning and make inquiry resources widely available for the current teaching profession.
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I wish to thank my parents – always constant suppliers of support and encouragement, and from whom I learned to be driven and for which I am extremely grateful. To them, I will forever be the eternal student.

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To my parents and Ger, I dedicate this thesis.
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Chapter 1

Introduction

1.0 Introduction

It has been reported that students begin to lose interest in mathematics and science during the middle school years (Ayers & Price, 1975; Simpson & Oliver, 1985; Finson & Enochs, 1987). It has been found that in general students’ attitudes toward science decrease with age (Osborne et al., 2003; Prokop et al., 2007). The falling interest levels in science among students as they progress through the junior cycle has been previously highlighted in other studies (Task Force on the Physical Sciences, 2002; Smyth et al., 2004; Smyth & Hannon, 2006; Barmby et al., 2008). The main causes for the decline in interest among young people for science are the following; what is being taught and in the way it is being taught (Syhmansky et al., 1983; Mao & Chang, 1998; Gibson & Chase, 2002; European Commission, 2007; Eberlein et al., 2008). It also has been found that the appeal of science decreases as students find schoolwork more challenging and have less access to exciting lessons which actively involve the students and are engaging (Smyth & Hannan, 2006; 2002).

This is a worrying trend. In the study by Liston & Regan (2009), on Irish Post-primary students attitudes towards biology and chemistry, 41% (n=300) of the senior cycle post-primary students’ interest in Biology had increased since the Junior Certificate Cycle, however with 21% decreasing since their study at junior cycle. We must ask is this decline in interest due to teaching and learning methodologies used in the Irish biology classroom and/or the content of the Biology Syllabus?

The OECD report (2006), Evolution of Student Interest in Science and Technology Studies, recommended that teaching should concentrate more on scientific concepts rather than on the retention of information. Much of the literature states that science teachers need to de-emphasise the memorising of facts and place a further emphasis on science in the everyday world through the process of inquiry based learning (Singer et al., 2000). Timmerman et al (2008) discusses how the traditional teaching methods appear satisfactory for gains in knowledge of content in concrete topics while inquiry based pedagogies are effective in stimulating respectable gains in knowledge and understanding of content of more abstract topics. For biology in particular the recent report by the National Research Council, Bio 2010 emphasizes the importance of how students are taught i.e. teaching and learning methodologies incorporated into the classroom, as well as the importance of the material
being taught in courses (National Research Council, 2010). The 2005 Eurobarometer study on “Europeans, Science and Technology” reports that the cause of declining interest in scientific studies was due to “science classes at school are not sufficiently appealing” (European Commission, 2007). The OECD’s 2006 report titled ‘Evolution of student interest in science and technology studies’ recommended that curricula should be redesigned to better reflect the reality of modern science and technology and emphasise their contribution to society. Students must also have access to information about science and technology careers that are accurate, credible and avoids unrealistic portrayals, (OECD, 2006).

Educational research is increasingly focused on how traditional modes of science teaching have contributed to the decline in the proportion of students taking science subjects (ICSTI, 1999). Inquiry based laboratory activities and how Biology is being taught to students has a considerable influence on students’ attitudes towards science, which further affects their enthusiasm for the subject, uptake and achievement levels (Fensham, 2006). Science lessons that incorporate laboratory investigative work regularly in the classroom are viable and effective teaching instructional methods for science teachers (Freedman, 1997; Robinson et al., 1999). Bio 2010 strongly advocates the use of an inquiry based approach and recommends reforming lab experiences from traditional, conformational cook book experiments to experiences that cultivate the ability of students to think independently – project based labs with discovery components (Timmerman et al., 2008). However different pedagogical skills in the teaching of biology may not be practiced by teachers in the classroom due to time and examination constraints.

1.1 Inquiry - Based Learning.

In recent times a lot of attention and focus has turned to teaching through inquiry. There are an increasing number of published reports and research papers such as “Curricular reform and inquiry teaching in biology: where are our efforts most fruitfully invested?” and “Promoting inquiry through science reflective journal writing, informing us that teaching science by inquiry is the way forward in science education reform” (Alabdulkareem, 2008; Ruiz-Primo, et al., 2008; Timmerman et al., 2008; Towndrow, et al., 2008). Inquiry-based learning has gained acceptance as a method for creating interest among students and for promoting the benefits of science and mathematics knowledge and skills (Chang & Mao, 1999; Gibson & Chase, 2002; St. Omer, 2002; Abd-El-Khalick, et al., 2004; Grandy & Duschl, 2005).
1.2 Situation In Ireland

There are many studies that have highlighted a worrying decline in young people’s interest in and take up of science in second level education, even when the demand for science graduates is continuously rising (Frame, 1996; Francis & Greer, 1999; Task Force on Physical Sciences, 2002; Regan & Childs, 2003; Department of Enterprise, Trade and Employment, 2006; Jenkins, 2006; European Commission, 2007; Politis et al., 2007). The decline in interest and in the proportion of students taking science subjects at Senior Cycle is an international phenomenon (Frame, 1996; Francis & Greer, 1999; Task Force on Physical Sciences, 2002; Regan & Childs, 2003; Jenkins, 2006; Politis et al., 2007).

The Department of Education and Science (2001) announced the need to reform the second level education system in Ireland and recommended that teachers make active learning methodologies like group work, discovery learning and peer assessment a priority across all subject areas. It was found that Irish students learn best by active learning, discovery learning being able to express their opinions and participating in practical activities (Smyth et al., 2006).

The Irish Government’s Strategy for Science, Technology and Innovation 2006-2013 states that “if we aspire to build a sustainable knowledge economy and become world leaders in STI we must build strong foundations in primary and second level education and our system needs to develop to make this happen. Interest in science must be stimulated at an early stage and fostered throughout the educational system” (STI, 2006). The Irish Government’s Strategy for Science, Technology and Innovation (2006) aims to focus particularly on problem based learning which has its foundations in Inquiry Based Science Education (IBSE), which they hope will significantly change the nature of teaching in sciences at both primary and secondary schools. The strategy proposes to increase participation rates in the science subjects by reforming the science curricula for leaving certificate; investment in continuous professional development and networks for teachers; awareness promotion and the provision of guidance materials; rebalancing the content of the science curriculum in the direction of problem solving and; revisiting the issue of technical assistance for schools to facilitate practical coursework.
1.2.1 Primary Science

The Revised Primary Science Curriculum (DES, 1999) and the new Junior Cycle Science Syllabus (DES, 2003) has brought about a period of change in primary and post primary pupils’ experiences of school science in Ireland. These new curricula have been developed in a bid to address international and national concerns regarding school science. The revised Primary Science Curriculum (DES, 1999) is being implemented on schools for the past seven years and for the first time includes science as a subject in its own right. The Primary Science curriculum encourages the development of pupils’ scientific knowledge of a wide variety of different concepts in physics, chemistry and biology and there is an increased emphasis on the development of scientific process skills and designing and making skills from junior infants to sixth class (age 4 – 12 years).

The aims of the Science Curriculum are as follows

- To develop knowledge and understanding of scientific and technological concepts through the exploration of human, natural and physical aspects of the environment.
- To develop a scientific approach to problem-solving which emphasises understanding and constructive thinking.
- To encourage the child to explore, develop and apply scientific ideas and concepts through designing and making activities.
- To foster the child’s natural curiosity, so encouraging independent enquiry and creative action.
- To help the child to appreciate the contribution of science and technology to the social, economic, cultural and other dimensions of society.
- To cultivate an appreciation and respect for the diversity of living and non-living things, their interdependence and interactions.
- To encourage the child to behave responsibly to protect, improve and cherish the environment and to become involved in the identification, discussion, resolution and avoidance of environmental problems and so promote sustainable development.
- To enable the child to communicate ideas, present work and report findings using a variety of media.

(DES, 1999, p. 11)
The new Science Curriculum placed an emphasis on the development of the child’s basic scientific skills which would allow and enable them to explore and investigate their own world around them. This involved channelling the pupil’s curiosity in practical work and relating it to scientific concepts. The new curriculum revolved around developing two types of understandings within the child: Conceptual and Procedural (DES, 1999, p.6). Conceptual understanding deals with the development of scientific knowledge while procedural understanding centred around the child developing an understanding for scientific processes. The two understandings are interlinked and developed in tandem. This science curriculum aimed at improving the level of achievement in science and science-related activities amongst Irish primary school children (DES, 1999). To summarise, the Irish Primary Science Curriculum highlights the significance of utilising inquiry-based approaches in primary science, similar to those used internationally (DES, 1999).

The NCCA Primary Curriculum Report (1999) concluded that “practical investigation is central to scientific activity and to the development of a broad range of enquiry skills”. The Inquiry based skills expected to develop through science activity were defined in the NCCA Report (1999) as “observing, hypothesising, predicting, experimenting, planning fair tests and analysing results. Skills and methods that are developed through scientific investigations, such as decision-making, data collection, the interpretation of evidence and the communication of results and ideas”. This highlighted the importance of investigation and practical based work as an effective means to help young children acquire scientific knowledge. Subject matter and Scientific concepts were to be used in conjunctions with the development of ‘skills of investigation’ (NCCA, 1999).

1.2.2 Junior Cycle Science
The Post-primary curriculum review led to the new Junior Cycle being introduced in 2003 and an emphasis on “investigations” in practical work in the form of Coursework B, which must involve elements of inquiry. The new syllabus was divided into three sections: written exam (65%), coursework A (10%), coursework B (25%). (D.E.S, 2003)

The introduction of the new Junior Certificate Science syllabus saw an increased emphasis on scientific investigations and the applications of science process skills in student activities. The revised syllabus places student learning in the context of science activities, emphasizing inquiry-based hands-on engagement through which the students can develop their
understanding of the scientific concepts and principles involved, together with appropriate
science process skills (DES, 2006, p.1). To complement this change, a new assessment
structure was devised and implemented, providing practical assessment components —
Coursework A and Coursework B. However, since the introduction of the Coursework B
assignment significant problems have been highlighted by the science teachers, including the
workload involved, poor ability of the students to carry out the investigations, lack of
resources and the effect the increased workload is having on teaching time required to finish
the syllabus (Higgins, 2009).

A significant proportion (41%) of science teachers were reported as ‘dissatisfied’ or ‘very
dissatisfied’ with the coursework B element of the syllabus (DES, 2006 p.15). Science
teachers reported that since the introduction of new syllabus, their workload increased and the
majority of them (94%) are giving a considerable amount of extra time to help their students
with coursework B (Higgins, 2009). One possible reason for dissatisfaction may be that
teachers are required to spend a large amount of time helping their students complete their
work because the students are unable to carry out the investigations themselves due to poor
problem-solving skills and lack of experience in using unguided investigative practical
approaches. The Junior Certificate syllabus suggests that the experience gained through the
completion of Coursework A is sufficient to prepare the junior cycle students for the
Coursework B component. However, this is not the case; students do not get the opportunity
to develop their skills in planning and conducting investigations when completing the
Coursework A experiments as these are often taught using a ‘recipe-style’ approach and the
students simply complete the task without thought or reflection (Broggy, 2011). This was
reported also in a recent TALIS (Teaching and Learning International Survey) report (2009)
which found that the traditional model of teaching, where teachers lead instruction, was still
very much the dominant approach to teaching in Irish schools. In a recent post-primary
curriculum review, it was found that rather than being engaged in scientific investigations
(essentially what inquiry based learning focused on), teacher explanation, teacher
demonstration, reading and writing featured frequently in pupil’s science lessons (Varley et
al., 2008). The TALIS report (2009) stated that teachers in Ireland were ‘less supportive of
constructivism beliefs’ and ‘more supportive of transmission beliefs’ (Shiel et al, 2009).

The Relevance of Science Education (ROSE) report (2007) found 50% of Junior
Certificate Science pupils view the subject as ‘difficult and demanding’. It also reported a
decrease in the amount of A grades awarded at Higher Level from 2006 – 2009 i.e. for the
new science syllabus and a steady increase in the number of pupils getting C and D grades. The pupils also did not agree strongly with the statement ‘school science is interesting’ or that ‘science was very relevant to their everyday lives’ (Matthews, 2007). Therefore a review of the teaching and learning methodologies being used in the Junior Certificate Science classroom and a review of the content of the Junior Certificate Science Syllabus is merited. Another ROSE report described how not all objectives outlined in science syllabus are being met and this may explain the negative attitudes towards science at Junior Certificate level. This has progressed to the decrease in science subjects at Leaving Certificate level (Matthews, 2007).

1.2.3 Revision of the Senior Cycle Science Subjects
In 2003, the NCCA ‘Directions for development’ set out a vision for Senior Cycle Biology that included a different learning experience and school culture for senior cycle students, a rebalanced curriculum and different assessment arrangements. Research by the Economic and Social Research Institute (ESRI) (2007) on the experience of students in post primary education and extensive public consultations concerning senior cycle developments have cast doubt on whether the changes in the Biology Syllabus of 2002 have genuinely reshaped educational experiences in the classroom. A discussion paper on ‘leading and supporting change in schools’ (NCCA, 2009) arose out of a Council discussion in 2008 that saw questions being raised about the current models for the implementation of change and how effective they have proven in terms of achieving real and lasting change in teaching and in school culture. Then in 2010 the ‘Report of the Innovative Taskforce’ by the Irish Government emphasised the ‘belief that Ireland needs to substantially raise national mathematics and pure science attainment particularly at second level’ in order ‘for Ireland’s ability to reposition industry towards knowledge intensive high technology sectors, which will depend critically on the supply of people with mathematics, science, engineering and technology skills’. This view is strongly supported by the NCCA.

The European framework for key competences (2007) presents eight key competencies that include communication in the mother tongue, communication in foreign languages, mathematical competence, basic competences in science and technology, digital competence, learning to learn, social and civic competence, sense of initiative and entrepreneurship and cultural awareness and expression. For lifelong learning all citizens should acquire these competencies in order to be successful in a knowledge society. The National Skills Strategy (2007) supports the views of Report of the Innovative Taskforce.
(2010) when it states, "employees in all jobs will be increasingly required to acquire a range of generic and transferable skills including people related and conceptual/thinking skills... with a requirement for flexibility, continuous learning and individual initiative and judgement". These views are also supported by the NCCA in Innovation happens, classrooms as sites of change (NCCA, 2010). The new biology syllabus takes note of these key competencies and have introduced them as "five keys skills", which include "information processing, communication, being personally effective, being a critical and creative thinking and working with others". (NCCA, Biology Draft Syllabus, 2011). These five skills are incorporated to enhance the students' learning, to broaden their scope of learning and increase their capacity for learning. The learner will be resourceful, engaged, confident and an active learner when they have completed the new Leaving Certificate Biology Syllabus (NCCA, 2009).

1.2.4 Revision of the Senior Cycle Biology Syllabus

The NCCA biology course committee and Board of Studies for Science have been involved in drawing up a draft new syllabus for Leaving Certificate Biology.

In May 2011, an open consultation process has began by the National Council for Curriculum and Assessment (NCCA) who have revealed their new syllabi for senior biology, physics and chemistry. The NCCA are requesting teachers, parents, students and members of the science community to comment on the content and approach outlined in their documents.

There have been changes to the content of each of the syllabi but the biggest change in approach to senior cycle science is the introduction of a practical component in the assessment procedures for each of the subjects. Twenty percent of a student's total mark in each of the subjects will be awarded based on the completion of mandatory practicals throughout the two years of study (5%) and a 90 minute practical test (15%) where pupils will be asked to complete a series of three or four short set tasks, assessing their practical skills and ability to analyse data and draw conclusions (NCCA, Biology Draft Syllabus for Consultation, 2011).

The key skills such communicating, critical and creative thinking and working with others in each syllabus are appropriate and praiseworthy. The use of terms like "design", "apply knowledge", "interpret", "discuss" and "analyse" in the learning outcomes of each syllabus is commendable. However, there is a concern that the syllabi is still very teacher driven and exam orientated. (http://www.frogblog.ie/2011/04/ncca-reveals-new-biology-chemistry.html accessed on 12/6/11 at 17:00). In the proposed new Biology Syllabus, the NCCA discusses how senior cycle learners should be encouraged to develop the knowledge,
skills, attitudes and values that will enable them to become independent. Leaving Certificate Biology supports the use of a wide range of teaching and learning approaches. As learners progress they will develop learning strategies that are transferable across different tasks and different subjects enabling them to make connections between biology, other subjects and everyday experiences. By engaging in self-directed activities and reflection learners will assume much of the responsibility for planning, monitoring and evaluating their own learning and in so doing will develop a positive sense of their own capacity to learn. By engaging in group work learners will develop skills in reasoned argument, listen to each other, inform one another of what they are doing, and reflect on their own and the work of others. (NCCA, 2011). In order for this new syllabus to be successfully implemented sufficient time will have to be allocated to using inquiry based learning, for the students to become active learners and be engaged properly in the learning process. Also teachers will need a lot of technical and professional support to implement such a new way of thinking and learning, in their classrooms.

1.2.5 The NCCA Aims For New Biology Syllabus

The NCCA Biology Syllabus aims to give learners an appreciation of the complexity of the processes of the cell and of the organism, an appreciation of the diversity and interrelationships of all living things and their environment, whilst also developing the ability to investigate and to critically and ethically evaluate the global and local application of scientific knowledge. (NCCA Biology Draft Syllabus, 2011) The overall aim of senior cycle education sees the learner at the centre of the educational experience. This experience will enable learners to be resourceful, to be confident, to participate actively in society and to build an interest in learning and an ability to learn throughout their future lives (NCCA, 2009).

The NCCA want to achieve a post primary education that will emphasise the development of knowledge and deep understanding, for learners to take more responsibility for their own learning, to improve the balance between the acquisition of skills and knowledge and an enhanced focus on learning and the learner (NCCA, 2009). The NCCA want students to develop scientific inquiry skills including the ability to analyse qualitative and quantitative data and consider their validity and reliability. The assessment of these skills will be done in a different way than they are currently, with students being awarded up to 20% for practical write ups and assessment and 80% for written assessment (NCCA, Biology Draft Syllabus, 2011). The NCCA want teaching and learning methodologies that motivate and interest
learners and allow them to progress. A wide range of activities such as poster presentations, investigative and practical activities, field trips and debates that mirror the work of the scientist can deepen and help students to apply their learning. Therefore in order for the new syllabi to be a success, a strong emphasis will be placed on inquiry based learning and teachers will have to change how science is being taught.

1.3 Senior Cycle Biology
Biology remains to be the most popular of the science subjects at senior cycle. The ROSE (Relevance of Science Education) study found that both boys and girls have a shared interest in biology more so than chemistry and/or physics (Matthews, 2006). The NCCA reported that first year post-primary students’ attitudes towards learning about biological topics were more positive than their attitudes towards learning about topics in physics and chemistry (Varley et al., 2008). In this study, questionnaires were completed by 234 students ranging in age from 12-15 years old. Learning about topics within human and animal biology was seen positively by more than half of respondents (Varley et al., 2008). Prokop et al., (2007) suggested that the most pronounced reason for student’s interest in biology lessons was that they are interested in dealing with live animals and plants during which they can relate to. However, plant biology was not so positively construed, with less than half of respondents claiming to enjoy learning about this topic (Varley et al., 2008).

1.3.1 Numbers taking Leaving Certificate Biology
There has been a steady increase in the numbers of students taking Leaving Certificate Biology over the past eight years. Data obtained from the Department of Education and Science (DES) (www.examinations.ie) show that biology has remained the most popular science subject for students at senior cycle (Figure. 1 and Table 1).
Since 2002 the numbers taking biology and chemistry have increases, whereas the numbers taking physics have decreased. Biology is the most popular subject with nearly four times as many students taking biology than chemistry.

Table 1.1 Number of Irish Post-Primary Students Examinations Candidates in Biology, Chemistry and Physics from 2002 – 2010. Data accessed from www.examinations.ie

<table>
<thead>
<tr>
<th></th>
<th>Biology</th>
<th>Chemistry</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>29249</td>
<td>7548</td>
<td>6745</td>
</tr>
<tr>
<td>2009</td>
<td>28101</td>
<td>7403</td>
<td>6924</td>
</tr>
<tr>
<td>2008</td>
<td>26607</td>
<td>7114</td>
<td>7113</td>
</tr>
<tr>
<td>2007</td>
<td>17521</td>
<td>6927</td>
<td>7251</td>
</tr>
<tr>
<td>2006</td>
<td>17048</td>
<td>7072</td>
<td>7335</td>
</tr>
<tr>
<td>2005</td>
<td>17482</td>
<td>7366</td>
<td>7944</td>
</tr>
<tr>
<td>2004</td>
<td>16011</td>
<td>7227</td>
<td>8148</td>
</tr>
<tr>
<td>2003</td>
<td>13783</td>
<td>6698</td>
<td>8806</td>
</tr>
<tr>
<td>2002</td>
<td>13773</td>
<td>6497</td>
<td>8651</td>
</tr>
</tbody>
</table>

The current Biology Syllabus was introduced into schools in September 2002 and first examined in June 2004. From 2002 to 2010 the numbers taking ordinary level biology has decreased, with the numbers taking ordinary level chemistry and physics fluctuating slightly from year to year. There has also been a slight increase in the numbers taking higher level
biology from 2002 -2010, with the numbers taking higher level chemistry and physics fluctuating slightly from year to year.

Table 1.2 Numbers and percentages of candidates sitting the Higher Level and Lower Level Biology Examination Papers from 20002 – 2010.

<table>
<thead>
<tr>
<th>Year of examination</th>
<th>Total Biology Candidates</th>
<th>% Sitting Higher Level Biology</th>
<th>% Sitting Ordinary Level Biology</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>29249</td>
<td>20971 (72%)</td>
<td>8278 (18%)</td>
</tr>
<tr>
<td>2009</td>
<td>28101</td>
<td>20,102 (72%)</td>
<td>7999 (18%)</td>
</tr>
<tr>
<td>2008</td>
<td>26607</td>
<td>18,322 (69%)</td>
<td>8,285 (21%)</td>
</tr>
<tr>
<td>2007</td>
<td>25,791</td>
<td>17,521</td>
<td>8,270</td>
</tr>
<tr>
<td>2006</td>
<td>24,887</td>
<td>17,048</td>
<td>7,839</td>
</tr>
<tr>
<td>2005</td>
<td>25,360</td>
<td>17,482</td>
<td>7,878</td>
</tr>
<tr>
<td>2004</td>
<td>24,023</td>
<td>16,011</td>
<td>8,012</td>
</tr>
<tr>
<td>2003</td>
<td>22,671</td>
<td>13,783</td>
<td>8,888</td>
</tr>
<tr>
<td>2002</td>
<td>22,064</td>
<td>13,773</td>
<td>8,291</td>
</tr>
</tbody>
</table>

In recent years the number of students taking the higher level course has risen by 3% and the figure has remained stable despite the increase in candidates (Table 1.2). Also another point to note is that the percentage of numbers failing higher level biology is also increasing. However we have to consider the numbers taking biology is increasing also every year. In 2010 for both chemistry and physics 20.85 of higher level students got A1 or A2 compared to 17.4% for Biology. This reflects the wider intake into biology and probably that chemistry and physics tend to attract students of higher ability (Childs, 2010).

1.4 Rationale for carrying out this research

The Higher Education Authority (HEA) chief executive Tom Boland has stated that there is "alarm" at the extent to which the second-level school system is producing students who "learn to the test". These students are then going on to third level where they are expecting the same spoon-feeding. We need to seriously re-imagine key levels of our second-level system” (Walshe, 2009). The D.E.S states in the current Biology Syllabus that "the general aim of education is to contribute towards 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”. However the Leaving Certificate Biology Syllabus certainly does not fulfil these aims. In the objectives of the Junior Certificate Science syllabus, it states “a wide range of teaching approaches may be used” and “teaching strategies should promote the aims, objectives and learning outcomes described in the syllabus and they should encourage investigative work as well as experimental work”. In the aims of the Leaving Certificate Biology syllabus, it states “teaching strategies should promote the aims and objectives of the syllabus” and “teachers are encouraged to develop in their students positive attitudes”.

However, neither the Junior Certificate Science Syllabus nor the Leaving Certificate Biology Syllabus outlines how this is to be carried out by teachers. A gap clearly exists between the aims of the DES and the knowledge base, resources and professional skills of science and biology teachers. This is an area which must be addressed if inquiry-based learning is to become a practical tool in the teaching of biology. This research project aims to address this gap. Teachers need to be given a clear vision of what school biology should become. Teachers need to be seen as key agents of change (NCCA, 2008). Rather than teaching facts, teachers need to become more aware of and interested in promoting inquiry into their biology lessons. In order for meaningful change to occur, it must be realised that educational change can only happen through teachers and school management, and their interactions and relationships with the learner (NCCA, 2010).

This research study was divided into three parts;

- Part 1: Exploratory Phase;
- Part 2: Development of Inquiry Based Teaching Resources;
- Part 3: Intervention Programme.

Part one proposes to examine teachers’ and students’ existing attitudes towards and perceptions of inquiry and to understand how best to encourage teachers and students to engage in inquiry-based learning in Irish post-primary schools. This was achieved by the development and distribution of three questionnaires (science student, biology student and biology teacher) to eight post-primary schools around Ireland. A total of 574 science students, 202 biology students and eight biology teachers participated in the questionnaires. The qualitative research involved three biology students and four biology teachers who were chosen to participate in an interview. The analysis of both questionnaires and interviews
revealed that an intervention programme would be the most effective method to encourage and promote teachers to use inquiry-based methods.

Part two focused on designing and developing different inquiry resources for the teaching of biology in Irish second level schools. These resources related to Leaving Certificate Biology topics but involved the use of inquiry skills and inquiry-based learning.

Once the resources were developed, the research study progressed to part three. A pilot school was chosen and permission was sought and granted to implement the intervention programme with two transition year classes over a fourteen week period. The pilot school chosen for the intervention programme has a 14 week module allocation period and due this time constraint only five lessons were developed and contained a pre- and post-questionnaire, lesson plan, worksheet, task sheet and photos. The transition year classes were divided into two groups. The first group engaged in a traditional science/biology class while the second group engaged in inquiry based lessons. To ascertain the students’ understanding before and then after the lesson each topic was evaluated using the pre- and post-questionnaires, worksheets and task sheets. Two transition year students from the traditional class and four students from the inquiry class were interviewed to investigate if there was a difference between the achievements and attitudes in the two different classes towards biology.

Anderson (2002) emphasises there is a need for teachers to understand the nature of scientific inquiry and inquiry-based learning. In order for change to be successful, professional development is needed to help teachers change and reconstruct their role as science educators (Bell & Gilbert, 1996). An evaluation of Irish students’ overall science performance (PISA, 2006) which ranked Ireland 14th of 30 OECD countries led to an examination of the Junior Cycle syllabus and the conclusion that it had “not yet led to any discernable improvement in students’ science achievement” (Eivers et al., 2007). It is well established in literature that successful implementation of curricular reform is extremely challenging (Fullan, 2007) and that the curricula being implemented in schools maybe quite different from the intended curricula. Bybee (2000) states that teachers do not have a clear definition of what inquiry is and although it is included in the science curriculum, it is often viewed as a body of knowledge, rather than a process in which a better understanding of the world can be obtained. The idea of inquiry-based learning has thus far been adopted in theory into Biology Syllabi but has not yet been carried out effectively in practice (Bybee 2000).
1.5 The Aims of this research project

Part 1: Exploratory Phase
- To gain an insight into the attitudes and perceptions of qualified science and biology teachers and students towards the use of Inquiry based teaching and learning in the Irish Post-Primary Classroom.
- To investigate the extent to which the principles of scientific inquiry teaching and learning are being practiced in the Senior Cycle Biology classroom from a teacher and student perspective.

Part 2: Development of Inquiry Based Teaching Resources
- To design and develop different inquiry resources for the teaching of biology to foster student’s enthusiasm and increase achievements in this subject.
- To provide teachers with inquiry based methodologies and tools to make necessary adjustments in the classroom to adapt to the new Leaving Certificate Biology Syllabus.

Part 3: Intervention Programme
- To investigate the effect Inquiry Based Learning on how students engage in the learning process and their overall understanding in science
- To investigate if students’ scientific skills need further development in anticipation of the proposed practical assessment the draft biology syllabus.
- To promote innovation in teaching, promoting the students to reason and analyse topics in biology.
- To assess transition year students’ achievements and attitudes in the two different classes towards biology.

1.6 Research Questions
1. What teaching and learning methods are most dominant in Irish post primary schools?
2. Is there a perceived difference in the practice of inquiry based skills between Junior Certificate Science students and Leaving Certificate Biology students?
3. Is there a need for an intervention programme to help teachers and students learn and use basic inquiry skills?
4. Will the intervention programme develop students’ inquiry skills and help prepare students for the new Leaving Certificate Biology Syllabus practical assessment?
Chapter Two

Literature Review

2.0 Introduction

This chapter will explore the literature that is relevant to understanding inquiry-based teaching and learning. The first section (2.1) of this chapter will define inquiry, and describe the history and early movements towards inquiry-based learning as well as the advantages of incorporating inquiry-based learning into teaching. The second section (2.2) discusses the teaching and learning methodologies most commonly used in science teaching by teachers. The third section (2.3) examines literature relating to teaching methodology styles used in the classroom, and the implications of incorporating inquiry methods. The fourth section (2.4) looks at the constraints of the current Irish science syllabi in using inquiry in the classroom, current assessment techniques used, and some inquiry assessment models. The fifth section (2.5) will examine the benefits of transition year, teaching methodologies and approaches in transition year and barriers to teaching and learning in transition year. The chapter concludes with a brief conclusion. All literature will be examined from national and international reports, and research publications.

2.2 What is Inquiry?

Inquiry is the basic learning process of — identifying a question, designing an investigation, collecting data, developing a hypothesis, answering and modifying the original question and communicating the results (Flick, 2005). Inquiry is a pedagogical method that combines hands-on activities with student-centred discussion and discovery of concepts (Uno, 1990). Inquiry also aids memory and is effective in helping students learn scientific concepts. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (NRC, 1996). The critical skills developed by students include observing, hypothesizing, predicting, designing an investigation to solve a problem, measuring accurately, processing and interpreting data, drawing conclusions, inferring, generalizing, recognising assumptions, understanding limitations of scientific investigations, classifying, evaluating, making rational judgments based on information and explaining and applying knowledge to new situations (Uno, 1990).

The qualities promoted by inquiry and utilised by students in the classroom are the same qualities that scientists use in research, lab and learning (Flick, 2005). By using inquiry in
the classroom, students are provided with opportunities to stimulate higher-order thinking, allowing them to carry out their own investigations, especially open-ended investigations, where students pose the problem to be investigated and design their own procedures to answer the questions. Students are able to learn from one another in the group which helps to promote good collaboration skills, communication skills and social skills as well as science learning (Flick, 2005). There are different characteristics that can be fostered within the students by using inquiry in the classroom. The characteristics are as follows: commitment, creativity, curiosity, diligence, fairness, flexibility, imagination, innovation, integrity, openness, persistence, reflection and sensitivity. The skills required in inquiry in biology are similar to those involved in scientific investigations, i.e. observation, measurement, experimentation, communication, thinking processes such as inductive reasoning, formulating hypotheses and theories, deductive reasoning, as well as analogy, extrapolation, synthesis and evaluation (Llewellyn, 2005). Therefore, if science is taught effectively the result will be to reinforce desirable human attributes and values – curiosity, openness to new ideas and scepticism.

2.1.1 Types of inquiry

The principles of inquiry-based learning are incorporated into a wide variety of teaching methodologies that are discussed in section two. In particular, discovery learning, constructivism and problem-based learning are the teaching methodologies most associated with inquiry-based learning.

There are two distinct forms of inquiry; inductive inquiry and deductive inquiry

2.1.2 Inductive inquiry

The inductive approach begins by exposing the student to a concrete instance of the concept. The learner is encouraged to raise questions, observe patterns, and make generalisations from their observations. The teacher’s role is to make sure students have opportunities to make appropriate generalisations and to guide students (Grumbine et al., 2003). The students move from specific cases to more general concepts (Hassard, 2005).

According to Orlich et al. (1990) inductive inquiry is a method that teachers use when they present sets of data or situations and then ask the students to infer a conclusion, generalization, or a pattern of relationships. Guided inquiry is a form of inductive inquiry, where students work independently to determine the methods that can be applied to successfully investigate a
problem posed by the teacher. Unguided inductive inquiry involves the student selecting the phenomena and the method of investigation, not the teacher. (Hassard, 2005) The teacher may gather the class together for a brainstorming session to discuss potential phenomena to explore and study, based on the class's work to date. Small teams of students are then organized and discuss the list of topics and phenomena generated in the brainstorming session, and then proceed to devise a project of their own (Hassard, 2005).

In both forms of inductive inquiry, the students are engaged in learning about concepts and phenomena by using observations, measurements and data to develop conclusions and ask questions about what has been learned (Hassard, 2005). However, Windschitl (2002) points out that the deceptively minor differences between guided and unguided inquiry had monumental implications in the classroom for what students actually did. He points out that guided inquiry was far more intellectually challenging for learners and pedagogically complex for teachers to manage than the unguided. Unguided inquiry was remains challenging for both learners and teachers (Hassard, 2005).

2.1.3. Deductive inquiry

Spangler (1986) defines deductive inquiry as;

*The human process of going from one thing to another, i.e., of moving from the known to the unknown ... Utilising what he knows, the human being is able to move to what he doesn't see directly. In other words, the rational person by means of what he already knows, is able to go beyond his immediate perception and solve very obscure problems. This is the nature of the reasoning process: to go from the known to the unknown.*

In deductive inquiry, the student begins with the big idea, conclusion, or general concept and move towards specific cases (Hassard, 2005). Teachers use problem-solving to provide a perspective for students in which they will propose solutions to problems and make recommendations toward what should be done to change, improve, correct, prevent or better the situation (Hassard, 2005). It is imperative for inquiry-based learning that students develop these skills. One of the most successful methods by which a student will learn is to stand back from the activity they are doing, process their experiences, reflectively think about what they are doing, recall from experiences and reason as to how the activity being carried out will link to current and future learning situations (Onan, 2009).

Many of the laboratory activities that are embedded in secondary science textbooks are deductive inquiry exercises (Hassard, 2005). This is because students have already been
introduced to the concept in class and the laboratory experiment serves to show them directly something they already conceptually know. The lab is designed to help students confirm the concept (Hassard, 2005) and the outcome is generally known before doing the experiment (Grumbine et al., 2005).

2.1.4 History of inquiry

"If a single word had to be chosen to describe the goals of science educators during the 30-year period that began in the late 1950s, it would have to be INQUIRY." (DeBoer, 1991, p.206). Inquiry as a teaching and learning methodology is not a new phenomenon. This methodology predates Socrates and his way of leading students to self-knowledge through aggressive questioning (Orlich et al., 1990) and it has also been documented that early efforts stressing the inquiry-based process skills of scientists in the classroom were seen in the 1930's (Yager, 1997). Herbert Armstrong in 1898 introduced a _heuristic approach_ (step by step), where no books were used and no directions were given by the teacher. Herbert Spencer (1820 -1903) shared this view and believed that students should directly contact nature and observe natural objects and then form their own conclusions. J. Richard Suchman is credited as the originator of an inquiry teaching program that was widely used throughout the United States and he once said _inquiry is the way people learn when they are left alone._ That is, he developed inquiry training to teach students a process for investigating and explaining unusual phenomena. Based on a conception of scientific method, he set out a programme which attempted to teach students the skills and language of scholarly inquiry (Suchman, 1962).

John Dewey (1909) supported project learning and felt that science learning must include the process aspect of science and not just the information aspect (Barrow, 2006). Dewey advocated child-centred learning based on real-world experiences. This led to the first inquiry-based learning methods in the United States educational system. These efforts seriously attempted to turn the traditional approach into learning through investigation with a spotlight on developing reasoning abilities (Barrow, 2006). However, it would take a further forty years before Dewey's view of science would make its way into large scale science curriculum movement (Hurd, 1961).
2.1.5 Early moves towards inquiry-based teaching and learning

In the early 1950’s, the Soviet Union launched Sputnik into space, which caused a push for improved science achievement and advancement in the science curricula in the USA. The National Science Foundation sponsored curriculum development projects in the 1950’s and 1960’s such as Biological Sciences Curriculum study (BSCS), Chemical Education Materials Study (Chem Study), Science Curriculum Improvement Study (SCIS), Physical Science Study committee (PSSC) and Elementary Science study (ESS), as a response to the perceived superiority of the Soviet Union in science and mathematics education. However, the projects failed to generate a systematic method of inquiry teaching. The approaches of ‘discovery’, ‘inquiry’ and ‘problem solving’ were not always made clear to teachers, who found it difficult to implement.

Schwartz et al. (2004) discussed how in the 1800’s, lab instruction became popular because it was felt by many that first-hand observation and manipulation were useful in disciplining the mind. A popular theory at that time was that mental behaviour was compartmentalised into several faculties or abilities such as logic, memorisation and observation. This became known as Faculty Theory which included laborious tasks during instruction to ‘exercise‘ and strengthen students’ minds. Faculty theory lost favour and there was a shift from rote learning towards efforts to present meaningful information and develop positive attitudes.

The committee report from the Central Association of Science and Mathematics Teachers in 1901 on secondary education in America expressed a sentiment to teach students scientific concepts and reasoning skills. Galloway (1910) cited in Lawson (2010) identified ways to motivate students to select appropriate teaching materials and to teach ‘scientific spirit and method’. Overall, the committee wanted more emphasis on ‘reasoning out’, problem raising and solving rather than memorisation (Schwartz et al., 2004). In 1996 the US Standards introduced inquiry instruction in its own standards describing how good science teaching should be accomplished.

Many European theorists contributed to what we today refer to as inquiry-based learning. Jean Jacques Rousseau was a Genevan philosopher during the 18th century. He believed that children should learn what they want to learn and learn through nature. Jean Piaget (1896 – 1980) was a Swiss philosopher believed that children should construct their own knowledge and he focused on the student being actively involved in their own learning. Lev Vygotsky (1896 – 1934) believed that children created their own concepts and he placed

2.1.6 Advantages to incorporating inquiry-based lessons

**Student benefits** - Flick (2005) discusses how incorporating inquiry-based learning allows students to become engaged, think critically, conceptualize questions and search for possible explanations to questions, which would counteract the effect of "spoon feeding". Students are provided with opportunities that stimulate higher order thinking, which allow them to carry out their own investigations. This gives students opportunities to work like true scientists. The qualities that inquiry promotes and students utilize in the classroom are the qualities that scientists use in research, in the lab and learning. Students show interest and imagination in science by acting as researchers and viewing themselves as scientists; by engaging in diligent investigations from their self-generated questions, by reflecting on and taking responsibility for their individual learning, working and communicating in groups, connecting new knowledge to prior understandings and demonstrating their understanding of science and abilities in a variety of ways. Students are able to learn from others in the group which helps to promote good communication and people skills as well as lifelong science learning (Linn, 2000). Research findings indicate that, "students are likely to begin to understand the natural world if they work directly with natural phenomena, using their senses to observe and using instruments to extend the power of their senses" (National Science Board, 1991)

**Long-term educational effects** - A focus on inquiry changes the focus of school curriculum from the memorisation and recall of facts to thinking skills that can be applied to personal and societal decisions. Walshe (2009) states that "too many students are being spoon-fed and are not learning to think for themselves" Higher Education Authority (HEA) chief executive Tom Boland said there is "alarm" at the extent to which the second-level school system is producing students who "learn to the test". These students are then going on to third level where they are expecting the same spoon feeding. Mr. Boland claimed that "we need to seriously re-imagine key levels of our second-level system" (Walshe, 2009). Inquiry-based programs at the middle-school grades have been found to generally enhance student performance, particularly as it relates to laboratory skills and skills of graphing and interpreting data (Mattheis & Nakayama, 1988). Evidence also shows that inquiry-related
teaching is effective in fostering scientific literacy and understanding of science processes (Lindberg, 1990), vocabulary knowledge and conceptual understanding (Lloyd and Contreras, 1985, 1987), critical thinking (Narode et al., 1987), positive attitudes toward science (Kyle et al., 1985; Rakow, 1986), higher achievement on tests of procedural knowledge (Glasson, 1989), and construction of logico-mathematical knowledge (Staver, 1986).

2.1.7 Scientific inquiry

In Europe and America, students’ understanding of science and its processes beyond knowledge of scientific concepts are strongly highlighted in the current reform efforts in science education (AAAS, 1993; NRC, 1996; NSTA, 1989). The National Science Education Standards (NSES) (1996) state ‘that students should understand and be able to conduct a scientific investigation’. The Benchmarks for Science Literacy (AAAS, 1993) advocates an in-depth understanding of scientific inquiry (SI) and the assumptions inherent to the process. Both documents clearly support the importance of students possessing understanding about scientific inquiry, not just the ability to do inquiry. ‘Scientific inquiry’ refers to the methods and activities that lead to the development of scientific knowledge. Within the classroom, scientific inquiry involves student-centred projects, with students actively engaged in inquiry processes and meaning construction, with teacher guidance, to achieve meaningful understanding of scientifically accepted ideas targeted by the curriculum. (Schwartz et al., 2004). It is defined by Kyle (1980) as a systematic and investigative performance ability which incorporates unrestrained inductive thinking capabilities after a person has acquired a broad and critical knowledge of the particular subject matter through formal learning processes. Chinn and Malhorta (2002) contrasted the cognitive processes that were needed in authentic scientific inquiry with the processes that were needed when doing simple inquiry tasks. These processes include generating research questions, designing studies, making observations, developing theories and explaining results.

Bybee (2002) wrote of using the term “scientific inquiry” in three distinct, but complementary ways: as science content that should be understood; as a set of cognitive abilities that students should develop; and as teaching methods that science teachers could use. Authentic scientific inquiry is what scientists conduct in everyday practice (Roth, 1995) and once students have constructed a working concept of the scientific inquiry process, they are on the path to thinking and acting like scientist. Teaching science as inquiry learning encourages students to apply critical thinking and reasoning skills to gain new knowledge.
about the natural world. Scientific inquiry is completed within the context of understanding the appropriateness of an investigation to solve a specific problem or scientific phenomena (Wetzel, 2009).

### 2.1.8 Scientific method versus scientific inquiry

Scientific inquiry and scientific method have both similarities and differences. Through these similarities and differences the two lead to quite different impressions about the nature of scientific work. The processes of scientific method and scientific inquiry both begin with a problem to be investigated, pose questions and formulate a hypothesis (NSES, 1996).

In inquiry, students are asked questions to examine their previous knowledge of the subject or problem to be investigated. Using the scientific method also calls for using already known information to form a hypothesis. Another similarity between the two is materials. Inquiry gathers materials to help in collecting, analyzing and interpreting data, as does the scientific method (NSES, 1996).

One difference between inquiry and scientific method is the process each follows. The scientific method teaches skills such as observation, inference, and experimentation steps shown in Figure 2.1 below:

![Figure 2.1 Process of Scientific method. (Source: Holt Earth Science (Allison et al., 2008, p. 10)](image-url)
Textbooks commonly present "the scientific method" as a standardized, linear, four- or five-step process, from forming a hypothesis to making and testing a prediction and revising the hypothesis (NSES, 1996). The process of scientific inquiry is different. Scientific inquiry, in short, refers to the systematic approaches used by scientists in an effort to answer their questions of interest (Lederman, 2009). Inquiry will push students beyond just experimentation to become independent learners and inquirers (NSES, 1996). Scientists describe a more complex, nuanced, and question-driven process that is both richer and less rigid.

The "inquiry wheel" of Reiff et al. (2002) (Figure 2.2) below summarizes a more realistic inquiry process.

![Figure 2.2. Inquiry Wheel - Scientific Inquiry Process](Reiff et al., 2002)

Another difference is that in inquiry, students find not only possible answers to questions, but also develop an understanding about scientific inquiry (NSES, 1996). A student can think and act in ways associated with inquiry, such as question and think logically and critically about explanations, construct and analyze new or different evidence and recognize and analyze alternative explanations and predictions (NSES, 1996). By using inquiry, one learns how to communicate scientific arguments and evidence. The scientific method is more of a skill process, whereas inquiry is more a scientific way of life. Once students begin to question, plan and conduct investigations, gather data, think critically and logically about relationships between evidence and explanations and construct and analyze alternative explanations and are able to communicate scientific arguments, they begin to be scientifically literate (NSES, 1996).
Inquiry and the scientific method then, lead to quite different interpretations about the nature of scientific work. If the scientific method only was used to describe how science works to gain new information, then science would be viewed as being a very simple process. Learn the process, and you learn how to "do" science. On the other hand, if one looks at inquiry, one would learn that science is a multifaceted activity (NSES, 1996). It goes beyond just learning a process; it becomes a way of thinking. Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work” (NSES, 1996). Students may not perceive science as a way of knowing about their world, but rather as facts that must be memorized (NSES, 1996).

There appears to be a difference of opinion regarding the method scientists follow and the method students are being exposed to in textbooks. Experimental designs very often conform to what is presented as the scientific method and the examples of scientific investigations presented in science textbooks many times are experimental investigations (Lederman, 2009). The traditional view emphasized that scientists follow a step-wise procedure referred to as the scientific method” (Abd-El-Khalick, Waters, & Le, 2008; Chiappetta et al., 1993; Gibbs & Lawson, 1992; Irez, 2008; Reiff, Harwood, & Phillipson, 2002). What is traditionally called the scientific method” is actually experimentation (Bell & Binns, 2010). Scientists do use a variety of methods to conduct their work and that there are multiple types of research, including descriptive research, correlation research, epidemiological research, and experimental research (Bell & Binns, 2010). Although inquiry seems to be the best approach for becoming scientifically literate, different strategies and learning experiences should and must be implemented.

2.1.9 The nature of science (NOS)

The phrase nature of science refers to the values and assumptions inherent to scientific knowledge and the development of scientific knowledge (Lederman & Lederman, 2004). NOS involves portraying science in such a way that goes beyond thinking of science simply as a body of knowledge requires an understanding of the nature of science itself (Lederman, 1992). There is no single NOS that fully describes all scientific knowledge and enterprises (Schwartz & Lederman, 2002) and an active debate at the philosophical level about NOS (McComas, 1998) in ongoing. However, in order to help individuals understand the basics of science to promote effective science literacy, there is an agreement about the aspects of NOS
among science educators (Karakaş, 2008). The next section below will discuss the general aspects associated with NOS.

According to Lederman & Lederman (1997) and Lederman et al. (2000), seven general aspects of NOS are believed to be accessible to students and relevant to their daily lives.

1. A crucial distinction between observation and inference. Observations are descriptive statements about natural phenomena that are "directly" accessible to the senses. Inferences are statements about phenomena that are not "directly" accessible to the senses.

2. A distinction between scientific laws and theories. Laws are statements or descriptions of the relationships among observable phenomena. Theories, by contrast, are inferred explanations for observable phenomena.

3. That all scientific knowledge is, at least partially, based on and/or derived from observations of the natural world. All of the theories and laws developed by scientists must be checked against what actually occurs in the natural world.

4. That all scientific knowledge involves human imagination and creativity. Science involves the invention of explanations and this requires a great deal of creativity by scientists.

5. All scientific knowledge is at least partially subjective. Scientists' theoretical commitments, beliefs, previous knowledge, training, experiences, and expectations actually influence their work.

6. Science affects and is affected by the various elements and contexts of the culture in which it is practiced. In short, science is socially and culturally embedded.

7. Scientific knowledge is subject to change. This knowledge, including "facts," theories, and laws, is tentative and subject to change. Scientific claims change as new evidence is brought to bear on existing theories or laws, or as old evidence is reinterpreted in the light of new theoretical advances or shifts in the directions of established research programs.

In order for teachers to develop informed conceptions of these aspects of NOS, an explicit reflective rather than an implicit approach is used (Abd-El-Khalick et al., 1998). Implicit approaches assume that an understanding of NOS is simply a by-product of participating in scientific inquiry (Lederman, 1992). An explicit reflective approach, not to be confused with didactic instruction, views NOS as a cognitive outcome and intentionally draws learners'
attention to relevant aspects of NOS through instruction, discussion, and questioning in the context of activities, investigations and historical examples used in daily science instruction’ (Schwartz & Lederman, 2002).

Schwartz et al. (2004) describes an implicit inquiry-based pedagogical approach as the absence of specific attention to NOS. The message about NOS is communicated and assumes that the constructed understanding of NOS is a natural consequence of engaging in inquires. In contrast, the explicit inquiry-based pedagogical approach to teaching NOS provides inquiry-based learning opportunities with the added instructional component of specific attention to NOS aspects. Recent work according to Akerson & Abd-El-Khalick (2003) indicates that an explicit reflective approach, combined with classroom modelling of lessons emphasising aspects of NOS, is effective for in-service teachers in developing their own NOS conceptions and abilities to teach NOS to their students. Explicit instruction is needed both to prepare teachers (Abd-El-Khalick & Lederman, 2000) and to lead students to understand the nature of science (Khishfe & Abd-El-Khalick, 2002). Helping teachers to focus on nature of science as an important instructional objective resulted in more explicit nature of science instruction (Lederman et al., 2001).

2.1.10 Incorporating NOS into lessons and adapting activities for inquiry

A study by Karakas (2008) shows that students have not acquired an adequate understanding of NOS. Students believe that scientific knowledge is absolute and a scientists’ main concern was to collect and classify facts in order to uncover natural laws, and prove their hypotheses true (Lederman et al., 2000). It appears that even the most capable students and those most interested in science showed a lack of knowledge of the aspects of science, such hypothesising and experimenting (Lederman et al., 2000). Many researchers argue that science curricula are not successful in improving such knowledge (Abd-El-Khalick, 1998). Hodson (2010) sets out something of a manifesto for teaching about NOS:

What I am advocating for inclusion in the school science curriculum… is understanding of the role and status of scientific knowledge, an ability to understand and use the language of science appropriately and effectively, the capacity to analyze, synthesize and evaluate knowledge claims, some insight into the socio-cultural, economic and political factors that impact the priorities and conduct of science, a developing capacity to deal with the moral-ethical issues that attend some scientific and technological developments, and some experience of conducting authentic scientific investigations for themselves and by themselves. (p. 18)
Hodson (2010) believes that developing suitable curriculum models is only one part of the process of transforming professionally-produced public knowledge into a form suitable for engaging the interest of young learners. Lederman (2004) explains that students will come to understand NOS as a by-product of “doing” science-based or inquiry activities. If post primary students are expected to develop more adequate conceptions of NOS and scientific inquiry, then, as any cognitive objective, this outcome should be planned for, explicitly taught, and assessed.

The second part involves the work of the classroom teacher who teaches using various activities, teaching models, examples and the learners’ previous knowledge. Hodson (2010) points out that learning for understanding does not equate to adopting beliefs. Teachers have to be convinced that constructivist approaches to classroom teaching are likely to be effective in facilitating student learning, before they fully commit to adopting them. Hodson (2010) also explained that a problem with asking teachers to teach something that is both new and different to their familiar curriculum is that it makes the developed resources of an experienced science teachers irrelevant with the possibility of them reverting to just ‘telling’ students. They will need to develop expertise and flexibility in the new areas of teaching. Such shifts may be difficult to achieve, and that learners may ‘acquire’ and demonstrate new ways of thinking which exist alongside existing ideas that continue to be more influential.

Lederman (2004) explains that incorporation of all aspects of NOS should not be addressed in every lesson or activity. He talks about how lessons can be adapted to focus on a few aspects that best fit, and an effective way to do this is through reflective discussions and careful questioning. Taking time is important during and at the conclusion of any activity, to explicitly point out to students the aspects of NOS that are highlighted. The teacher may initially have to be directive, but the discussions about NOS from your students should be more easily elicited as time goes on. Lederman & Lederman (2004) stress that N.O.S activities do not need to be created from scratch. All that is needed is the placement of some carefully planned questions within the activities of the lesson; if the activity is a science activity, it can contain NOS below the surface. The questioning and discussions can bring the NOS to the surface and promote student learning in both the subject matter and the aspects of NOS chosen to emphasize.
2.2 Teaching and Learning Methodologies in Science Teaching

Inquiry-based learning is incorporated into a wide variety of effective teaching and learning methodologies appropriate for the science classroom i.e. discovery learning, constructivist approach to teaching; questioning skills; cooperative and active learning; problem-based learning and critical thinking. The following sections will introduce, describe and provide details of these different teaching and learning methodologies. Each section will provide a rationale for using such methodologies, the principles behind such methodologies and how they are used in the science classroom, the advantages and disadvantages of the methodologies and any implications there may be to the implementation of such teaching methodologies in the Irish Science classroom. All information provided is sourced from educational theorists, National and International research.

2.2.1 Discovery learning

The underlying principle of discovery learning incorporates inquiry-based learning and has been studied and analysed by educational theorists and physiologists such as Piaget, Papert and Bruner. Discovery learning has active learning at its core and can be defined as ‘active learning that is likely to produce long-lasting meaningful knowledge when successful’ (Good and Brophy, 1995). The four positive attributes of discovery learning are motivation, retention, achievement and transference. According to Bruner, true learning involves ‘figuring out how to use what you already know in order to go beyond what you already think’ (Bruner, 1983). The transference of information through discovery learning is more effective than using traditional methods such as rote learning. Bruner (1983) argues that if a child arrives at an understanding on their own, they will generally develop a more meaningful understanding than if it was proposed to them by others. They develop problem-solving skills and confidence in their own learning abilities. They learn how to learn, as they learn. Students are motivated by the process of discovery learning as they engage in the activity themselves. Students having discovered new concepts through inquiry and through their own personal experience are more effective in recalling this information than pupils who are taught through direct transmission of knowledge. However, according to Schank and Cleary (1994), the school setting is a barrier in the assimilation of discovery learning due to time constraints, set curricula and teacher accountability.

Mayer (2002) highlights the advantages of discovery learning and the effects this teaching methodology has on the students' approach to learning. He illustrates that through
the incorporation of discovery learning students become competent in processing information and hence become proficient problem solvers and learners. It promotes critical thinking and builds on the student’s prior knowledge of the subject matter and their understanding of the topic being taught. The learning process through the medium of discovery learning is active and not passive. (Nam-Hwa Kang, 2007 cited in NRC 1996). According to Schank and Cleary (1994), discovery learning makes the learning process fun, compared with a didactic classroom that is teacher-centred and teacher-led. Students are engaged in looking at and investigating new concepts and ideas for themselves rather than directly instructed by their teacher, and they acquire new learning skills such as analyzing information, reasoning skills and application skill.

2.2.2 Constructivism

The constructivist approach to teaching and learning have been promoted by many scholars such as John Dewey, Jean Piaget, Lev Vygotsky and Jerome Bruner (Snowman & Biehler, 2006). Constructivism is a major principle in current educational thinking, so unless its methods are seen as compatible with inquiry teaching there would really seem to be little point in proceeding with the development of an instrument to look at the extent of inquiry teaching. This is a teaching style developed by Piaget and Vygotsky in which pupils learn by constructing their own meaning and building on their existing knowledge. In Piaget’s view — adolescents actively construct their own cognitive worlds; information is not just poured into their minds from their environment” (Santrock, 2001). Learning by constructivism allows pupils to become responsible for their own learning, it allows pupils to be active learners which stimulates their intellect and encourages them to develop an enthusiasm for the subject.

Constructivist teachers and researches provide lots of support and guidance for inquiry-based teaching and learning. Catherine Twomey Fosnot (1989) writes:

*These problems are endemic to all institutions of education, regardless of level. Children sit for 12 years in classrooms where the implicit goal is to listen to the teacher and memorise the information in order to regurgitate it on a test. Little or no attention is paid to the learning process, even though much research exists documenting that real understanding is a case of active restructuring on the part of the learner.*

Learning needs to be conceived of as something a learner does, not something that is done to a learner. Fosnot (1989) also points out that students should not be powerless and dependent on the institution, but need to be empowered to think and to learn for themselves. Hodson (2009)
reports that pupils taught by more _constructivist_ teachers seem to demonstrate similar perceptions of scientists as those taught by more _didactic_ teachers (p. 55), perhaps in part because even experienced teachers may revert to _telling_ when moved out of their comfort zones. Hodson (2009) also points out that learning for understanding does not equate to adopting beliefs (p. 122): teachers have to be convinced that constructivist approaches to classroom teaching are likely to be effective in facilitating student learning before they fully commit to adopting them.

2.2.3 Similarities between constructivism and inquiry teaching

There appears to be a number of similarities between the needs of constructivism and the strategies suggested for inquiry teaching, so that the two may be regarded as complementing each other. The following are some particular areas where the two methodologies are intertwined:

- **Use of discussion** – this is vital to social constructivism and also critical to inquiry teaching in allowing students to clarify and refine their beliefs.

- **Concept of knowledge being uncertain** – inquiry methods note the importance of recognising the existence of alternative perspectives and interpretations, whilst constructivism sees the idea of conflict as being important in allowing cognitive change.

- **Use of historical perspectives and stories** – in inquiry it allows students to see how science progresses and in constructivism it is important as the use of such stories provides a starting point for students to relate their own experience to.

- **Scientific method skills** such as interpreting, generalising and problem-solving are seen as basic to inquiry as they allow people to use the processes of science, even in times of changing knowledge. With regard to constructivism, the development and use of these skills must provide individuals with the opportunity to further explore their own beliefs.

- **Use of open-ended investigations** – this is integral to the ideas of inquiry. It must also be extremely important in constructivism as such investigations pave the way for conceptual growth and bring about cognitive conflict leading to conceptual change.
Implications for implementing constructivism can be best viewed by looking at the three facets of constructivism. Firstly, meaningful learning is the active creation of knowledge structures from personal experience. Each learner builds a personal view of the world by using existing knowledge, interest and goals (Brooks and Brooks, 1999; Perkins, 1999). Secondly, the essence of one person’s knowledge can never be totally transferred to another person because knowledge is the result of a personal interpretation of experience, which is influenced by such factors as the learner’s age, race, gender and knowledge base. And thirdly, constructivism does not necessarily mean that everyone walks around with a personal, idiosyncratic view of the world. There are also two variations of constructivism that may cause confusion among teachers. Cognitive constructivism focuses on the cognitive processes that take place within individuals. It is the ability to assimilate information effectively into existing schemes and develop new schemes and operations (Duffy & Cunningham, 1996; Fosnot, 1996). Social constructivism holds that meaningful learning occurs when people are explicitly taught how to use the psychological tools of their culture, like language and mathematics.

### 2.2.4 Problem Based Learning (PBL)

The primary concept of PBL is that the problem or puzzle to be solved is given to the students at the beginning of the learning process rather than at the end. This concept moves away from what is being taught by the teacher and focuses on what the students are learning. PBL is not a new model of instruction. Plato and Socrates required that their students think, retrieve information for themselves, search for new ideas and debate them in a scholarly environment. This process differs from the teacher-dominated approach used in most educational settings (Neufeld & Barrows, 1974). Essentially, problem based learning is a small group teaching method that combines the acquisition of knowledge with the development of generic skills and attitudes (Wood, 2008). According to Finchan et al. (1997), ‘PBL does not present a new curriculum but rather the same curriculum through a different teaching method’.

**Critical Thinking** - Problem solving promotes critical thinking among students as they brainstorm problems within a topic. Elder and Paul (1994) suggested that critical thinking is best understood as the ability of thinkers to take charge of their own thinking. For students to think critically they must ask questions. Students’ critical skills are nurtured in classrooms where questioning, brainstorming, hypothesizing, reflecting, and imaging are encouraged.
Critical thinking is fostered among the students by allowing them to discuss, reflect and analyse the situation or problem (Bloom, 1995). Active learning can make the subject more enjoyable for both teachers and students, and, most importantly, it can cause students to think critically (Duron et al., 2006).

Critical thinking is an important and necessary skill for citizens to make good decisions on important social, political and economic issues (Syed, 2004) Critical thinking is necessary for students to be lifelong learners. Educators must give up the belief that students cannot learn the subject at hand unless the teacher covers it (Duron et al., 2006). Problems associated with the implementation of critical thinking include class size, time constraints and professional development. While most teachers believe that developing critical thinking in their students is of primary importance (Albrecht & Sack, 2000), few have an idea exactly what it is, how it should be taught, or how it should be assessed and may be somewhat uncomfortable to both students and teachers (Duron et al., 2006).

Problem based learning has similar problems when it comes to implementing it into classrooms such as time and cost (Finucane et al., 1998). Another problem with the integration of P.B.L into the classroom is if students or teachers are unresponsive to it (Finucane et al., 1998). Students may not be comfortable with taking on the responsibility, as they may be so used to being told what to do or what to learn, that some may end up falling behind with their work. Teachers may be unsure and feel awkward with their new role as facilitator. According to the Organisation of Economic Co-operation and Development (2009), the misuse of inquiry teaching strategies in Ireland has led to problems in teaching as teachers have misused their role in the classroom. They would rather instruct than facilitate learning because it gives them more of a dominant role in the classroom.

**Questioning Skills** - There are two types of questions asked in post primary schools - lower order and higher order questions. Lower order questions are often simple questions requiring basic recall of information learned (Bloom, 1956) and the higher order type questions demand applications of knowledge (Bloom, 1956; Cotton, 1988).

The higher order questions are more appropriate for encouraging students to think more deeply and critically, to problem solve, encourage discussions and stimulate them to seek more information (Forrester, 2009). The thinking skills developed by students associated with asking questions include investigating natural phenomena, solving problems, and
making sense of data, formulating conclusions. These skills are relevant for a student's everyday life and for developing problem solving and decision making skills (Bloom, 1956).

Questions are an important pedagogical tool as it provides a distinctive insight into students' prior knowledge of a topic, a factor that is important for implementing Learning Cycles such as the 5 E’s Learning Cycle. The use of higher and lower order questions is widely used in the classrooms. However, research shows that only 5% of teacher directed questions are higher-order divergent (Wilen, 1987). While bloom's taxonomy (1958) articulates a wide breadth of question types and while teachers know that asking multiple types of questions is good pedagogy, the research indicates that teachers consistently revert to asking lower level convergent questions far more often than any other type of question (Wilen, 1987). Experiencing questions at repetitively low levels limits children’s opportunities to further develop their ideas and to be supported to reach higher cognitive levels (Bruner, 1996; Vygotsky, 1978).

A strategy known as wait-time refers to the amount of time the teacher allows to elapse after he/she has posed a question and before a student begins to speak (Mauigoa-Tekene, 2006). For effective questioning in class, researchers such as Cazden (2001) have found that teachers who extend the wait times to three to five seconds between the initial question and the student response gain a number of benefits, such as students giving longer responses; speculating and hypothesizing more; asking more questions and more students participating in responding.

Observational Skills - For over three decades a focus on ‘science process skills‘ including the skill of observation, has been highly promoted in school science. One influential elementary curriculum developed during the science curriculum reform flurry of the 1960s-Science: A Process Approach--was organized around the development of skills (AAAS, 1975). More recently, curriculum standards in science, related to observation, have typically appeared in sections related to learning through inquiry. According to the National Research Council (NRC,1996), students in the earliest school years should be expected to use simple tools--magnifiers, thermometers, and rulers--to gather data and learn what constitutes evidence (pp.122-123). Strategies for helping young students make detailed observations have been described (Checkovich and Sterling, 2001), and ways of linking observations to familiar readings have been offered (Angus, 1996).
In post-primary school, students should learn to conduct systematic observations, interpret data, use computers to collect and display evidence, and base explanations on observations, design and conduct investigations that involve the use of equipment and procedures to collect data, the use of computers to analyze data, and the development of models or explanations based on the evidence from investigations (NRC, 1996; p. 145, 175). To engage in effective observations, students should keep a notebook that accurately describes observations made during experimentation or demonstrations, that carefully distinguishes actual observations from ideas and speculations about what was observed, and that is understandable weeks or months later (AAAS, 1989).

Interestingly, Haslam and Gunstone (1996) provide evidence that students tend to view observation as a teacher-directed process rather than a self-directed pursuit of evidence. Student conceptions of evidence-based inferences also seem limited. Surprisingly, many students do not see the process of observation as being particularly relevant to the science learning process (Haslam & Gunstone, 1998). P.B.L also fosters active learning and co-operative learning. These learning strategies improve communication skills within the class as the students learn to work together. Most students enjoy the active participation which. They consider the process to be stimulating, relevant and even fun, while teachers have increased student contact (Finucane et al., 1998). Both active and co-operative learning will now be discussed.

2.2.5. Active Learning and Co-operative Learning.

Active learning is a term that was popularized by Bonwell and Eison (1991) and refers to several models of instruction that focus the responsibility of learning, on learners. They defined active learning as any teaching methodology that gets the students actively involved in the learning process. It engages the student in a physical, cognitive and emotional way, placing the student at the centre of the learning process (NCCA, 2005). Active learning is the basic underlying principle of science education and encourages students to take more responsibility for and ownership for their own work (Grabinger & Dunlap, 1995). Active learning is embedded in the foundations of and provides fundamental basis of a constructivist approach to teaching inquiry-based learning and co-operative learning activities.

Co-operative learning is described by Smith (2000) as „working together to accomplish shared goals. Individuals seek outcomes that are beneficial to themselves and
beneficial to all other group members”. Small groups are used so students can work together to maximise their own and each others’ learning (Johnson et al., 1991). They must work in teams to accomplish a common goal, where all members must co-operate to complete the task and each member is accountable for the final outcome (Smith, 2000) and for encouraging and supporting other group members to learn (Johnston et al., 1998).

The role of the teacher is that of a facilitator rather than an expert dispensing knowledge. The facilitator moves about the classroom, observing the interactions between group members and providing an informal assessment of how well students are learning and understanding the topic (Johnston & Johnstown, 1989). Co-operative Learning is a methodology that requires teachers to learn five basic elements to create unique lessons tailored to the needs of their students. These five elements include positive interdependence, face-to-face interaction, individual accountability, group processing and teaching of social skills (Johnston et al., 1998). Results show that co-operative learning promotes higher achievement and greater retention than individualistic experiences (Slavin, 1995; Clarke, 1988). The NCCA emphasise the importance of involving students in their own learning, teachers sharing goals with students and the provision of regular feedback to students (NCCA, 2008). These key principles mirror many of the elements of co-operative learning.

2.3 Style of Classroom Teaching

2.3.1 Traditional versus inquiry-based lessons

The Teaching and Learning International Survey, TALIS (2009) Report found that teachers in Ireland were “less supportive of constructivism beliefs” and “more supportive of transmission beliefs” (Shield et al., 2009). In Ireland the present-day pedagogical approach involves didactic teaching because the “institutional and authoritarian fits the ‘jug and mug’ pedagogical approach but does not fit any of the more enlightened approaches in learning” (Molloy, 2004). In June 2009, the OECD launched an international report on its Teaching and Learning International Survey (TALIS) – a survey of teaching conditions and learning environments in lower-secondary schools in 24 countries. More teachers in Ireland than in many TALIS countries emphasize structuring practices in their teaching, where learning goals are explicitly stated, homework is reviewed, and student understanding is frequently checked. Student-orientated practices, such as students working in groups and providing input into planning classroom activities, and enhanced activities, such as extended projects and essays in which students must explain their reasoning, are used less often.
The hardest issues to grapple with relates to actually improving teaching practice. Teachers in most countries report using traditional practices aimed at transmitting knowledge in structured settings much more often than they use student-oriented practices, such as adapting teaching to individual needs. And even less do they use enhanced learning activities that require a deeper cognitive activation of students. In most European countries, science teaching methods are essentially deductive. The presentation of concepts and intellectual frameworks come first and are followed by the search for operational consequences, while experiments are mainly used as illustrations (European Commission Report, 2007).

The report recently issued by the OECD – "Evolution of Student Interest in Science and Technology Studies" (2006) highlights that, while young children have a natural curiosity of these subjects, traditional formal science education can stifle this interest and therefore can have a negative impact on the development of attitudes towards learning science. Teachers often choose a traditional ‘chalk and talk’ approach with which they feel more comfortable and avoid inquiry-based methods that require them to have deeper integrated science understanding. Kyriacou (1997) previously reported that direct teaching was more frequently used than active learning methodologies. The focus is therefore on memorizing rather than on understanding; and furthermore, heavy workloads are reported to leave little time for meaningful experiments. The report recommends that ‘teaching should concentrate more on scientific concepts and methods rather than on retaining information only’ and that stronger support should be given to teacher training in science (OECD, 2006).

The science education community mostly agrees that pedagogical practices based on inquiry-based methods are more effective, but the reality of classroom practice is that in the majority of European countries, these methods are simply not being implemented (European Commission Report, 2007). A change is under process in some countries towards more extensive use of inquiry-based methods; however, the mainstream still remains mainly deductive. Inquiry-Based Science Education (IBSE) methods are also effective in post primary education. However, this approach faces more reluctance from teachers as they often consider it as time-consuming leading to conflict with the requirement to deliver curricula content.

Improvements in science education should be brought about through new forms of pedagogy: the introduction of inquiry-based approaches in schools, actions for teachers training to IBSE, and the development of teachers’ networks should be actively promoted and supported (European Commission Report, 2007). The Irish science syllabi encourage inquiry in the classroom and outline the aims and objectives necessary for it to be implemented at
Junior and Senior Level (Department of Education and Science, 2003). The move is needed from the traditional teaching methods to more inquiry-based lessons with inquiry-based science education and traditional deductive approaches are not mutually exclusive and they should be combined in any science classroom to accommodate different mindsets and age-group preferences (European Commission Report, 2007). In order to ascertain the best way to implement this change, an understanding of these two types of lessons is needed.

2.3.2. Traditional science lessons

Traditional learning describes the teacher as an information provider and students as passive learners (Llewellyn, 2005). There is little emphasis on students internalising the information presented, desks are arranged in straight rows with the teacher’s desk in the front centre of the room. Normally a single textbook is used which is accompanied by several demonstrations and laboratory experiments. The students take notes, fill out handouts and worksheets which all emphasise rote learning and memorisation. (Llewellyn, 2005). Brooks and Brooks (1999) outline a traditional class as one where:

- the curriculum is presented with emphasis on basic skills;
- there is strict adherence to the curriculum;
- the students are viewed as ‘blank’ slates’ onto which information is etched by the teacher;
- the students primarily work alone;
- the teacher validates the student learning by seeking correct answer to questions;
- and assessment occurs almost entirely through testing.

According to Anderson (2002) the teacher’s role in a traditional classroom is as a ‘dispenser of knowledge’. Hammerman (2006) describes teacher behaviour in a traditional classroom as:

- teach is to ‘tell’ mentality;
- vocabulary words are defined and memorised;
- All activities for students are directed using cook book method;
- Tells the students what they will be learning;
- Uses the same content every year.

She also describes students as ‘passive receivers’ who ‘memorise terms and facts and follows the teacher’s directions with no deviation’. Hammerman (2006) describes students work as
School science classrooms remain so teacher-directed due to the ease of expository teaching, the standards and assessment constraints that teachers face, and teachers‘ previously held beliefs about ‘good’ teaching and learning (Llewellyn, 2005). He also believes that most teachers prefer and are more comfortable doing traditional lab and prescribed activities with their students because it was the way they were taught. Abd-D-El-Khalick (2004) talks about how lab exercises miss the opportunity to make learning more meaningful when teachers do not ask the students to use their results to make new predictions, hypotheses or to explain everyday events. A study on nine high school biology laboratory manuals was carried out by Germann et al. (1996). It was a descriptive study to determine how well laboratory manuals promote the basic science process skills that are involved in scientific inquiry. Ninety activities were selected from nine manuals in eleven topic areas. The activities included two subsamples of five experimental and five descriptive exercises. The results indicate that in general, high school biology lab manuals are highly structured in that they provide step by step detailed instruction or cookbook methods. They usually ask students to manipulate materials, make observations and take measurements. The conclusion states that;

_These manuals seldom provide opportunities for students to pose questions to be investigated, formulate a hypothesis to be tested, predict experimental results, design observations, measurement, work according to their own design, formulate a question or apply an experimental technique based on the investigation._

This again reiterates the point that students are rarely asked to use what they have learned to make predications or hypothesis or to explain common natural objects or events during class and practical time (Germann et al., 1996)

### 2.3.3 An inquiry-based learning class

Inquiry-based classrooms are quite different to traditional classrooms in terms of what the student and teachers do. An inquiry-based classroom is described as ‘student or learner centred’ (Llewellyn, 2005). The atmosphere promotes effective learning situations by making students feel that their ideas, thoughts and opinions are valued. In the classroom, students‘ desks are arranged in a ‘U’ shape or in groups with evidence of their work displayed and computer resources available for student use (Llewellyn, 2005). Group work help students
learn from each other, share and challenge their ideas (Jablin et al., 2001). Students learn to construct knowledge together and build positive peer relationships, build self confidence while working collaboratively in a group. By working cooperatively, students enjoy being together and creating experiences which are meaningful and make them feel secure, confident and committed to their own education (Jablin et al., 2001).

Hammerman (2005) describes teacher behaviours in an inquiry-based classroom as one that uses "a variety of methods and strategies for investigations". Students are allowed to ask questions and design activities to facilitate student thinking. Teachers use wait time in questioning to encourage critical and creative thinking and give instruction that guides students to concept and skill development. Students are active learners who record data, process information and build on their understanding (Hammersman, 2005). Students use terms and facts to describe, interpret and communicate their understanding and design activities and investigations to answer their questions.

The student tasks are varied with emphasis on investigations. Inquiry investigations stimulates students to think critically about the data and evidence accumulated during their inquiry (Llewellyn, 2005). Students analyse and synthesize the data and make judgements and evaluations concerning their evidence and conclusions. They use thinking skills that cause them to reflect about their work and pose logical arguments to defend their conclusions (Llewellyn, 2005). These types of thinking skills are far superior in developing scientific literacy than the lower level, knowledge type questions often repeatedly posed to students in traditional classrooms, where recall of science fact is valued (Llewellyn, 2005). Students in an inquiry-based classroom show evidence of thinking, reasoning and problem solving skills and of being responsible learners (Hammersman, 2005).

2.3.4 Planning inquiry-based lessons using the five E’s learning cycle

The constructivist approach to science lessons uses the Five E Learning Cycle as a guide. It was originally proposed for elementary school science programs in the early 1960s by J. Myron Atkin and Robert Karplus (1962) and has been documented by Lawson et al. (1989), Bybee (1997) and Colburn and Clough (1997) to name a few. It has in the last ten years become very popular among teachers. Many articles in The American Biology Teacher refer to this learning cycle as very effective lesson plan. This is one of the constructivist learning models that will be
used in this research project to design and develop inquiry-based lesson plans for the intervention programme (See Appendix 8 on attached CD). The traditional three-step lesson plan in science begins with introducing new vocabulary, then providing a step-by-step laboratory procedure to verify the information present and finally finishing with an end-of-chapter problem or test. The 5E learning model is a constructivist teaching strategy that includes five stages consistent with cognitive theories on how learning occurs:

1. Engagement - Activating, engaging and identifying misconception
2. Exploration - Discovery phase
3. Explanation - Processing for meaning
4. Elaboration - Making connections
5. Evaluation - Shaping understanding

The following table describes what students and teachers do during each stage of the learning cycle. It also shows the educational advantages students gain by being taught science this way.

Table 2.1 below shows the 5 stages of the 5E learning model in the constructivist approach to teaching.

<table>
<thead>
<tr>
<th>Stage</th>
<th>What student does...</th>
<th>What teacher does...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engage</td>
<td>• Asks questions</td>
<td>• Creates interest</td>
</tr>
<tr>
<td></td>
<td>• Shows interest in topic</td>
<td>• Generates curiosity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Raises questions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Elicits responses that uncover what the students know or think about the topic</td>
</tr>
<tr>
<td>Explore</td>
<td>• Thinks freely but within limits of the activity</td>
<td>• Encourages students to work together without direct instruction</td>
</tr>
<tr>
<td></td>
<td>• Tests predictions and hypotheses</td>
<td>• Observes and listens to students</td>
</tr>
<tr>
<td></td>
<td>• Tries alternatives and</td>
<td>• Asks probing questions to redirect the students’ investigation when necessary</td>
</tr>
<tr>
<td>Explain</td>
<td>Elaborate</td>
<td>Evaluate</td>
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</tr>
</tbody>
</table>
| • Discusses them with others  
  - Records observations and ideas  
  - Explores possible solutions or answers  
  - Listens to others‘ explanations  
  - Listens and tries to comprehend explanations  
  - Refers to previous activities  
  - Uses recorded observations in explanations | • Applies new labels, definitions, explanations, and skills in new but similar situations  
  - Draws reasonable conclusions from evidence  
  - Records observations and explanations  
  - Checks peers for understanding | • Answers open ended questions by using observations, evidence and previous explanations | • Encourages students to explain concepts and definitions in their own words  
  - Asks for justification and clarification from students  
  - Formally provides definitions, explanations, and new labels | • Observes students as they apply new concepts and skills  
  - Assesses students’ knowledge/skills  
  - Ask open ended questions | • Encourages students to use formal labels, definitions, and explanations  
  • Encourages students to apply or extend concepts and skills in new situations  
  • Refers students to existing data and evidence (from explore stage) |
In order to implement learning cycles, teachers need to recognise that students construct knowledge from existing knowledge and the importance of eliciting prior understandings in ascertaining what students know prior to a lesson is imperative. Teachers need to find out what existing knowledge their students possess. Failure to do so may result in students developing concepts very different from the ones the teacher intends (Bransford, Brown, and Cocking 2000). Teachers should be trained about the usage and importance of 5E Learning Cycle based on constructivist approach and they must be able to plan the instructional activities accordingly (Kilavuz, 2005). Time is important for students to reflect on both the learning content and the learning process they engaged in. Not having enough time is a factor mentioned by teachers as an impediment to implementing inquiry-based methods (Llewellyn, 2005). Instructional methods such as case studies, debates, individual and group summarising, and team teaching are appropriate instructional activities but are time-consuming. They are important to instigate internal conflicts, facilitating the learner's individual development of understanding (Kanucka & Anderson 1999).

2.3.5 Student’s attitudes and perceptions toward Inquiry-Based Learning

Students may find the transition to an inquiry-based class unnerving initially because they are generally not accustomed to making their own decisions about experimental procedures and this make some students very uncomfortable. A study conducted in 2006 supported the Department of Education and Science recommendations that teachers should make active learning methodologies a priority as students felt they learn best by active learning, discovery learning and being able to express their opinions and participate in practical in practical activities (Smyth et al., 2006). Crawford (2000) reveals student opinions based on their inquiry-based lessons. One student saying "you know, other classes, you know, you sit down
and listen to a lecture . . . It is definitely my best class’. (Crawford, 2000 - Interview, 11/18/96). Another student commented that she ‘liked the hands on work instead of book work, because I got more out of the class. I also tried harder because what we were doing was worthwhile and beneficial to society’. One other student said that he ‘presents material in an interesting way, and use material in real life situations’ (Questionnaire, 6/5/97). In Crawford (2000), one student said she learns not by doing the experiment but by writing about it in her lab reports. She says it is ‘just because you have to put it down on paper and you have to think about it and you have to think about what you are writing’. Another student said that ‘if I am not interested in a topic, I just will not learn it because it has no meaningfulness’. In this case, wonder and curiosity are motivating factors this student and not grades. In the results, the data showed this student did not make any new links about biological processes but the student states;

I wouldn’t say I increased my knowledge about biology but it helped me look at things more in depth and in a more critical manner. They way it is designed it just helps you sit and look at it and thinks about what you’re sitting looking at. Not just look at it and say “okay” but look at it and understand why. (Crawford, 2000).

In Wallace (2003) a student explains their perception of an inquiry lesson. He says;

I want to make up my own lab – I love it when they just say ‘here u go, go to it’. You learn from your failures... and you turn to the people next to you and you ask ‘what did you do” and you realise ‘oh that is where I messed up” then you understand even more why it happened.

Ho Im Neo et al. (1997) talk about student reflections on encountering an inquiry-based lesson;

—‘science is a very adventurous topic. I thought it was magic. It was really interesting”

—‘Those lessons were very fun. I did not know that magnetism causes floating”

—‘We enjoyed learning through playing and not from the textbooks...’’

—‘We want more of these fun science classes in future”.

2.3.6 Teacher attitudes and perceptions towards inquiry-based learning

Teachers find the transition from traditional to inquiry style challenging as they are initially surprised by a sense of chaos in their classrooms which is the result of having students
involved in different aspects of a project at the same time and being actively engaged in their learning (Weaver et al., 2008). Llewelyn (2005) talks about how inquiry may appear on the surface to be unstructured and open-ended to some teachers but as student involvement increases so does the need for the teacher to manage the classroom movement and communications. Inquiry creates time constraints and discomfort is then felt by teachers (Ediger, 2001). There are teachers who have never engaged in the learning of science through inquiry (Haefner 2001). According to Melear (2000) “there are too few in education that have practiced science and have experienced inquiry first hand”.

It is also felt that assessing the learning is too complex and time consuming (Melear, 2000; Windschitl, 2000; Colburn, 2000). When teachers use inquiry-based strategies they may find that teaching requires more preparation and anticipation of possible student questions. This leads to numerous teachers fearing that a students’ answer to an inquiry-based problem will not be direct or straightforward and may lie outside the teacher’s sphere of knowledge. Teachers have to be comfortable with the ideas of their pupils asking questions for which they might not know the answers (Chin, 2002). Teachers feel they do not have time for exploration of ideas, much less teach the content the students are required to learn as it would take too much instructional time (Abd-El-Khalick et al., 2004). Llewellyn (2005) lists the following top ten reasons why teachers say they do not incorporate inquiry-based learning into their teaching:

10 – “I am more comfortable with traditional labs”;
9 – “I lose control with inquiry-based labs”;
8 – “There is no professional development”;
7 – “Inquiry is not a focus in book we use”;
6 – “Students need to be told how to do the experiment”;
5 – “There is not enough supplies and equipment to do inquiry”;
4 – “I have a final exam to teach to”;
3 – “Students do not have inquiry skills”;
2 – “Students are accustomed to getting the answers from the teacher”;
1 – “I do not have enough classroom time to do inquiry. A lesson can be quicker through demo or didactic teaching methods”.

2.3.7 Implications of Introducing Inquiry-Based Learning

Hammerman (2006) explains that availability of resources, time, professional development support and flexibility of scheduling could form impediments for successful implementation of inquiry. She regards professional development as being important and states “teachers must be given the opportunity to develop their own understanding and appreciation of inquiry”. Teachers
need to work collaboratively with colleagues, assess the effectiveness of work and modify it if needed. Without this practice teachers will not be able to implement inquiry in their classroom (Hammerman, 2006).

Steven Rakow (1986) points in his book _Teaching Science as Inquiry_ that behaviours and attitudes of the teacher play an essential role in inquiry teaching. The characteristics of successful inquiry teachers includes having model scientific attitudes, being creative and flexible, using effective questioning strategies and being concerned both with thinking skills and science content (Rakow, 1986). The greatest challenge to those who advocate inquiry teaching is the perceived threat to the traditional and dominant role of the teacher in secondary education (Hassard, 2005). Teachers must depart from the traditional role as primary givers of information and become the science teacher that "takes-on" the inquiry philosophy and become more of a facilitator and manager of the learning environment. The student must be placed in the centre of the inquiry teacher's approach to teaching, thereby fostering the student's self-concept and development (Hassard, 2005) with the student also adapting to this new role.

According to Anderson (1996) the implications for implementing inquiry fall under three dimensions - the technical dimension, the political dimension and the cultural dimension. The technical dimension includes; prior commitments to a textbook for example, the challenges of assessment and of new teacher and student roles, inadequate in-services that are not sustained for a sufficient length of time and limited resources (Anderson, 1996).

The political dimension included parental resistance, unresolved conflicts among teachers, lack of resources, and differing judgments about justice and fairness. The cultural dimension, which is most important because beliefs and values are so central to it, included the views of assessment and the preparation ethic, meaning teachers feel a commitment to get the course covered because of a perceived need to prepare students for the next level of schooling (Anderson (1996).

In order for successful implementation, all dimensions must be addressed in depth and systemically (Anderson, 2002). Many curriculum materials are still based on traditional approaches and fail to engage students in inquiry (Volkmann & Abell, 2003). This research project aims to change this by developing activities and resources to promote inquiry in a classroom situation with little preparation from the teacher.
2.3.8 Constraints to incorporating inquiry-based lessons

This section will outline the constraints associated with incorporating inquiry-based lesson. The following sections will introduce, describe and provide details of how these different constraints affect the incorporation of inquiry-based lesson. These constraints have been well documented in various literatures including Schwab (1961), Llewellyn (2005), Abd-El-Kalick (2002) and Timmerman (2005) to name a few. All of the information provided is sourced from educational theorists, National and International research.

**Time** - The syllabus and curriculum set by Department of Education and Science outlines the topics, class duration, period allocations and assessment and in the biology syllabus (2011) it mentions that ‘teachers are encouraged to exercise discretion when allocating time periods to the various elements of the syllabus’. Students are examined on the topics within the syllabus and all material must be covered (DES, 2011). Schwab (1961) acknowledged the contention that inquiry methods take too long with too much time needed to develop good inquiry materials and too much energy expanded to maintain level of enthusiasm through five classes each week. He was of the opinion that it was a serious question as to whether the many topics commonly covered in traditional high school sciences courses were necessary or even desirable. It was noted by Solomon (1994) that Armstrong’s inquiry methods were too slow for covering the Higher School Certificate examinations. Herron (1971) stated that one thing that we could be sure of was that inquiring laboratory activities took longer. Connelly *et al.* (1997) supported this, noting that it may be necessary to sacrifice some content coverage in using inquiry methods.

With the pressure on teachers to finish the subject course, there are findings that some teachers/schools see inquiry-based instruction as potentially disadvantageous to their students. In the USA, teachers and schools face pressures of heightened accountability trickling down from the Federal Government and the No Child Left Behind Act of 2001. The theme in the implementation of Tasmania’s new ‘Essential Learnings Curriculum’ stresses that teachers should teach in less breadth, but in more depth. ‘The Essential Learnings’ advocates an inquiry approach across the curriculum; this is a means of addressing teacher concerns. Horizon Research (2003) considered that the content standards themselves are too daunting and it is not possible to teach all of the content embedded in the NSES or the Benchmarks in the 13 years available to the school system, using the pedagogies recommended by the NSES in Ireland.

The opportunity for students to problem solve and design their own investigations
may be constrained by the daily schedule of 45 minute periods (Llewellyn 2005). The lack of
time that most teachers currently have for lesson preparation is likely to be a factor
preventing them from adopting strategies which require significant preparation time. And
teachers using inquiry methods will require more preparation time (Volmann & Abell, 2003).
To implement constructivist and inquiry-bases strategies, block scheduling becomes a viable
alternative for extended instructional time and opportunities for teachers across disciplines to
integrate their curricula and develop team-teaching partnerships.

Teachers feel that inquiry-based learning takes too much time, when students develop
their own questions, the questions do not relate to the required curriculum, teachers are
uncomfortable sorting questions, and teachers feel unprepared to help students with difficult
questions, due to the lack of background knowledge (Pierce, 2001).

**Breaking with the Traditional** - For many decades there have been both educational and
political policy debates over the merits of "inquiry-based" and "direct" approaches to
teaching science, with strong opinions on both sides. In broad practice the pendulum has been
mostly on the direct side (National Research Council, 2000; American Association for the
Advancement of Science, 1990).

Teachers need to alter their traditional teaching methods of lectures, discussions, and
asking students to memorize materials for tests and become more of a facilitator than as a
disseminator of information (Xiuping, 2002). Instructors focus their attention on questioning
student logic and beliefs, providing hints to correct student reasoning, providing resources for
student research, and keeping students on task. Some teachers may have trouble breaking out
of their past habits (Xiuping, 2002).

For many high school science teachers, lecture and discussion methods are the
primary means to dispense or impart knowledge to their students (Llewellyn 2004). These
teachers see lecturing as the most effective and efficient way to transmit large amounts of
content information to their students in a relatively short period and it is also the method by
which many teachers learned science when they were in high school (Llewellyn, 2004). It is
also a method by which many teachers learned science when they were studying to become
science teachers. Therefore, based on prior experience, we should not be surprised that so
many science classes are lecture-based as this is why teachers are comfortable with
traditional teaching methods.

Most teachers are well equipped in providing hands on and problem solving activities
to students but there is a lack of philosophical foundation in learning theory for Inquiry
To establish inquiry-centred environments, teachers need to accept changes in their role and in the atmosphere of the classroom (Llewellyn, 2004).

**Scientific Literacy** - This topic gained spotlight with the American Association for the Advancement of Science's (AAAS) publication of *Science for All Americans* in 1989. AAAS's Project 2061 defined the term to include 'significant science facts and principles, characteristics of science, interactions of science and society, and applications of science to everyday life, which must be possessed by responsible citizens in today's world'. The goal of science education should be to prepare scientifically literate students who can use science to improve their own lives, cope with an increasingly complex technological world, and make science-related decisions as responsible citizens (AAAS, 1989).

Hodson (2009) describes the drive to improve scientific literacy as an urgent imperative to increase the number of talented young people seeking to enter science, to support economic development in 'developing' nations and to maintain the industrial economic base in 'developed' nations. Many authors suggest that to improve teachers' and consequently their students' scientific literacy, teachers' training, such as science methods courses, need to portray the true nature of science (Driver *et al*., 1997; Duschl, 1990; Hodson, 1988; Monk & Osborne, 1996).

Gallagher (1991) states that 'teachers have no formal education in the history, philosophy, or sociology of science, nor has their scientific training provided them with much understanding of the processes by which scientific knowledge is formulated'. He explains that teachers do not see the practical applications of their science training and as a consequence they frequently fail to point out obvious connections between class work and the world outside of school. There are obstacles that interfere with scientific literacy and rather than teach in an inquiry fashion to promote scientific literacy, critics assert that students are being taught in preparation for standardized testing (Bentley *et al*., 2002; Grossen, Romance, & Vitale, 1994; Rescher, 2000). Alternatively, others claim that science teachers have little or no concern for reading in science and do not see reading as an important part of science (Wellington & Osborne, 2001).

**Textbooks** - Llewellyn (2005) discusses how textbooks are the greatest single source of information from printed materials used in high schools today. In any high school or college science classrooms you will find a single textbook being used. The primary purpose of a book is to enable high school science teachers not only to develop an understanding of scientific
inquiry but also to gain an appreciation of the skills, dispositions, and attitudes in creating a "culture of inquiry" within themselves as well as their classrooms (Llewellyn, 2004). Although many curricular materials bear the label "inquiry", upon closer inspection what may be claimed to be inquiry falls short of the vision of inquiry put forth by the National Standards (NRC, 1996). On a number of occasions in the literature, there is a lack of textbooks and other curriculum materials which really encourage inquiry learning. Teachers often state that a lack or equipment or resources is a barrier to using inquiry-based methods (Keys & Bryan, 2001; Welch et al., 1981). Many high school science teachers begin the school year by introducing the scientific method to students. The scientific method is so important to many textbook publishers that it is predominantly introduced in the first chapter of many secondary school science textbooks and it consists of rigid sequenced steps (Llewellyn 2004).

Hurd et al. (1980) found that whilst inquiry was a stated goal of biology programs, few biology activities (10%) stress independent inquiry. Tobin and Gallagher (1987) noted because of the large emphasis placed on content in science classrooms and the extensive use of the text that changing the text could be a means of bringing about a change. This is not the sole reason for teachers not using inquiry-based methods. Eltinge and Roberts (1993) explain that a textbook may have a very high level of inquiry but be used in a manner which enhances rote learning or a highly inquiry oriented course can be run using most traditional of textbooks (Romey, 1968). Jiménez Aleixandre (1994) agreed and reminded us that classroom materials designed to involve pupils are not enough if the teacher's strategy is not appropriate. While Chinn and Malhorta (2002) noted that textbooks, which remained important in many schools, were dominated by oversimplified inquiry tasks that bore little resemblance to authentic scientific reasoning. Also, textbooks tend to be written for a national audience so publishers fear swaying too far from the "middle of the road" from what schools expect in a textbook. To move towards a constructivist culture, teachers and administrators should consider a multi-text approach while using primary sources of relevant information (Llewellyn, 2005).

**Experiments** - Most lab notebooks/ workbooks that often accompany biology books do not provide the student the opportunity to pose a question to be investigated (Llewellyn, 2005). The usual high school science "experiment" is unlike the real thing (AAAS, 1993). According to the AAAS (1993) the experiment in a traditional class is one where;
The question to be investigated is decided by the teacher, not the investigators; what apparatus to use, what data to collect, and how to organize the data are also decided by the teacher (or the lab manual); time is not made available for repetitions or, when things are not working out, for revising the experiment; the results are not presented to other investigators for criticism; and, to top it off, the correct answer is known ahead of time. (p. 9)

Llewellyn (2005) discusses how during labs, time is not made available for repetitions or for the revising the experiment. Students are not given a chance to design observations, measurements or experimental procedures and in a typical classroom setting the results are not presented to other investigators for criticism. The lab manuals do not allow students to formulate a hypothesis to be tested or predict experimental results (Llewellyn, 2005). More importantly, the correct answer is known ahead of time. Therefore the lessons do not promote inquiry and problem solving (Germann et al., 1996).

**Lack of support and continuous professional development (CPD) in inquiry-based learning** According to the NRC (1996) a constructivist and inquiry-based culture can be created by the conventional view of professional development for teachers shifting from technical training for specific skills to opportunities for intellectual professional growth. Opportunities such as understanding the theoretical foundations for constructivism along with teaching strategies consisting of scaffolding, co-operative learning and implementing performance assessments.

Professional development can only really happen if it is supported by schools and management and if teachers are supported in implementing the new ideas and strategies in their classroom practice (Akerson & Hanuscin, 2007). Teachers are traditionally isolated often working independently from one another. When teachers do meet it is typically for a staff meeting or an informal workshop. Current school schedules, incentives, and reward systems are not conducive to professional learning communities (Purdon, 2003). The issue of teachers not being trained to teach science as inquiry must be regarded as a significant one, particularly in today’s science classrooms. Hurd (1969) noted that the reaction of teachers to criticism over the way in which they taught high school science was they were teaching what they were taught in their pre service training and that very little if any time was devoted to learning about science as science.

According to Powell et al. (2002) incorporating inquiry effectively into the curriculum is difficult because most teachers need ongoing professional development to help them learn how to use inquiry effectively. Llewellyn (2005) concurs and states that
professional development should be a continuous and lifelong process but too often teachers experience professional development as fragmented, one-shot workshop or in-services that centre on the transmission of either content knowledge or classroom management skills presented from the speaker to the audience.

**Student Behaviour** - A survey by Save British Science that was reported by BBC News item (School science labs inadequate, 2004) found that practical lessons had been cancelled in more than three-quarters of the 67 schools surveyed, and that in 57% of those cases the reason given was rowdy student behaviour. Dr Simon Campbell the president-elect of The Royal Society of Chemistry, was quoted as saying that fewer kids were having practical classes, largely because of poor discipline. Laboratory work is important in an inquiry-based lessons, so if less practical work is occurring in schools, then it is likely that inquiry methods are being implemented fully.

The alternative side to student behaviour is the unanticipated problem that students will have the traditional assumptions of learning. Most students have spent their previous years assuming their teacher was the main disseminator of knowledge (Xiuping, 2002). Because of this orientation towards the subject-matter expertise of their instructor and the traditional memorization of facts required of students, many students appear to have lost the ability to „simply wonder about something’ (Reithlingshoefer, 1992). This is especially seen in first year students who often express difficulties with self directed learning (Schmidt et al., 1992).

**Undergraduate teacher training** - A lot of noise, mess and misuse of materials in science activities may be a particular problem for science teachers but as Uno (1990) has suggested that it extends to college training. Uno (1990) reported that in his experiences leading workshops at American Institute of Biological Sciences annual meetings few attendees had used inquiry. He identified the reason for this as being because their own undergraduate program had not offered adequate classes to prepare them to teach in that manner.

Kashmanian Oates (2002) considered inquiry teaching in the college context and described how an inquiry-based science curriculum supported the seven principles for best practices in undergraduate education including encouraging student/faculty contact, active learning, cooperation among students, emphasising time on task, giving prompt feedback and respecting diverse talents and ways of learning.
According to Timmerman et al. (2008), University faculty often express frustration with the accuracy of students' understanding of science in general. University science faculty express dissatisfaction with the level of understanding and skills achieved by students in traditional course settings (Bowen et al., 1999; Alters & Nelson, 2002) and many proposed inquiry-based pedagogies to address these needs across a wide variety of fields (Hake 1998; Birk and Kurtz 1999; Bell 2001). For Biology in particular, the recent report by the National Research Council (NRC), *Bio 2010* (Committee on Undergraduate Biology Education 2003) emphasises the importance of how students taught, as well as the content addresses in courses. (Timmerman et al., 2008). The National Academies' report, *Bio2010: Transforming Undergraduate Education for Future Research Biologists*, identifies potential changes in undergraduate education designed to improve the preparation of students in the life sciences, with a particular emphasis on the education needed for future careers in biomedical research.

The report looks at content, teaching approaches, curriculum requirements, funding and other issues. Undergraduate biology education can be effectively transformed only through close and sustained collaboration between colleges, universities, government agencies, professional societies, and foundations (National Research Council, 2003). It is often assumed that once a useful pedagogical approach is identified, it will be reproducible, easy to disseminate, and simple for another faculty member to implement in his/her home institution. The reality is that in teaching, as in research, faculty needs to be trained to carry out new tasks and their efforts to do so need to be recognized (The National Research Council, 2003).

*Confusion with implementing Inquiry-Based Learning* - According to Abd-El-Kalick (2002) the National Science Education Standards (NSES) does not operationally define inquiry. The NSES provided guidance on what science students are to know, how teachers are to teach science and how teachers are to assess students. It is argued that there is a lack of a clear definition and teachers are confused by the meaning of Inquiry and with little clarification in the Science Syllabi, it is easy to see how teachers are confused as how best to implement inquiry-based learning (Barrow, 2006).

2.4. Constraints of the Current Irish Science Syllabi in using inquiry in the classroom
The Organisation of Economic Co-operation and Development (OECD, 1997) has recognised the mismatch between the stated goals of education and the practice in schools for many years. In recent years the DES (2001) reiterated the need to reform the second level education
system in Ireland and recommended that teachers make active learning and methodologies like group work, discovery learning and peer assessment, priority across all subject areas.

2.4.1 Department of Education and Science
The current Irish Leaving Certificate Science syllabi are designed to incorporate the following components: science for the enquiring mind or pure science, to include the principles, procedures and concepts of the subject as well as its cultural and historical aspects; science for action or the applications of science and its interface with technology; science that is concerned with issues —political, social and economic — of concern to citizens‘ (Junior Certificate Science Syllabus, 2004). The biology syllabus states that ‘All Leaving Certificate programmes, in contributing to a high quality education, emphasize the importance of: self-directed learning and independent thought; a spirit of inquiry, critical thinking; problem solving, self-reliance, initiative, and enterprise, preparation for further education, for adult and working life and lifelong learning‘.

2.4.2 The Syllabi Aims
The aims of the Junior and Senior Sciences Syllabi have some aspects in common but are quite different when associated with inquiry-based learning. The general aim of the Revised Science Syllabus is concerned with the development of scientific knowledge, skills, concepts, and attitudes essential for the responsibilities of citizenship in today's world, development of scientific literacy and associated science process skills, together with an appreciation of the impact that Science has on our lives and environment. The other aims strive to encourage the development of manipulative, procedural, cognitive, affective and communication skills through practical activities that foster investigation, imagination, and creativity, provide opportunities for observing and evaluating phenomena and enable students to acquire a body of scientific knowledge appropriate to their age (Junior Certificate Science Syllabus, 2004).

The biology syllabus has a general aim of preparing students for the requirements of further education or training, for employment and for their role as participative, enterprising citizens. Other aims are to contribute to students' general education through their involvement in the process of scientific investigation and the acquisition of biological knowledge and understanding, to encourage in students an attitude of scientific enquiry, of curiosity and self-discovery and to develop an understanding of biological facts and principles (Leaving Certificate Biology Syllabus, 2006).
2.4.3 **Junior Certificate Science Syllabus Objectives**

The Junior Certificate Science Objectives are plentiful. They are detailed and descriptive and allow for opportunities for students to engage in inquiry-based Learning. Some of the objectives detail how the student will develop skills associated with the manipulation and interpretation of data and equipment, procedural plans and the use of the scientific method in problem solving. Logical thinking, inductive and deductive reasoning, and the formation of opinions and judgments based on evidence and experiment, independent study and cooperative learning and the application of scientific knowledge to everyday life experiences are some of the other objectives mentioned.

The syllabus emphasises practical activities as an essential element in science. They serve to encourage accurate observation and careful recording, promote logical patterns of thought, develop manipulative skills, and arouse and maintain interest in the subject. Some of the activities that are engaged in during practical work include measuring, recording, calculating, graphing or tabulating, presenting information, findings or conclusions in a variety of forms, analysing, testing and preparing.

2.4.4 **Leaving Certificate Biology Syllabus**

The Leaving Certificate Biology Syllabus has less detailed and descriptive objectives with an emphasis on three parts:

1. **Knowledge, Understanding and Skills** - where students should have a knowledge and understanding of biological facts, terms, principles, concepts, relationships and experimental techniques, including practical laboratory skills. Such skills should include an ability to carry out practical work, laboratory work and fieldwork activities safely.

2. **Application and Interface with Technology** - students should be able to apply, where possible, their knowledge and understanding of biology in environmental, industrial, agricultural, medical, waste management and other technological contexts.

3. **Science in the Political, Social and Economic Spheres** - Students should be able to apply, where possible, their knowledge and understanding of biology in personal, social and economic spheres and to make informed evaluations about contemporary biological issues.
2.4.5 Similarities between current Junior Science and Senior Biology Syllabi

There are similarities between the Junior and Senior Syllabi. There is a mention of inquiry in the Senior Syllabus in the form of ‘enquiry’. The Junior Syllabus mentions ‘inductive and deductive reasoning’ and ‘co-operative learning’ along with placing emphasis on skills to be used during practical activities all of which can be associated with IBL. In both Syllabi, there is an emphasis placed on sciences being part of the students every life, scientific literacy, scientific knowledge, an understanding of subjects and encouraging curiosity and interest through investigations. But are these emphasises being made a reality in the Irish classroom?

2.4.6 The differences between Junior Science and Senior Biology Syllabi

There are striking differences between the two syllabi with regard to emphasising IBL. Firstly, the Junior Syllabus Objectives explains in detail how the students will succeed in the above Junior Certificate Science aims. The course is activity-based in its design and emphasises practical experience of science, explaining in detail each skill involved. Through a variety of investigations and experiments, students attain the specified learning outcomes, developing appropriate science process skills and a knowledge of underlying science concepts.

The Leaving Certificate Biology Syllabus mentions that students should understand ‘experimental techniques, including practical laboratory skills... and their skills should include an ability to carry out practical work, laboratory work and fieldwork activities safely’. There is little emphasis on the practical aspect of the biology syllabus, which makes up 15% of the final written exam. The researcher believes that this give justification to the research undertaken.

The Laboratory activities is a spring board opportunities for students to engage in IBL but with little emphasis on Laboratory or practical activities, it appears unlikely that students are engaging in IBL at senior level. There does not appear to be any opportunities to design procedures, pick materials for equipment, create theory, to question or hypothesize, to repeat experiments or to retest hypothesis. There is a reoccurring emphasis on content; knowledge and understanding with the overall aim to equip students with skills for further education. However, there is no mention of what these skills are or how they are to be developed. Inquiry is mentioned once in the form of ‘enquiry’ where the syllabus aims to encourage in students an attitude of scientific enquiry. There is no explanation as to what enquiry is or how to encourage it.
2.4.7 Teachers and the science syllabi
Teachers were mentioned very briefly in the Junior and Senior Syllabi. The Junior Certificate Science Syllabus mentions how ‘a wide range of teaching approaches may be used. Teaching strategies should promote the aims, objectives ... and they should encourage investigative work as well as experimental work‘. The Leaving Certificate Biology Syllabus was briefer saying ‘teaching strategies should promote the aims and objectives of the syllabus‘. Teachers are encouraged to develop in their students positive attitudes and approaches to safety in the range of activities they encounter and to inspire in them an awareness of the values of creating a safe working environment. The question is how do teachers do this? What tools do teachers have to help or encourage them to change from the traditional didactic method of teaching to Inquiry-based teaching methods? This research is aiming to help teachers incorporate IBL into their lessons with the use inquiry-based lesson plans, worksheets and materials to help teachers make the transition happen easier and stay using IBL in their classrooms.

2.4.8 Aspirations of Syllabi
The Junior Certificate Programme aims to extend and deepen the range and quality of the young person’s educational experiences in terms of knowledge, understanding, skills and competencies and prepare the young person for the requirements of further programmes of study, of employment or of life outside full-time education. It is intended that the Leaving Certificate Biology Syllabus will prove relevant to the lives of students and inspire in them an interest in and excitement about biology. It should provide them with the knowledge, skills and understanding to pursue further education, training and employment in biology-related fields and thereby respond to the needs of the economy and contribute to sustained economic development.

2.4.9. The NCCA and a New Senior Cycle Biology Syllabus
A consultation period for new senior cycle syllabi was opened by the NCCA in 2011. Focusing on the biology syllabus, a major difference between current biology syllabus and the proposed syllabus is the introduction of the practical exam worth 20% of overall marks. This will greatly improve the importance of inquiry-based skill/scientific skills, creative and critical thinking and encourage students to be responsible learners. The new biology syllabus aims to give learners an appreciation of the complexity of the processes of the cell and of the
organism, of the diversity and interrelationships of all living things and their environment and to develop the ability to investigate and to critically and ethically evaluate the Global and local application of scientific knowledge (NCCA, Biology draft syllabus, 2011).

The objectives focus on building knowledge in the subject matter but more importantly on developing different skills. Skills such as the ability to apply the knowledge the students acquire and scientific inquiry skills such as the ability to interpret and analyse qualitative and quantitative data. There are opportunities;

- To develop skills in laboratory procedures and techniques
- To assess the uses and limitations of these procedures through engagement in a wide variety of practical activities.
- To develop the ability to explain, evaluate and communicate the results of their experimental and investigative activities in verbal, graphical and mathematical form
- To display their understanding in more than one form.
- To encourage learners to be future scientists means students need to develop a deeper understanding of the ethical, environmental and technological aspects of biology and how biology contributes to the social and economic development of society.

There is an important need for students to be able to make informed conclusions about contemporary biological and environmental issues, including those that raise ethical questions.

2.4.10. Differences between the current biology syllabus and the proposed biology syllabus

The skills set out by the current syllabus for students to ascertain are manipulation of apparatus, following instructions, observation, and recording, interpretation of observations and result and a practical enquiry and application of results. In the new biology syllabus there is emphasis on Skills - practical skills for experiments and lifelong useful skills like communication, evaluation, concluding, forming opinions, deciding and developing procedures.

The current biology syllabus sets out to prepare students for the requirements of further education or training. The objectives have an 'Application and Interface with Technology' and also a Science in the 'Political, Social and Economic Spheres' section. These sections differ to the new biology syllabus, where there is an emphasis on having a biology qualification and how it can lead to many exciting and rewarding careers. There is an
emphasis on what students can use biology for if they carry on with it to third level – Biology based courses include amongst others, biomedical, environmental, agricultural, food, health, sports and forensic science. Biotechnology is at the forefront of some of the most controversial advances in human knowledge. There other area mentioned is Community and Society. It stresses the importance of biology in our lives and for the future of the human race and gives examples of where it is useful such as sequencing the human genome, gene localization and identity, gene therapy, the creation and release of genetically engineered organisms, bioengineered pharmaceuticals, and ecosystem management of marine.

2.4.11. Assessment

Resnick & Resnick (1991) briefly explain that the;

*Power of tests and assessments to influence educators’ behaviour is precisely what makes them potent tools for educational reform. In imposing public accountability programs, it is the intention of state education departments and legislatures to influence what is taught and the standards of performance. In other words, tests have become instruments of school reform. They are introduced not just to provide neutral indicators of the education system’s performance, but also in the hope of upgrading curriculum, teaching and academic performance.*

(INTO 1997)

As science teachers, we need to determine what students have learnt. Exams and tests are necessary evils of schools and even mentioning these words can sometimes strike fear in the hearts of most students (Llewellyn, 2004). Standardised tests, end of topic tests, midterm and final year exams have become a routine part of the schools’ instructional programs. Some estimates report that schools devote as much as 20 days or one tenth or the academic year to national testing (Llewellyn, 2004). The traditional methods of assessing content knowledge are done using a paper-and-pencil test. In order to prepare for this type of assessment, students need to rote learn and then regurgitate their information (Llewellyn, 2004).

There are alternative strategies and useful means to measure students’ competence in scientific inquiry. Inquiry assessment will test not only content knowledge but also science process skills, scientific reasoning skills and metacognitive skills (Llewellyn, 2004). However, the National research council (2001) suggests that inquiry is difficult to assess in a onetime test and recommends that assessing inquiry skills is best done over extended periods.
of time rather than during a test in a single class period. Horizon Research (2003) commented that a factor working against inquiry, at least in the United States, might be the increasing influence of state and district tests. They stated that anecdotal evidence told them that teachers believed in the standards, but that on the other hand they were held accountable for state and district tests, which in many cases were not standards-based. Interview and survey research suggests that teachers feel pressure to deliver high student test scores (Barksdale-Ladd & Thomas, 2000; Hoffman, Assaf, & Paris, 2001).

In addition, many teachers indicate that they view the high-stakes tests as an imposition on their professional autonomy, an invasion into their classrooms, a message that the state views them as incompetent, and a hindrance to professional creativity (Luna & Turner, 2001). As districts and schools put more emphasis on test performance, teachers may not have as much flexibility in their classrooms. They may face pressures to teach topics that they are less interested in or believe are less important for students or they may need to teach in ways that increase test-scores but not other important skills (Boyd et al., 2005).

In America, as a result of this pressure some teachers have cheated to improve student scores. Teachers have taken actions such as illicitly reviewing tests in advance and tailoring their instruction to match specific questions; improperly giving students passing grades when they score tests for the state; and telling students to correct answers they knew were wrong. In Ireland, that since the introduction of the revised syllabus with the coursework B the teachers workload had increased and the majority of them (91.4%) were devoting a ‘considerable’ or ‘very considerable’ amount of time to helping their students with coursework B (Higgins, 2009). The impact of coursework B on teachers’ satisfaction with the syllabus is also reported in a study carried out for the Department of Education and Science (DES, 2006). The report stated that 41.2% of science teachers were ‘dissatisfied’ or ‘very dissatisfied’ with the Coursework B element of the syllabus (DES, 2006, p. 15). One possible reason for this dissatisfaction may be that teachers are required to spend a large amount of time helping their students complete their work because the students are unable to carry out the investigations themselves due to poor problem solving skills and lack of experience in using investigative practical approaches. (ISTA, Science, 2010)

There is pressure on teachers to adequately prepare students for assessment tasks, and if teachers do not perceive inquiry techniques as being the best means of doing so, they will feel compelled to not use them, no matter how much they may believe in the greater value of such techniques. This is reiterated by Tobin et al. (1990) who reported that teachers felt constrained by the tests and exams and by Tobin and Gallaher (1987) who noted that
academic work in high school classes was strongly influenced by the local assessment system. Gleeson (2000) agrees stating that as long as the education system at second level is dominated by the Leaving Certificate examination and subjects are heavily content-laden, didactic methods will predominate.

2.4.12. Aligning standards, instruction and assessment

There is an interrelationship among standards, instruction and assessment. Learning standards may originate or be guided by the national, state and be defined as learning goals, frameworks or syllabi. The standards are a start point in designing any instructional or assessment program. The instructional or assessment program – includes units of study, learning strategies and activities and the Assessment includes formative and summative assessment. All three aspects will complement each other when the curriculum is aligned. A problem with curriculum congruence usually arises when there is a mismatch or misalignment between the instructional strategies used by the teacher and the assessment techniques employed.

Teaching methods and approaches undertaken throughout the Junior and Senior cycle where there is an emphasis on attaining high grades in an end exam tend to be passive rather than active. Approaches tend to emphasis rote learning as opposed to understanding. The reasons given by teachers for this are exam pressure and lack of time. In order to counteract this problem, the NCCA is reviewing senior cycle syllabi in hopes for a future where students are given more responsibility for their own learning and teachers are the facilitators rather than then conveyors of knowledge as they presently are (McMorris, 2004).

2.4.13. Future assessment involving Inquiry

For constructivist teachers to align their instructional goals with assessment goals, they need the flexibility to have students demonstrate their competencies using forms of assessment other than paper-pencil, objective type examination. A shift towards the use of journals, portfolios, performance tasks with rubics and self assessment becomes essential (Llewellyn, 2004). These assessment types will be discussed in section 2.4.16. The daily lesson 35 - 45 minutes becomes constraining for teachers to implement constructivist and inquiry-based strategies. Block scheduling may have to be a viable alternative to extend instruction time and increase opportunities for teachers across disciplines to integrate their curricula and develop team teaching partnerships (Llewellyn, 2004).
2.4.14. NCCA New biology syllabus proposed Assessment

The new biology syllabus includes both a written and practical assessment. The written examination examines the knowledge, understanding and the application of biology principles and concepts; problem solving based on integration, analysis and evaluation of qualitative and quantitative and information and data; and the capacity to form reasonable and logical argument based on evidence. The percentage of total marks allocated to this component is 80% (NCCA, Draft Biology Syllabus, 2011). The second component assessment will assess students’ abilities to conduct investigations and communicate information and understandings based on these investigations. It is made up of two parts and the percentage of total marks allocated to the second component assessment is 20%. The practical examination is worth 15% and students’ are assessed on short tasks; learners record data, observations and analysis which is recorded on a task sheet and is marked externally. The other 5% is allocated to the laboratory notebooks. Students must complete the practical activities specified in the syllabus and each student is required to maintain a laboratory notebook over the two years of the course. This record must be available for inspection and marks will be awarded on a pro rata basis for the satisfactory completion of the specified practical activities. (NCCA, Draft Biology Syllabus, 2011)

2.4.15. Assessment Difference between current biology syllabus and proposed new biology syllabus

The current biology syllabus has 100% written exam with mandatory experiments conducted over the two year course to prove or enforce the concepts and content of the syllabus. Students generally conduct the experiments in groups, follow a recipe style procedure and write up their reports individually (Abd-D-El-Khalick, 2004; Llewellyn, 2004; 2005; Schwartz et al., 2004). The traditional written report is only one form of communication where learners will describe what they do and what they learn. The draft biology syllabus includes the mandatory practical activities but comments that students should engage in other forms such as project work, poster presentations, or power point presentations. Throughout the school year these type of activities generally do not get utilised as there is a focus and a drive from teachers to teach for the exam (Llewellyn, 2004). Through various formats of co-operative learning, students will discuss, debate, and reflect on their own thinking and learning. The Draft Biology Syllabus details how practical activities reinforce the understanding of concepts, principles, laws, and theories. It will support the development of
key skills in a variety of contexts. The scientific approach, interpretation of data and use of evidence and argument in evaluating biological information are central to both the practical activities and the theoretical concepts (NCCA, Draft Biology Syllabus, 2011).

2.4.16. Forms of Inquiry Assessment

This next section will look at the alternative forms of assessment to the current biology syllabus which is a 100% written examination (Biology Syllabus, 2010). A description of what the assessment involves and also what is expected of the teacher and students. The term ‘authentic’ or alternative assessment is used to describe measurements to assess inquiry and are similar in form to tasks/activities of scientists (Llewellyn, 2004). The Content and high-order thinking skills are assessed as well as opportunities for students to demonstrate creativity, problem solving and decision making. Llewellyn (2005) provides several types of assessment for science teachers in an inquiry-based classroom that will be discussed in the following sections. These include:

1. Performance tests
2. Rubrics, application questions
3. Monitoring charts
4. Capstone projects
5. Structured interviews

Performance tests – This is a form of open ended investigations, station – station lab tasks or structured tasks. This assessment provides an opportunity for students to demonstrate mastery of their understandings. Students engage in collecting information to solve a given problem and often construct a model based on the evidence collected. (Llewellyn, 2005) Tasks allow students to use knowledge to solve problems, use performance and science process skills to complete the task, collect data and evidence based upon their observations, construct and explanation in form of written report. Teachers must encourage problem solving, question students and create the time needed as the test can span over a few days (Llewellyn, 2005)
**Rubrics** – This is used with projects and performances tasks to provide a means for all students to achieve high standards by communicating what exemplary high standard work looks like (Llewellyn, 2005). A rubrics articulates to students' explicit performance descriptions and criteria for specific areas at different levels of competence. The students know what their teacher is looking for and provides a means for self reflection when evaluating their own work. The teacher can refer to the rubrics when students question what they have to do or if the teacher wants to set classroom work standards (Llewellyn, 2005).

**Application questions** – This involves questions that refer to an investigation the students completed and be utilised as a follow on to the next investigation (Llewellyn, 2005). They allow teachers to conduct assessments in situations where students use data and evidence from their original inquiry investigations to solve a problem in a related situation. Students will have to write hypothesis, design and carry out an appropriate investigation and record relevant data. They will also must complete a summary of the investigation and communicate their findings (Llewellyn, 2005). The teacher will get students to design other investigations using manipulated variables and test the students' understanding by listening to their summary and conclusions.

**Monitoring charts** – This involves observing the day to day performances with an informal and practical means of assessment. Teachers can observe and monitor a predetermined set of behaviours including brainstorming, following direction, interaction with peer, using equipment properly, acting responsibly (Llewellyn, 2002). Teacher moves about room and notes individual actions on a chart. Teachers can indicate the behaviour of students with a ☑️ + for above standard, ☑️ for at standard or ☑️ - for below standard performance (Llewellyn, 2005). Teachers are encouraged to observe and monitor all students fairly, make observations and also multiple observations to ensure reliability (Hart, 1994). Students participate in class to the best of their ability and make comments, express their ideas, ask questions and reiterate problems they encounter (Llewellyn, 2005).

**Capstone projects** – These are final inquiries, investigations, research projects or presentations that are usually completed toward the end of the school year. The students can work individually or in groups. They must develop a proposal to a research question. The students model the inquiry process by identifying a worthwhile and researchable question, planning the investigation, executing the research plan and drafting the research report. For
students, it will enhance speaking and listening skills, projecting their voice, making eye contact and speaking clearly (NRC 1996). The teacher acts as a mentor to student guiding them in writing the framework for their research question. The teacher approves proposal if the students design is feasible. This offers teachers a unique opportunity to judge how well students can integrate the knowledge from a science course and apply it in a research setting (Llewellyn, 2005).

Structured interviews – Interviews where the teacher provides several probing questions or visual prompts to elicit the student’s understanding of the concept. The questions can centre on the student solving a problem, making a predication, or drawing an inference about a particular situation (Llewellyn, 2005). The student can be given two or three main questions to be prepared before the interview. The student must research the answers to the questions but will not know what they will be asked during the interview. The student is empowered to make sure meanings are expressed thoroughly and they are understood (Dana, Lorsbach, Hook & Briscoe, 1991).

Some students can demonstrate their competence best by expressing themselves verbally and can blend their terminology with scientific terms to explain their understanding (Llewellyn, 2005). Structured interviews can be a viable means of assessing students’ understanding and it can be especially effective for students who suffer with exam anxiety (Southerland, Smith & Cummins, 2002). The structured interviews are time intensive so the teacher must select a number of questions that can be used to gauge the overall understanding of the class., the teacher can in more familiar cases circulate around the room, sit down with an individual student or group and discusses the investigation, the procedure, and the evidence being recorded (Llewellyn, 2005).

Self evaluation - This is a vehicle in which students assess their performance and metacognition skills through reflection on their own strengths and weaknesses. A set of statements and a rating scale is provided and students must circle the appropriate response for each statement (Llewellyn, 2005). Students provide individual feedback on their performance and must reflect on task and identify how they might improve their performance if they were to repeat the inquiry. The teacher will develop the self evaluating assessment sheets with statements that best show the students understanding.
2.5 Transition Year

This section will examine the benefits of transition year, teaching methodologies and approaches in transition year and barriers to teaching and learning in transition year.

2.5.1 Transition Year Science

A ROSE report (2007) outlines the negative attitudes pupils possess in relation to science from Junior Certificate level. For this reason, transition year programme is focusing at helping to transform these attitudes to become more positive (DES, 1996). Transition year offers pupils a break from exam focused study. As a result of the lack of a set curriculum in Transition Year, pupils are allowed to engage more freely with the subjects they study. The Transition Year programme guidelines for schools set out by the Department of Education (1993) advised teachers to allow pupils to ‘study areas of science not heretofore encountered. The Department of Education recommends the use of innovative and student-centred teaching and learning methods in Transition Year (NCCA, 2008). The freedom gives students the opportunity to design and carry out investigations and also to repeat the investigation if problems arise without the worry of time constraints, which they do not readily get opportunities to do in traditional classes. The reason Transition year is perfect for the preparation and practice of these skills is because there is lack of pressure and less time constraints that teachers generally feel in exam years.

As teachers do not have the time to develop new modules for TY, they revert back to the old reliable textbook which in turn leads to dull, monotonous lessons (Childs, 2006). The intervention programme aims to present teachers with prepared inquiry-based lesson plans with resources that link closely to the topics done in Leaving Certificate Biology. Childs (2006) commented that the TY Programme was the only sector of the Irish education system for innovation. The TY programme is ideal for encouraging pupils’ interests and expanding pupils’ knowledge of science away from the boundaries of the exam years (Glynn, 2005). Like Childs (2006) says; “seize the day and use Transition Year Option to ‘sell’ the science to your students” Hopefully this research project, which aims to provide teachers with lessons plans based on inquiry methodologies will help teachers do this. Lesson plans that focus on the Leaving Certificate Biology mandatory experiments, extended experiments, questions and equipment pack can be manipulated into a Transition Year Module.
2.5.2 Importance of Science and Transition Year

Students need to be encouraged to take and retain science subjects through to Leaving Certificate. In order to entice students to a certain subject they must be ‘wowed’ and interested. If they perceive it to be boring or difficult they will take another subject. The importance of science in Ireland can be seen in the _Report of the Innovative Taskforce_ by the Irish Government (2010) that emphasised the

_Belief that Ireland needs to substantially raise national mathematics and pure science attainment particularly at second level” in order for Ireland’s ability to reposition industry towards knowledge intensive high technology sectors, which will depend critically on the supply of people with mathematics, science, engineering and technology skills._

If students do not take science subjects at post primary, it has a knock effect in third level and naturally in this current economic climate, for Ireland’s Technology, Science and Engineering Sectors. According to Arundel (1990) _if a student drops all their science subjects after the intermediate, they virtually eliminate themselves from very many careers that would require a science of some sort in the relevant course_. Hanna (1992) felt that Science can provide pupils with _intellectual training_ that prepares them for a wide range of skills that can be used in many different sectors of society. Some pupils tend to cut all science subjects after Junior Certificate exams and this can have some very negative consequences for some pupils. The intervention programme hopes to rejuvenate methods of doing science in transition year with the overall aim of preparing and keeping students on at Leaving Certificate Level.

Transition Year is the best opportunity to encourage students to study science subjects not only at second level but also at third level and to make pupils more aware of the effect Science had on the environment and on their everyday lives (DES, 1995). According to Childs (2006) _if after we have taught science as teachers, our pupils don’t look at the world differently and see things they never saw before, then we have failed to teach them properly_.

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2.5.3 Intervention programme and Transition Year

This research project hopes to help address some of the constraints mentioned in the previous sections by making the transition from traditional method of teaching to inquiry-based method easier for teachers and therefore acceptable long term. This in term will hopefully spill over onto students and they in turn will also accept this method of learning.

To make the transition easier for teachers, this research project developed an intervention programme with five topics from the biology syllabus adapted for an inquiry-based lesson, lesson plans and resources. It was implemented into two classes of transition year students over a 14 week period in a pilot school. With 24 pupils in each class, one group underwent the inquiry lesson and the other group did a traditional class. This section on Transition Year is relevant because transition year students were used in the intervention programme. Part three of the aims of this research project states;

Part 3: Intervention Programme

- To investigate the effect Inquiry Based Learning on how students engage in the learning process and their overall understanding in science
- To investigate if students' scientific skills need further development in anticipation of the proposed practical assessment the draft biology syllabus.
- To promote innovation in teaching, promoting the students to reason and analyse topics in biology.
- To assess transition year students' achievements and attitudes in the two different classes towards biology.

2.5.4 Teaching Methods and Approaches in transition year.

According to the Department of Education and Science (2008) a key feature of Transition Year should be the use of a wide range of teaching/learning methodologies and situations. The goals and objectives of the programme can best be achieved by placing particular emphasis on negotiated learning, personal responsibility in learning, activity-based learning, team teaching approaches, group work, discussion, project work and research. These features were considered when developing the intervention programme.

According to Piaget (1952), students of this age group (transition year students are approximately 15 years of age) should be at the second of four stages of cognitive
development, otherwise known as the ‘Formal Operational’ stage of development. This stage is one where students are able to think abstractly, form hypotheses, problem-solve and engage mentally with manipulations (Snowman & Biehler, 2006). Snowman and Biehler (2006) recommend the idea of challenging the development of pupils’ cognitive understanding by giving pupils more challenging lessons or activities to complete. In Transition Year, the traditional teaching methods should be put to one side to encourage students to become independent and self-directed learners (Smyth et al., 2004). Sweeney et al. (2000) recommended that a combination of teaching methodologies such as debating, pair work, interviews, classroom discussions, practical work and visualisations be used that are relevant to the module being taught that will facilitate the learning experiences for pupils. The intervention programme contains tasks that ask students to develop and design experiments and carry out their own procedures. They work in groups and record their own experiment via photos or video. They make presentations to the class and present their findings in power point or poster format. These methods encourage self-directed and student-centred learning. The Transition Year teachers are not ‘bounded by course exams’ so there is more time to raise and explore such ideas and to pursue professional interests (Smyth et al., 2004).

Transition Year teachers are expected to use the constructivism teaching methodology in their classrooms. Many of the learning methodologies outlined by the Department of Education for Transition Year teachers can be said to be constructivist. According to Matthews (1994) constructivism attempts to find a common ground between teacher-led instruction and student-led discovery and inquiry learning. Although there are many positive attributes to using constructivism in the classroom, many Transition Year teachers are not teaching in ‘an innovative and unique manner’. However, on the other hand, it is also the case that Transition Year teachers incorporate more active learning methodologies than they do in their own classrooms (Hayes & Child, 2008).

2.5.5 Teachers and Transition Year

Transition Year allows teachers the freedom to incorporate a wide range of teaching and learning methodologies (Jeffers, 2002) without the constraints of the curriculum. It was also found that the majority of teachers enjoyed the freedom to choose their own content but felt it was a burden at times to come up with creative ways of teaching the subject. Pupils will be only benefit from the TY programme if the teacher is aware of how to use and design lessons
properly (Snowman & Biehler, 2006). The intervention programme hopes to solve this dilemma. The intervention programme intends to present teachers with example inquiry lessons, tasks and worksheets in order to encourage teachers to engage in inquiry-based learning. Teachers can adapt the lesson plans for future lessons on different topics and base them on the intervention programme examples given to them. Research showed the 75% of teacher reported that they do use different approaches to teaching TY classes than senior classes (Smyth et al., 2004) so there is hope that when teachers are given these inquiry resources they will happily implement them. It is important that science teachers get resources that encourage teachers to implement inquiry methods as they may be the most influential party in encouraging pupils and inspiring their pupils to pursue Science related careers (Carmicheal et al., 1988).

2.5.6 Teacher Adaptations to Inquiry.

Through adapting existing curricula to be more inquiry based, teachers are able to increase their content and pedagogical knowledge. Time is needed to complete the adaptations necessary to align lessons with the NSES. Continuous professional development in the form of workshop sessions need to be devoted to helping and preparing teachers for this task and working to adapt their curricula. Teachers need help to develop strategies for adapting their existing lessons and text to be inquiry-based and allow for emphasis of NOS elements. A walk through of an inquiry lesson with a facilitator and teachers in groups participating is an important way for teachers to understand how to deliver an inquiry-based lesson. Discussions and feedback on the lesson and advice from fellow teachers on how they can be enhanced is also important. As Loucks-Horsley et al. (1998) emphasised ‘reflection by an individual on his or her own practice can be enhanced by another’s observations and perceptions’. (Akerson & Hanuscin, 2007).

2.5.7 Barriers with Teaching and Learning in transition Year.

Childs (2006) asks ‘what happened to student to turn them off and destroy their innate curiosity and interest in Science’? He also found that after pupils in second level have experienced practical work in first year their enthusiasm disintegrates. Rudden et al. (2010) found that pupils lost interest in science because of the way it is implemented at junior cycle. For students who continue to transition year, the intervention programme hopes to reignite the true sense of doing science and encourage students to take science to Senior Cycle.
Childs (2006) believes that the lack of resources, poor facilities and inadequate time allocation for teachers are the main reasons why senior level Science subject uptake numbers are still decreasing and is turning out to be detrimental. The Inspectorate of the DES (2008) realised this fact also as the teachers included in the report blamed inadequate resources of their selection of teaching methodologies. The intervention programme serves to be the solution to this problem. If teachers have adequate resources the quality of learning for pupils will be effected greatly (Kyriacou, 2001). Teachers feel their training in ICT is extremely limited and the knowledge about how to integrate ICT into their classrooms is lacking (Inspectorate of DES, 2008). The development of the inquiry lessons through the intervention programme aims to show teachers how to use alternative forms of ICT that is not difficult such as poster or PowerPoint presentations, video presentations or photographic slideshows.

2.6 Conclusion
This chapter has presented a background on inquiry and the effect it has on the teaching profession and their students, the syllabi, curriculum and assessment. The next chapter will look at the methodological approach undertaken during this research project.
Chapter Three
Methodology

3.0 Introduction

This chapter describes the research strategy, methodologies and both quantitative and qualitative data collection techniques employed in the research study. The methods used to evaluate the intervention programme that involved 48 transition year students over a 14 week period in a pilot school will also be discussed. The intervention programme split the students into two groups - one group of 24 transitions students engaged in a traditional class while the other 24 transition year students engaged in inquiry based lesson. The intervention programme consisted of five lesson plans, task & worksheets and students filled in a pre and a post questionnaire for each lesson. The results of these questionnaires will be discussed in the results chapter. This chapter will begin by reiterating the aims of the project and research questions and discussing the overall action research strategies. The specific research methodologies will be discussed and a rationale will be provided on why these methodologies were chosen. Details on how these were implemented will be provided and issues relating to the limitations of the study, validity and ethical considerations will also be addressed.

3.1 Overview of the project

The Table 3.1 below sets out the aims of part one, two and three of the research project and the methodology used in each part.

<table>
<thead>
<tr>
<th>Aims</th>
<th>Method of data collection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part 1: Exploratory Phase</strong></td>
<td></td>
</tr>
</tbody>
</table>
| To gain an insight into the attitudes and perceptions of qualified science and biology teachers and students towards the use of Inquiry based teaching and learning in the Irish Post-Primary Classroom. | → Questionnaire distributed to science and biology teachers and their students.  
→ Interviews were conducted with biology students and teachers. |
| To investigate the extent to which the principles of scientific inquiry teaching and learning are being practiced in the Senior Cycle Biology classroom from a teacher and student perspective. | → Questionnaire distributed to science and biology teachers and their students.  
→ Interviews were conducted with biology students and teachers. |
### Part 2: Development of Inquiry Based Teaching Resources

<table>
<thead>
<tr>
<th>Activity</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>To design and develop different inquiry resources for the teaching of biology to foster student’s enthusiasm and increase achievements in this subject.</td>
<td>→ Extensive literature review on Inquiry Based Science Education</td>
</tr>
</tbody>
</table>
| To provide teachers with inquiry based methodologies and tools to make necessary adjustments in the classroom to adapt to the new LC biology syllabus. | → Interviews conducted with biology teachers  
→ Questionnaire distributed to Biology Teacher |

### Part 3: Intervention Programme

<table>
<thead>
<tr>
<th>Activity</th>
<th>Methods</th>
</tr>
</thead>
</table>
| To investigate the effect Inquiry Based Learning on how students engage in the learning process and their overall understanding in science | → Intervention programme  
→ Pre and post classroom worksheets  
→ Pre and Post Questionnaires  
→ Interview of transition year students |
| To investigate if students’ scientific skills need further development in anticipation of the proposed practical assessment the draft biology syllabus. | → Intervention programme  
→ Pre and post classroom worksheets  
→ Pre and Post Questionnaires  
→ Interview of transition year students |
| To promote innovation in teaching, promoting the students to reason and analyse topics in biology. | → Intervention programme |
| To assess transition year students’ achievements and attitudes in the two different classes towards biology. | → Pre and Post questionnaires were distributed to Transition year students  
→ Interview were conducted |
In order to decide on the design and development of the questionnaires and interviews, the following research questions were asked and a method of data collected decided on.

Table 3.2 The research questions and the data collection methods.

<table>
<thead>
<tr>
<th>Research questions</th>
<th>Method of data collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>• What teaching and learning methods are most dominant in Irish post primary schools?</td>
<td>→ Science and Biology student and teacher Questionnaires</td>
</tr>
<tr>
<td></td>
<td>→ Biology student and Teacher interviews</td>
</tr>
<tr>
<td>• Is there a scientific skills gap between JC science Students and LC biology student?</td>
<td>→ Science and Biology student and teacher Questionnaires</td>
</tr>
<tr>
<td></td>
<td>→ Biology student and Teacher interviews</td>
</tr>
<tr>
<td>• Is there a need for an intervention programme to help teachers and students learn and use basic inquiry skills?</td>
<td>→ Biology student and biology teacher questionnaires</td>
</tr>
<tr>
<td></td>
<td>→ Biology teacher interviews</td>
</tr>
<tr>
<td>• Will the intervention programme develop students' inquiry skills and help prepare students for the new biology syllabus practical assessment?</td>
<td>→ Intervention programme</td>
</tr>
<tr>
<td></td>
<td>→ Pre and post questionnaires</td>
</tr>
<tr>
<td></td>
<td>→ Transition Year Student interviews</td>
</tr>
</tbody>
</table>

3.2 Research Strategy

The Research project aims were developed and divided into three parts. Part one involved an exploratory phase to gather data in order to answer the research questions. This led to designing, developing and piloting questionnaires and interviews. Questionnaires were sampled to ensure clarity and ease of answering to maximise the return of answers. A Leaving Certificate Biology student, a Junior Certificate Science student and a Biology Teacher questionnaire were designed and were personally distributed and collected from eight secondary schools science/biology teachers around Ireland. Four science/biology teachers and three biology students were chosen for the interviews. The interviews not only allowed teachers and students to answer factual questions but to express their attitudes, ideas
and opinions towards the current methods of teaching and learning in post primary schools in Ireland and toward the current Leaving Certificate Biology Syllabus (Cohen, Mahon et al., 2007).

The resulting data generated from the questionnaires and interviews analysis are displayed in the results chapter. From the data, it became apparent that an intervention programme was the best approach to take action to promoting innovation in teaching and students to reason and analyse topics in biology. This led to part two of the research project that involved the design and development of different inquiry resources for the teaching of biology in Irish second level schools. These inquiry resources were then used in part three - the intervention programme.

The intervention programme was implemented using two transition year groups in a pilot school over a fourteen week period. It contained five inquiry based lesson plans with pre and post questionnaires, worksheets, tasks and photos. The lessons include some adaptations of current Leaving Certificate Biology topics and experiments. To establish the students’ understanding before and then after, the lessons were evaluated using a pre and post questionnaires for each topic along with worksheets and task sheets. To investigate the difference between the achievements and attitudes in the two different classes towards biology, two transition year students from the traditional class and four students from the inquiry class were interviewed. The flow chart (Figure. 3.1) summarises the steps taken by the researcher in this research project.

3.2.1 Research Methodologies

Research is a systematic way of asking questions, a systemic method of inquiry (Bell, 1993). There are numerous ways to gather information. These different methods should compliment and give confidence in the research. A mixed methodology approach was undertaken in order to collect data in this research project. Waring (2000) believes that the best approach is to use methodologies that complement each other. Limiting oneself to just one approach is not advisable. A diversity of imperfection allows us to combine methods not only to gain their individual strengths but also to compensate for their particular faults and limitations.

For this project, the questionnaire allowed for specific answers (quantitative and qualitative data), while the interview allowed the interviewee the freedom to elaborate on their answers providing more qualitative data. These methods complimented each other and blended the quantitative and qualitative methods (Nau, 1995). The greatest advantage of
using mixed methodology is the fundamental strategy to tackle a research problem with an array of methods that have non-overlapping weaknesses in addition to their complementary strengths (Brewer & Hunter, 1989). However there are many concerns with a mixed method approach also. When two reliable instruments yield conflicting results, then the validity of each is cast into doubt. When the findings of different methods agree we are more confident (Bryman, 2001). On the other hand, Bryman & Bell (2007) point out that the diversity related with mixed method research can give issues varied strength but it also can lead to incoherence and confusion.

There are a number of mixed method classifications. Outlined below are the two specific classifications –1) Morgan’s classification of mixed methods and 2) Tri-partite classification.

### 3.2.2 Morgan’s classification of mixed methods

Morgan’s classification outlines four approaches to mixed method research. These include;

1) Content analysis of empirical articles in referred journals in the social sciences;

2) Use of triangulation of quantitative research to corroborate qualitative research findings or vice versa;

3) A facilitation approach that arises when one research strategy is employed in order to aid research using the other research strategy;

4) A complementarily approach occurs when the two research strategies are employed in order that different aspects of an investigation can be dovetailed.

(Bryman, 2006).

Morgan (1988) proposed that these four approaches to mixed method are based on two criteria. Firstly, the priority decision – how far is a qualitative and quantitative method the principal data gathering tool. Secondly, the sequence decisions – which method precedes which? Does qualitative method precede the quantitative one or vice versa?

### 3.2.3 Tri-partite classification.

The second classification can in some ways replicates the first. Hammersley (1996) suggests tri-partite classification of the ways in which researchers employ different types of data in the processes of interpreting their data. The three parts include;

1) Triangulation, where one type of data is used to corroborate another type of data;
2) Facilitation that involves collecting a type of data that facilitates the collection of another type of data (pilot work to design a large scale survey)

3) Complementarity – two different sets of data are employed to address different but complementary aspects of an investigation

(Brannen, 1992).

### 3.2.4 Triangulation

Many different theorists have offered their interpretation of triangulation as the study or explanation of a situation from more than one vantage point or using a variety of research methods to give an in depth and impartial view of a situation. The use of different research methods can make an argument more persuasive once a proposition has been verified from more than one methodological source. It can also verify multiple facts or highlight problems (Altrichter et al., 2008; Cohen & Manion, 1986; Kane & O’Reilly –De – Brun, 2001; O’Donoghue & Punch, 2003; Webb et al., 1966).

Denzin (1978) identified four basic types of triangulation:

1) Data triangulation: involves time, space, and persons;

2) Investigator triangulation: involves multiple researchers in an investigation;

3) Theory triangulation: involves using more than one theoretical scheme in the interpretation of the phenomenon;

4) Methodological triangulation: involves using more than one method to gather data, such as interviews, observations, questionnaires, and documents.

Both Morgan’s and Tri-partite classifications of mixed methods was used to design this research project and focused on methodological triangulation. The rationale for using this method was that evidence from two sources (both quantitative and qualitative sources) is intuitively more persuasive than evidence from one (Brewer et al., 1989).

Triangulation was ensured in this research project by firstly carrying out an extensive literature review that can be considered as a qualitative technique of conceptual work and analysis of meaning before collecting any
further data (Bryman, 1988). Science and biology student and biology teacher questionnaires (quantitative methodology), biology student and teacher interviews (qualitative methodology), the pre and post questions for intervention programme (quantitative methodology), observations of inquiry based lessons (quantitative and qualitative methodology) and transition year student interviews (qualitative methodology) were also used in this research project to ensure effective triangulation.

3.2.5 Quantitative Research
Quantitative research methods attempt to gather data by objective methods to provide information about relations, comparisons, and predictions and attempts to remove the investigator from the investigation (Smith, 1983). Quantitative research methods used in the research project took the format of a questionnaire and intervention programme pre and post questionnaire i.e. the Science Student Questionnaire (see Appendix 2), the Biology Student Questionnaire (see Appendix 3), the Biology Teacher Questionnaire (see Appendix 4) and inquiry pre- and post- lesson Questionnaire (see Appendix 8 on attached CD). Although the questionnaires mostly involved the gathering of quantitative data and mostly contained close ended questions, some open ended questions were included which added another element of qualitative research to the project. The open ended questions were used to gather more detailed information and allow the respondents to elaborate further on their answers.

3.2.6 Qualitative Research
Qualitative research has been defined by many theorists as an investigative methodological approach to understanding human experiences and attitudes from contact with them in their real world settings. It is descriptive data that allows the participants to express their feelings and opinions on certain occurrences that have unfurled naturally (Dingwall et al., 1998; Jacob, 1988; Patton, 2001; Strauss & Corbin, 1990).

The qualitative research method used in the research project was an interview. The biology Students interview (see Appendix 5 on attached CD), science/biology teachers interview (see Appendix 6 on attached CD), and Transition Year Students interview (see Appendix 7 on attached CD) questions were developed and corresponded to the research aims and research questions. These interviews aimed to acquire a more in-depth understanding of the students and teachers’ opinions and views on the current methods of teaching and learning in post primary schools in Ireland, their opinions on the current biology
syllabus and feedback and views on what they would like to see included in the biology syllabus.

During this research project, qualitative research was also gathered through questionnaires, gathering data through open-ended questions providing more direct quotations (Jacob, 1988) and through the use of semi-structured interviews. This allows a freedom for the interviewee to express their views and opinions on certain topic which can be invaluable for any research as it is the people on the front line who have to carry out these changes and it is vital to get their views and support in order for implementation to be successful.

3.3 Part 1: Exploratory Phase

3.3.1 The Questionnaire: Science and Biology teacher and their students

The aim of the questionnaire was to gain an insight into the attitudes and perceptions of qualified science and biology teachers and students towards the use of Inquiry based teaching and learning in the Irish Post-Primary Classroom. In order to design and develop a questionnaire, a list of criterion was developed to answer the research questions and to meet the needs of those answering the questionnaire. A sample population and a control population were used. A sample population is defined by Fink (1995) as “those who are eligible are the target of the survey. The survey findings can only be applied to the target”. He also advises to define criteria for eligibility for the survey.

Table 3.3 The criterion used to determine participants for the science and biology student and teacher questionnaires.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td>• Junior cert. science students</td>
</tr>
<tr>
<td></td>
<td>• Leaving cert. biology students</td>
</tr>
<tr>
<td></td>
<td>• Range from 12 – 18 years old</td>
</tr>
<tr>
<td></td>
<td>• Teachers of science and/or biology</td>
</tr>
<tr>
<td>Ethics</td>
<td>• UL ethics committee clearance</td>
</tr>
<tr>
<td></td>
<td>• Parent/guardian consent</td>
</tr>
<tr>
<td></td>
<td>• Participant consent</td>
</tr>
<tr>
<td></td>
<td>• Questionnaires kept safely</td>
</tr>
</tbody>
</table>
3.3.2. Designing the questionnaire

Cohen et al., (2000) also states that the appearance of the questionnaire plays a significant role in it success. They say it must look easy, attractive and interesting rather than complicated, forbidding and boring. The length of both questionnaires and evaluation forms were kept to a minimum. A survey completed by Marton (2004) shows that the length of a questionnaire can influence outcome rates. If on first inspection of a questionnaire, a participant sees that there are a number of pages of questions to answer, this may disengage the participant and may lead them to either refuse to fill in the questionnaire or make a partial attempt at filling it in. The questions themselves should not be too long, a maximum of twenty words per line (Oppenheim, 1996). All this was taken into account when planning the questionnaires.

In this research project three questionnaires (i.e. A Leaving Certificate Biology student, a Junior Certificate Science student and a Biology Teacher) were designed, developed and distributed to eight post primary schools around Ireland. Each questionnaire was accompanied with an information and consent form (see Appendix 1). The information sheet contained details on the purpose of study, the data collection method and the confidentiality given to the participants. The consent form invited participants to take part in the research and explained that the participant was under no obligation to participate in the research and may withdraw at any time. All questionnaires had an instruction and general information section initially and then divided into further sections with specific headings (Bell, 1999).

Questionnaires are effective at asking the same questions and obtaining opinions from a large number of people at relatively low cost. Questionnaires are excellent at allowing
participants to express their attitudes, values, experiences and opinions at their own pace. Leading to more thoughtful, meaningful and useful responses that can be easily complied and analysed using SPSS and results illustrated in tables and a variety of graphs (Beiske, 2002; Bell, 1999; Brace, 2008).

The three questionnaires used in this research project included:

1) **Questionnaire One**

   **Title:** Junior Certificate Science Questionnaire (see Appendix 2).

   The science student questionnaires were distributed to Junior Certificate Science students in eight schools. One school was an all girls, three were all boys and four were mixed. A Total of 574 science students responded to the questionnaires.

   **Length:** Two A4 pages

2) **Questionnaire Two**

   **Title:** Biology Student Questionnaire (see Appendix 3)

   The biology student questionnaires were distributed to Leaving Certificate Biology students in eight post primary schools. A total of 202 biology students answered the questionnaires.

   **Length:** Three A4 pages

3) **Questionnaire three.**

   **Title:** Biology Teacher Questionnaire (see Appendix 4)

   The Biology teacher questionnaire were distributed to eight biology teachers in eight post primary schools. Seven of the biology teachers were female and one was male. Two of the teachers taught in an all boys, two in all girls and four in a mixed post primary school.

   **Length:** six A4 pages

**3.3.3 Question type**

The most important part of designing the question type is to ensure that the questions asked will provide answers to the research questions (Kane & O’Reilly – De Brun, 2001). The favoured format for the questionnaires was a mixture of closed, structured and open ended questions to increase the variety of data collection and to cover various interests and expression. These types of questions can be defined as:

- Open-ended questions: they have an advantage of offering a wide range of responses that capture the flavour of the people’s opinions, Questions without fixed limits or restrictions.
• Dichotomous question (Closed-ended): A Question with more than one possible answer from which one or more answers must be selected either a pre-existing set of dichotomous answers, such as yes/no, true/false, or multiple choice with an option for "other" to be filled in, or ranking scale response options.

• Likert- A scale, usually of approval or agreement used in questionnaires. The respondent is asked to say, whether for example they _strongly agree‘, _agree‘, _unsure‘, _disagree‘ or _strongly disagree‘.

(Beiske, 2002)

Oppenheim (1992) advises that dichotomous, multiple choice and rating scale type questions are quick to complete and straightforward to code. The closed questions enable the researcher to compile the responses with ease and record the results in the SPSS Version 18 statistical computer software. They are also easy to administer within the cohort as they are quickly answered. This type of quantitative research was used because they gather a lot of information in a short space of time and it can also help identify the elements which are common to a number of persons or observations (Nisbet and Antwistle, 1970). Closed questions can encourage students to answer questions to maximise data return. From experience as a teacher, students prefer the easy option and sometimes if an open question is asked, they can be unsure and choose to leave it blank. To overcome any disadvantage that Closed questions may limit respondents in their answers (Walonick, 1993). Some dichotomous, likert and open-ended questions with adequate space for respondents to expand their thoughts and opinions were provided in some questions in the questionnaire. Open questions were recorded and coded.

3.3.4 Closed ended question

The following section gives some examples of closed ended, open ended, dichotomous and likert scale questions. The main question type chosen for the science student and biology student questionnaire were closed ended. The question in figure 3.2. is an example of a closed ended question from the Science Student Questionnaire (see Appendix 2). A closed question structure was used to be as specific as possible. The questions were simply worded ensuring the questions were not misleading.
Q.5 You write up reports:

On your own □ In groups □

Figure 3.2. Example of closed ended question from science questionnaire.

The next closed ended question example is from the Biology Student Questionnaire (see Appendix 3). Some of the closed ended questions offered a three way response e.g. yes, no or I don't know like the question shown in Figure 3.6 and Figure 3.7.

Q.18 Do you think the current syllabus promotes good future scientists? (i.e. that the students engage in many of the same activities and thinking as true scientists)

□ Yes □ No □ I don't know

Figure 3.3 Example of closed ended question from biology student questionnaire.

The next example of a closed ended questions is from the Biology Teacher Questionnaire (see Appendix 4).

Q.23 Does the biology syllabus allow you to introduce scientific inquiry in your lesson?

□ Yes □ No □ I don’t know

Q.27 Do you use inquiry-based learning in your teaching?

□ Yes □ No □ I don’t know

Figure 3.4. Example of closed ended question from the biology teacher questionnaire.
A dichotomous multiple choice question was asked where a number of categories are presented for respondents to choose from in this questionnaire. Parahoo (1997) recommended the use of the ‘other/please specify’ option to prevent what he describes as a forced choice. This also allowed the respondent the opportunity to offer an alternative answer preventing them from being lead. The use of these closed-ended questions are advocated by Oppenheim (1992).

This is an example of a dichotomous question from the Biology Student Questionnaire (see Appendix 3). In this question the option of ‘other’ and ‘if other please specify’ was given to investigate what other main sources of knowledge is used by Biology Students and to not force students to choose one of the options given.

```
10. The main sources of knowledge you use in biology are:

[ ] Text Book  [ ] Workbooks  [ ] Extra Handouts  [ ] The internet  [ ] other

If other please specify:_________________________________________________
```

Figure 3.5. Example of dichotomous question from biology student questionnaire.

### 3.3.5 Open ended questions

Open ended questions can catch the authenticity, richness, depth of response, honesty and candour which are said to be the hallmarks of qualitative data (Cohen, Mahon et al., 2007). The biology teacher questionnaire used both open and closed ended question to gain an understanding of teacher issues and allow freedom for participants to express their opinions on the topic with extra space left after forced questions. An example of an open ended question in the Biology Teacher questionnaire can be found in figure 3.9.

```
Q.29 How do you incorporate inquiry into your teaching?

________________________________________________
________________________________________________
________________________________________________
```

Figure 3.6. Example of Open Ended Question From Biology Teacher Questionnaire.
The use of opened-ended questions in the questionnaire allowed the respondent to interact with the questionnaire allowing them a degree of freedom to express their true feelings on the matter, while not influencing the outcome for the question by pre-determining responses (Beiske, 2002).

3.3.6. Likert Scale Questions

A Likert Scale gives a range of responses to a specific question or statement (Cohen, Manion et al., 2007). The greater subtlety of responses that is built into this rating scale renders it very attractive as a tool for data collection. This type of question allows the researcher to understand the participants’ feelings towards a particular issue. It is useful for trapping opinions, attitudes and perceptions (Cohen, Manion et al., 2007). The Likert scale can encounter some problems such as misinterpretation of question or response by participants. Where some participants may answer ‘very often’ another participant may believe it is just ‘often’ (Cohen, Manion et al., 2007).

Both the Biology Student and Biology Teacher questionnaires included a Likert scale. Respondents answering a Likert scales question were provided with a range of possible responses to a question or statement (Cohen, Manion et al., 1989). Some example responses in the Biology Student and Biology Teacher questionnaires include;
- strongly agree/agree/disagree/strongly disagree;
- most important/important/less important/least important;
- very often/often/seldom/never;
- very large proportion/large proportion/small proportion/very small proportion/never.

An example of a Likert Scale question from the Science Student questionnaire can be seen in figure 3.7. The response range given in this question include very regularly / regularly / seldom / very seldom /never. Students were asked to tick the appropriate box that they believed expressed how often they questioned in science class.
Figure 3.7. Example of Likert scale from science student questionnaire

The next example is a likert scale question from the Biology Student questionnaire. The response range in this question was always/sometimes/never/not sure. The Biology students were asked to tick the appropriate box that expressed best how they learn biology.

11. Please tick the appropriate boxes from the following questions.

<table>
<thead>
<tr>
<th>VR</th>
<th>R</th>
<th>S</th>
<th>VS</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you ask questions in science?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you ever question the theory being taught?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you ever question and investigate the theory being taught with the teacher?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.8. Example of Likert scale from biology student questionnaire

3.3.7 Ranking Ordering

Ranking scales moves beyond multiple choice options and asks respondents to identify priority. It allows for a relative degree of preference priority and intensity that can be charted (Cohen, Mahon et al, 2007). The Biology Student and Biology teacher questionnaires both had one rank ordering question. The participants were asked what they believed students must do in order to achieve successful grades in the Leaving Certificate Biology Syllabus. The ranking responses given to participants where;

13. Please tick the appropriate boxes from the following questions.
A: Always S: Sometimes N: Never NS: Not Sure

<table>
<thead>
<tr>
<th>A</th>
<th>S</th>
<th>N</th>
<th>NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>You take information as a given without ever questioning it</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You learn by learning off a set of facts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You learn by trying to understand the topic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You learn by questioning the theory being taught</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You do their own research in biology at home</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1=most important
2= important
3= less important
4=least important

The participants were asked to rank in order of importance by circling a number which corresponded to importance. Figure 3.12 shows an example of the question asked in both the Biology Student and Biology Teacher questionnaire.

<table>
<thead>
<tr>
<th>Q 22. Rank the following in order of importance.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle the boxes 1-4.</td>
</tr>
<tr>
<td>1 = most important and 4= least important.</td>
</tr>
<tr>
<td>You can only circle a number once.</td>
</tr>
</tbody>
</table>

**In order for students to successfully complete and achieve good grades in the leaving certificate biology syllabus, they must:**

- Memorise scientific facts. 1 2 3 4
- Study in order to be able to answer past exam questions. 1 2 3 4
- Understand every topic. 1 2 3 4
- Develop scientific skills. 1 2 3 4

Figure 3.9. Example of Ranking Scale Question from Biology Student and Biology Teacher

### 3.4 Questionnaires

Table 3.4 Summarises the question format used in the Science and Biology Student and Biology Teacher questionnaire.

<table>
<thead>
<tr>
<th>Question Format</th>
<th>No. in Science Student Questionnaire</th>
<th>No. in Biology Student Questionnaire</th>
<th>No. in Teacher Questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open-ended</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Closed</td>
<td>6</td>
<td>9</td>
<td>24</td>
</tr>
<tr>
<td>Dichotomous</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
3.4.1 Piloting the Questionnaire & Sampling

Piloting can highlight any weaknesses in the questionnaires or the survey techniques. The questionnaires can then be edited in light if the results of the pilot study (Kothari, 2008). The purpose of a pilot exercise is to increase the response rate of participants and to weed out any in discrepancies so that subjects in your main study will experience no difficulties in completing it and so that you can carry out a preliminary analysis to see whether the wording and format of questions will present any difficulties when the main data are analysed (Fink, 1995). Piloting it is essential to ensure the questionnaire works for the chosen population and will yield the data that is required (Oppenheim, 1997). Piloting helps with wording of questions, ordering the sequence of questions and reducing the number of non-responsive rates. A poor question will produce a narrow range of responses or will be misunderstood by part of sample. Pilot work helps to conceptualise and reconceptualise the key aims of the research project and in making preparations for the intervention programme so that there should not be many errors and nothing will have been omitted. It helps produce an effective set of questions that respondents can answer which neatly embody the purpose of the research project (Oppenheim, 1997). Sampling is the process of obtaining information about an entire population by examining only a part of it (Kothari, 2008).

A pilot school was selected for sampling and piloting the questionnaires. The pilot school was a mixed rural public post primary school. There are 460 students and 36 teachers with three of whom teach Biology. The questionnaires were piloted with 69 Junior Certificate Science students ranging from first year to third year and 52 Leaving Certificate Biology students from fifth year and sixth year who were not involved in the final sample population but who met the eligibility criterion in Table 3.3. A purposive and convenience sample was chosen. Purposive sampling is a form of non-probability sampling (Polit & Hunglar, 1999). This is the type of sampling that will be used to select certain participants with the sample being "hand-picked" for the research. The advantage of purposive sampling is that it allows the researcher to home in on people or events, which have good grounds in what they believe, will be critical for the research (Dane, 1990). Convenience sample is the least rigorous technique, involving the selection of the most accessible subjects. It is the least costly to the

<table>
<thead>
<tr>
<th>Likert</th>
<th>3</th>
<th>3</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rating</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
researcher, in terms of time, effort and money, but may result in poor quality data and lacks intellectual credibility.

Feedback from the sample groups suggested changes that were needed in the questionnaire and were made accordingly. Some changes included word phrasing in sections, more space in areas given and headings modified (Bell, 1999). Also, the questionnaires were delivered personally by the researcher because it is more likely to get better co-operation if you can establish personal contact (Bell, 1993).

3.5 The Interviews
Interviews are a qualitative method of research used in this research project. An interview allows us to use the interviewees' expertise, knowledge and opinions. Burrell and Morgan (1979) and Kirk and Miller (1986) observe that the emphasis is placed on the understanding and explanation of the unique and particular individual case rather than the general and universal. The purpose of interviews is to obtain information either in the form of factual replies to factual questions or responses to attitudes, ideas and feelings, or perceptions and expectations (Oppenheim, 1992). The chief merits of interviews according to Kothari (2008) include;

- More information in greater depth can be obtained
- The ability to overcome the resistance of a respondent
- A Greater flexibility for the opportunity to restructure questions
- Personal information can be obtained easily
- Interview may secure spontaneous reaction from the respondent.

The Interview aims to investigate areas of concern identified by teachers during the interview. The intervention programme was designed with these areas of personal and professional concern in mind. The interview approach chosen was a semi-structured interview (i.e. Biology Teachers Interview transcript see Appendix 6; Biology Students Interview transcripts see Appendix 5 both on CD attached). The Interview questions were developed and corresponded with the aims of the Part One: Exploratory Phase, Part Two: Development of Inquiry Based Teaching Resources and Part Three: Intervention Programme of this research project.
3.5.1 Aim of Interviews:

- To investigate the extent to which the principles of scientific inquiry teaching and learning are being practiced in the Senior Cycle Biology classroom from a teacher and student perspective.
- To gain an insight into the attitudes and perceptions of qualified science and biology teachers and students towards the use of Inquiry based teaching and learning in the Irish Post-Primary Classroom.
- To investigate the extent to which the principles of scientific inquiry teaching and learning are being practiced in the Senior Cycle Biology classroom from a teacher and student perspective.
- To investigate the effect Inquiry Based Learning on how students engage in the learning process and their overall understanding in science
- To investigate if students’ scientific skills need further development in anticipation of the proposed practical assessment the draft biology syllabus.
- To assess transition year students’ achievements and attitudes in the two different classes towards biology.

3.5.2 Interviewees

Table 3.5 Criteria used to chose students and teachers for an interview.

<table>
<thead>
<tr>
<th>Transition Year Student</th>
<th>Biology Students</th>
<th>Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th Year Student</td>
<td>5th year or 6th year Biology</td>
<td>Taught 5th &amp; 6th year Biology</td>
</tr>
<tr>
<td>Range in age 14 – 16 years old</td>
<td>Range in age 16 – 18 years old</td>
<td>Taught Junior Certificate science</td>
</tr>
<tr>
<td>Taken science for Junior Certificate</td>
<td>Taken science for Junior certificate</td>
<td>Selected randomly from the nine participating schools</td>
</tr>
<tr>
<td>Participated in either the traditional science class or the inquiry based lessons.</td>
<td>Selected at random</td>
<td></td>
</tr>
<tr>
<td>Selected at random</td>
<td>Mixed school</td>
<td></td>
</tr>
<tr>
<td>Mixed school</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Leaving Certificate Biology students were provided with an information sheet and consent form (see Appendix 1) which needed to be signed by their guardian before agreeing to the interview. The interviews were then conducted in an open space in the presence of another adult.

Table 3.6 Dates and Location of Biology Student Interviews.

<table>
<thead>
<tr>
<th>Interview (see Appendix 5)</th>
<th>Date of Interview</th>
<th>Location of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology Student Interview 1</td>
<td>17th February 2010</td>
<td>Colaiste Mhuire, Johnstown, Kilkenny</td>
</tr>
<tr>
<td>Biology Student Interview 2</td>
<td>18th February 2010</td>
<td>Colaiste Mhuire, Johnstown, Kilkenny</td>
</tr>
<tr>
<td>Biology Student Interview 3</td>
<td>18th February 2010</td>
<td>Colaiste Mhuire, Johnstown, Kilkenny</td>
</tr>
</tbody>
</table>

To assess the achievements and attitudes of the students who participated in the intervention programme, two students from the inquiry class and two students from the traditional class were interviewed.

Table 3.7 Date and location of Transition Year Student Interviews.

<table>
<thead>
<tr>
<th>Transition Year Students -Traditional Class (Interview transcripts see Appendix 7)</th>
<th>Date of Interview</th>
<th>Location of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Student Interview 1</td>
<td>16th May 2011</td>
<td>Kilkenny</td>
</tr>
<tr>
<td>Traditional Student Interview 2</td>
<td>17th May 2011</td>
<td>Kilkenny</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transition Year Student Inquiry Class (Interview transcripts see Appendix 7)</th>
<th>Date of interview</th>
<th>Location of interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inquiry Student Interview 1</td>
<td>18th May 2011</td>
<td>Kilkenny</td>
</tr>
<tr>
<td>Inquiry Student Interview 2</td>
<td>18th May 2011</td>
<td>Kilkenny</td>
</tr>
<tr>
<td>Inquiry Student Interview 3</td>
<td>19th May 2011</td>
<td>Kilkenny</td>
</tr>
<tr>
<td>Inquiry Student Interview 4</td>
<td>19th May 2011</td>
<td>Kilkenny</td>
</tr>
</tbody>
</table>
The science/biology teachers were contacted in their schools initially by phone to arrange a time and the interviews were then held in their schools so as to minimise any burden of commute to the interviewee. Permission was requested from each interviewee to use a recording device before the interview starts. However, during two interviews, the interviewees requested that a dictaphone was not used to record the interviews and so note taking was used instead. Each interviewee was welcomed, informed of the purpose of the interview, ensured that the interview is confidential and thanked for their participation. Throughout all interviews the participants were encouraged to speak at length and to introduce and to articulate their own concerns (Oppenheim, 1992).

Table 3.8 Date and locations of the Biology Teacher Interviews.

<table>
<thead>
<tr>
<th>Interviewees</th>
<th>Date of Interview</th>
<th>Location of Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher interview 1</td>
<td>9th March 2010</td>
<td>Kilkenny</td>
</tr>
<tr>
<td>Teacher interview 2</td>
<td>12th March 2010</td>
<td>Dublin</td>
</tr>
<tr>
<td>Teacher interview 3</td>
<td>19th April 2010</td>
<td>Port Laois</td>
</tr>
<tr>
<td>Teacher interview 4</td>
<td>23rd April 2010</td>
<td>Tipperary</td>
</tr>
</tbody>
</table>

3.5.3 Design of Interview

A semi-structured and personal interview was used during this qualitative research. A semi structured interview involves predetermined questions but also a flexibility to the approach of questions with a greater freedom to ask or omit questions if the situation so requires (Kothari, 2008). Cohen, Mahon et al. (2007) describe a semi structured interview as modification of a structured interview. A personal interview involves the interviewer asking the respondent questions with face to face contact. It is a form of direct personal investigation. A semi structured and personal interviews are time consuming and expensive but these methods were chosen for this research project as the most effective method of gathering qualitative data.

Cohen and Crabtree (2006) mention that being able to prepare the questions ahead of time and allowing informants the freedom to express their views in their own terms are just some benefits associated with a semi-structured interview.
3.5.4 Type of Interview Questions

The prime purpose of the interviews is to generate further ideas about topics and variables that should be included in the research plan and every effort should be made to get respondents to express their own feelings and ideas spontaneously in their own words. (Oppenhiem, 1997). The questions need to allow for this to happen. Loose structured open ended questions based on the aims of the research project and the research questions were chosen as the best approach for the interviews to guide the interviewees. This facilitated the flexible approach taken, where respondents could expand on the pre-determined questions where necessary, to maximise the benefits of the interview. Open ended questions are used to develop an overall picture of interviewee’s point of view and encourage people to talk about whatever is important to them. It is important to allow the respondent freedom to talk about what is of central importance to him or her (Bell, 1993).

This type of question was chosen to help establish a rapport, gather information and increase understanding. Most importantly, to gain someone's opinion or understanding, one needs more than the simple brief response such as “yes” or “no.” (Oppenheim, 1997) which is associated with a typical closed-ended question. Open-ended questions invite others to “tell their story” in their own words but during the interview so it is important not to lead people in a specific direction, be bias or worse, get caught in the trap of role reversal where the respondent replies to the interviewer with what would you like to know? (Oppenheim, 1997)

As interviewees have given up their time to participate, it is important to pay attention to the participants and engage with them during the interviews. Respondents may only feel comfortable talking about issues or concerns if they feel the interviewer has maintained a receptive and non judgmental attitude throughout the interview. When questions are asked they should be as open and as projective as possible (Oppenheim, 1997).

Some examples of open ended questions used in the Biology Teacher Interview (see Appendix 6) include:

1. Would you like to state any opinions (strengths/weaknesses) on LC biology syllabus?
2. What motivates you to teach in the science class every day?

Some examples of open ended questions used in the Biology Student Interview (see Appendix 5) include:

1. What are the topics that you find the most difficult to learn and why?
2. Do you like doing Biology experiments? Why?
3.5.5 The Interview Process

The interviews began with a short informal chat to help relax and familiarise the interviewee. To get the most out of each interview, the interviewer must have developed the interpersonal skills necessary to encourage the respondent to talk openly and freely on personal matters. Tone of voice, a pleasant and polite manner, an acceptance and non-judgemental attitude and a willingness to listen should be among these interpersonal skills. Throughout the interviews, it was important to remember not to lecture people or show surprise or shock or distaste. When a question is asked the interviewee should be allowed to talk with no interruption (Kane & O’Reilly – De Brun (2001:205)).

The interview will follow an agenda that is unknown to the interviewee. This agenda is based on the research questions. According to Kane & O’Reilly – De Brun (2001:199) “you determine the agenda and the categories in which people give information back to you”. To ensure information is given back, a rough idea of what questions is decided on before the interview so as to make sure the responses are adequate. The hidden agenda is only hidden in the sense that it should not be too obvious to the respondent. The interview should move naturally from topic to topic, maintaining the fiction of an interesting conversation.

3.6 Part 2: Development of Inquiry Based Teaching Resources

The aims for developing the inquiry based teaching resources included;

- To design and develop different inquiry resources for the teaching of biology in order to foster student’s enthusiasm and increase achievements in this subject
- To provide teachers with the tools (teaching techniques) and methodologies to make the necessary adjustments in the classroom to adapt to the new LC biology syllabus
- To meet the need of the students to promote inquiry, life long enthusiasm and interest in biology
- To promote innovation in teaching, promoting the students to reason and analyse topics in biology.

3.6.1 Design of inquiry based lessons

To design and develop the five inquiry lesson used in the intervention programme, the researcher used two main book resources called ‘Biology Inquiries – Standards-Based Labs, Assessments and Discussion Lessons’ by Martin Shields (2006) and ‘Teaching High School
Science through Inquiry' by Douglas Llewellyn (2005). For this research project, the five inquiry lessons used in the intervention programme had similar layouts and used the 5 E learning cycle along with worksheets and tasks sheets that were adapted to suit the Irish Biology Syllabus. Each lesson plan was designed with aims, objectives, time allocation, equipment needed, necessary preplanning, lesson summary and a 5 E’s Learning Cycle with the following headings; engage, explore, explain, elaborate and evaluate. Depending on the lesson, safety, the expected exploratory outcomes or responses and resources that are associated with specific experiments were provided. Each lesson plan also contained separate task sheets and worksheet. To evaluate students understanding and attitude towards the topic, a pre- and post- questionnaire for each lesson was developed and distributed to each student to complete before and after each lesson.

3.6.2 Inquiry Based Biology Lesson Student Booklet

A sample of the five inquiry lessons including lesson plan, task sheet and worksheets that was used in the intervention programme can be found on the accompanying CD.

Each student was given a folder for the duration of the intervention programme. The students were asked to keep all completed pre and post questionnaires, task sheets, worksheets and any other resources in the folder in the order of lessons completed.

Figure 3.10. Transition year students present their resource folders.

2.6.3 Lesson One – Introduction to Inquiry

*Inquiry Dice* and *Inquiry Dice with a Difference* are two fun and interesting lessons that introduce inquiry skills to students. The tasks get students to develop and use inquiry skills to find out what lies on the bottom end of both inquiry dice.
The introductory questionnaire and lesson worksheets serve to gather information about the students' understanding and opinions of what scientists and scientific skills are, what teaching and learning methods have they encountered and what aspect of science do student like the most. Once the lesson has been carried out, class and group discussions commence and students discuss what they have done in the lesson, their conclusions and how they arrived at this conclusion. The teacher can lead the discussion towards skills they used and relate these skills with skills of scientists and then the term scientific skills. Students then have an understanding and can put a meaning to what they have done in the lesson.

3.6.4 Lesson Two – Experimentation

Designing Experiments and the Design, Dissect and Presentation lessons give students the opportunity to exercise the knowledge they learned in the previous lesson. The first lesson serves to prepare students ability at designing an experiment. The task gets students to think of and examine claims such as 'an apple a day keeps the doctor away' that they may have heard from their every day life and in groups, design and plan a fictional experiment and present it to their fellow classmates in a Power Point presentation.
Figure 3.12. Transition Year student presenting his PowerPoint during the Experimentation Lesson.

This lesson allows for students to be as creative as they want but still keeping in mind the purpose of the task. The Design, dissect and presentation lesson gets students to use the skills developed in the previous lessons to carry out the task of planning and designing their own dissection experiment. This lesson allows for students to use their psychomotor skills and information technology skills. The students were given the option of recording their dissection using a video or photographs to tell the dissection story and then presenting their results in a poster format to their fellow classmates.

Figure 3.13. Transition Year students display their Design, Dissect & Presentation posters.
Students were evaluated on their experimental design, results shown in the poster/video/photographs and questions they answered during their presentation. Students were asked to fill out pre and post questions after completing the experimentation lessons.

3.6.5 Lesson three – Osmosis

Osmosis Onions Lesson and Osmosis Egg Mayhem lesson were the next challenging lessons for students. The Osmosis Onions task and worksheet gets students to make up different concentrations of salt solutions and plan how to use them to show their effect on onions cells. This lesson is based on the osmosis topic and mandatory experiment at Leaving Certificate Biology but modified to incorporate inquiry based methods.
The *Osmosis Egg Mayhem* task allows students to create a life sized cell that has undergone plasmolysis, a hypotonic or a hypertonic condition. After completing the experiments, group and class discussion and presentations of their findings occur. The worksheet can be used in class time or for homework. The students must present their findings to the class. The class discussion enables the teacher to bring up scientific terms that correspond to the experiment and what the students were doing. Both lessons get students to work as a team, use the skills from the previous experimentation lesson to plan and carry out their experiment and develop further scientific skills with each new lesson. All students who completed the osmosis lessons were asked to fill in a pre and a post osmosis questionnaire.

3.6.6 Lesson four – Enzymes

*Enzymes away!* Lesson and *Enzymes Cause Expansion* were the next lessons students encountered during the intervention programme. The *Enzymes away!* Lesson is a modified version of the mandatory enzyme experiments found on the Leaving Certificate Biology Syllabus. In this lesson, students observed initially and then had to discuss and brainstorm what they thought was happening. The task asks students to decide on a factor that they think would influence the activity of an enzyme. They then had to design an experiment to show the effect of this factor on the enzyme and see if they can influence the time it takes for the paper disc to rise to the surface and a method to record their results.
Figure 3.16. Transition Year Students working on their Enzyme experiment and filling in worksheets.

The students recorded their observations, data and graph on the task worksheet and once they completed their task, they discussed in groups their results and their conclusions. Class discussions enable the teacher to introduce different terms associated with enzymes such as catalyst and can lead to different but relevant biology topics. Students completed the worksheet for homework or in class after the discussion. The Enzymes Cause Expansion lesson is an alternative experiment for enzymes. In this lesson, the worksheet asks students to investigate two vials containing unknown substances. Students must use observational and experimental skills to investigate which vial is considered a living substance. An assessment task is also included that asks students to design and carry out an experiment based on the materials given and students understanding and knowledge from the previous lessons. Students were asked to fill out a pre and a post questionnaire once they completed the enzyme lessons.

3.6.7 Lesson Five – Mitosis

The Mitosis sequencing lesson aims to get students thinking about cell division, build on students’ previous knowledge and then introduce students to mitosis. Students were given a task sheet that asked students to brainstorm their ideas of cell division and mitosis. Based on their previous knowledge, they were asked to explain how they thought an animal cell would undergo division. The task asks students to examine a worksheet with a disorganised sequence of cell division. Students worked in groups and discussed how they would place the sequence in order and display their results, with most students choosing a poster format.
Once the groups were happy with their sequence all groups presented their poster and reasons for their sequence. Some students realised that their sequence was wrong and so returned to their groups to reshuffle their sequence. This lesson is more abstract than previous lessons and required students to pattern form, to think creatively and critically. Students must look at the sequence and try to find a logical pattern of events. During the presentation, their fellow students asked questions, pointed out flaws or disagreed with their sequence. The group of students presenting had to explain their reasoning and thinking behind their sequence, justify their sequence and why they thought it was correct. After the presentations and correct sequencing, class discussions can introduce cell division terms, the titles of each stage of cell division and students can come up with ways of remembering the stages. Students had a worksheet to do for homework or during class time after the discussion. Students were once again asked to complete a pre and post questionnaire for the mitosis lesson.

3.7. Part 3: The Intervention programme

3.7.1 The Intervention Programme

The aims of the intervention programme are;

- To investigate the effect Inquiry Based Learning on how students engage in the learning process and their overall understanding in science
To assess transition year students’ achievements and attitudes in the two different classes towards biology.

The intervention programme was implemented into transition year in pilot school over a 14 week period. The pilot school was a suburban, mixed, community school with 460 students and 36 teachers. Transition year was chosen due to course and time flexibility as well as less pressure or time constraint on teachers and students as it is not an exam year. A total of 48 transition year students were involved in the intervention programme. Two groups were created and consisted of 24 mixed ability students. The first group engaged in a traditional science/biology class while the second group engaged in inquiry based lessons. The students had to fill in a pre- and post- questionnaire for each lesson to assess and evaluate the students understanding of the lesson. The results from these pre and post questionnaires will be displayed in section two of the results chapter.

Initially, permission was requested from the Principal of the pilot school to implement the intervention programme in May 2010. This also included requesting the transition biology class and being able to be in a computer room and a laboratory at least twice a week. The permission and room accommodations were granted and the researcher began work on developing and designing inquiry based lessons and resources. The lessons were timetabled on a weekly basis with the initial Inquiry Introduction, Experimentation and Mitosis Lessons taking one to two weeks. The larger lessons such as Osmosis and Enzymes took required more time and took between three and four weeks to complete because they had more experiments that students had to design and carryout and students also had to present their findings in Poster, presentation, Power Point or video format.

The timeline shown in Table 3.9. below outlines inquiry lessons on a weekly basis. This was simply a guide for the researcher and could be changed as and when was necessary. The pace and attendance of transition year students as well as the length of time needed for the lesson sometimes were deciding factors in choosing which lesson to do next.

To investigate if students’ scientific skills need further development in anticipation of the proposed practical assessment the draft biology syllabus.

To investigate if there is a scientific skills gap between Junior Certificate Science and Leaving Certificate Biology.

To assess transition year students’ achievements and attitudes in the two different classes towards biology.
Table 3.9 Outline of The Lessons Done Week by Week In The Pilot School.

<table>
<thead>
<tr>
<th>Preplanning May - Aug</th>
<th>Week 1 Sept</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permission requested &amp; granted lesson plan developed &amp; intervention pack created</td>
<td>Inquiry Dice &amp; Inquiry Dice with a difference</td>
<td>Designing experiment &amp; PowerPoint presentation</td>
<td>Design a dissection experiment</td>
<td>Dissect &amp; poster presentation of dissection</td>
<td>“Osmosis egg mayhem” experiment</td>
</tr>
<tr>
<td>Week 6 Nov</td>
<td>Week 7 Jan</td>
<td>Week 8</td>
<td>Week 9</td>
<td>Week 10</td>
<td>Week 11</td>
</tr>
<tr>
<td>Elaboration of “osmosis egg mayhem” experiment</td>
<td>“Osmosis onions” experiment</td>
<td>Enzymes away experiment</td>
<td>Elaboration of “enzymes away” experiment</td>
<td>“Blow those balloons” experiment</td>
<td></td>
</tr>
<tr>
<td>Week 12</td>
<td>Week 13</td>
<td>Week 14 April</td>
<td>Postplanning May - June</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Blow those balloons” Task</td>
<td>Mitosis introduction &amp; Worksheet</td>
<td>Comparison worksheets</td>
<td>Evaluation of worksheets Analysis of pre &amp; post questionnaires Appendix development</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.7.2 Evaluating Lessons

In order to evaluate the effect of inquiry-based learning on how students engage in the learning process and their overall understanding in science, each student had to fill in a worksheet, task sheet and a pre- and post- questionnaire for each lesson. The questionnaires investigated the students’ prior knowledge of the topic from previous traditional classes in the pre questionnaire and then the knowledge after the student had participated in the inquiry class in the post questionnaire. The questions related to what the students investigated, how they carried out their investigation, how they displayed their results, what terms they understand, their explanations/conclusions and how they reached them and the scientific skills they used during the lesson. The pre and post questionnaire responses were compiled by SPSS version 18 and Microsoft excel version 14 to be analysed. The results from these pre and post questionnaire will be shown in part two of the results chapter.

In order to assess if students’ scientific skills needed further development or if there is a scientific skills gap between Junior Certificate Science and Leaving Certificate Biology, all students were again asked to fill in worksheets, task sheets and interviews were conducted. Six transition year students were interviewed to investigate their opinions and understanding of inquiry-based lessons and to allow them to communicate their feelings, what they had enjoyed or disliked about the lessons. The interviewees included two students from the traditional class and four students from the inquiry class. The interviews were coded and
analysed. The interviews allowed for the students achievements and attitudes in the two different classes towards biology to be compared. The pre- and post-questionnaires were inputted into SPSS version 18 and Microsoft excel 2007 and also analysed. Results and graphs were generated and these are displayed in the results chapter.

3.7.3. Reliability and Validity

Validity and reliability are two factors which any qualitative researcher should be concerned about while designing a study, analysing results and judging the quality of the study (Patton, 2001). Lincoln and Guba (1985) agree by stating that: "Since there can be no validity without reliability, a demonstration of the former [validity] is sufficient to establish the latter [reliability;]" (p. 316).

Joppe (2000) defines reliability as:

*The extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable.* (p. 1)

Joppe (2000) also provides the following explanation of what validity is in quantitative research:

*Validity determines whether the research truly measures that which it was intended to measure or how truthful the research results are. In other words, does the research instrument allow you to hit "the bull’s eye" of your research object? Researchers generally determine validity by asking a series of questions, and will often look for the answers in the research of others.* (p. 1)

Qualitative validity refers to the extent to which the stated interpretations are in fact true. There are two types of validity – Internal and External (Anderson, 1998). Internal validity refers to the validity of the data measured and to be confident that the results obtained are true for those participating. External validity refers to the generalisability of the results obtained and if the researcher is in a position to generalise them (Anderson, 1998). If the validity or trustworthiness can be maximized or tested then more credible and defensible result” (Johnson, 1997, p. 283) may lead to generalizability which is one of the concepts suggested by Stenbacka (2001) as the structure for both doing and documenting high quality qualitative research.

Triangulation according to Cohen, Mahon et al (2007) is when two or more methods of data collection are used. To ensure validity in this research project, quantitative (i.e.
literature research and review, student and teacher questionnaires and pre and post questionnaires and student observations during the intervention programme) and qualitative (i.e. student and teacher interviews and transition year student interviews) methods of data collection were used. This is a powerful way of demonstrating validity (Campbell & Fiske, 1959). When there are divergent sources of data converging on similar conclusions (Anderson, 1998) and the findings of different methods agree, limitations can be reduced and confidence is instilled in the project (Bryman, 2001).

Some other sources of error that can reduce the validity of a project includes poor sample selection and resultant bias, simple coding errors, misunderstanding of management and research questions by the researchers and misunderstanding of the investigative questions by the respondents (Anderson, 1998; Cohen, Mahon et al., 2007). According to Carspecken (1996:141) cited in Cohen, Mahon et al (2007), there are several actions that can be taken to ensure validity. During this research project these actions were kept in mind and include;

- Using interviews and group discussions with the subjects themselves
- Peer debriefing to check bias of if the data is too selective
- Repeat interviews with participants if possible
- Avoid leading questions in interviews
- Ask participants to use their own terms in describing naturalistic contexts and encourage them to explain these terms.

This research project had many research questions. In order to answer these questions, literature review and research, questionnaires, interviews, development of inquiry lessons, implementation of intervention programme and observation of classes in the intervention programme were undertook. All of the data was assessed and analysed. The reliability of this data and therefore the validity can be seen from the results presented in the results chapter which will be discussed at a later stage.

3.8 Ethical issues

Kvale and Flick (2007) caution that there are many ethical issues involved in research. Potential participants must be informed why the research is being carried out and what it hopes to achieve, and they must be assured of confidentiality (Morgan & Symon, 2004).

Ethical approval for the research project was requested to the University of Limerick Ethics committee prior to distribution of the questionnaires, interviews with Biology Students, Biology Teachers and Transition year Biology students and the pre and post
questionnaires for the intervention programme. An Information sheet with details of the research project was prepared with the purpose of the research and what was required of the participants and how the information will be used and provided to the Ethics Committee.

Due to the students being under 18 years of age, confidentiality and consent is extremely important. A consent form signed by the students’ parents or guardians and an information sheet explaining the purpose of the research was also designed which ensured the participants anonymity and their right to withdraw from the project at any time. They were informed that all information gathered would remain confidential in accordance with the Data Protection Act (2003) and that the data will be securely held in a locked filing cabinet and will be retained for 7-10 years (as required by UL Ethics Committee).

3.9 Limitations

During the course of my research there were some limitations encountered. The main constraints on the research were:

- Cross sectional study of short duration and an isolated pilot that included only five biology topics developed for the inquiry lesson plans. To assess the effectiveness of inquiry based learning a future longitudinal study would be needed to assess students from first year to six year student consecutively.
- Transition Year students attendance was poor during some lessons due to a busy transition year schedule that included a musical practice, sporting events and work experience. The absenteeism of some students meant the lessons had a low questionnaire response rate. Due to the short time frame of 14 weeks for implementing the pilot intervention programme, these lessons could not be revisited for these students.
- Questionnaires were not returned from two post primary schools.
- Preset category responses in the questionnaire may limit the responses if participants find the answers do not best suit their opinion or attitude towards the topic in question.
- The use of a Likert scale can only examine if a person is more or less favourable towards a topic but we cannot tell how much more or less they are. There is no belief that the five positions indicated on the scale are equally spaced.
- Discrepancies in the questionnaire answers must be considered as some participants may have been in a rush while filling out the answers.
• The response rate of parental consent for students to be interviewed was slower than planned and one biology student never returned consent and therefore could not be interviewed.

• There is a need for a wider scale distribution of the Science and Biology teacher and student questionnaire as well as a greater number of teacher interviewees to gain a clearer understanding of their attitudes and perceptions on the use of inquiry-based teaching and a clearer picture of the practice of inquiry-based learning in Irish post-primary schools.
Chapter Four

Results of Questionnaires and Interviews

4.1 Survey results of science students

This section presents the results of science and biology student and biology teacher questionnaires and interviews. Science students were not interviewed as it goes beyond the scope of this research project which focuses on senior cycle biology.

Questionnaires were distributed to eight schools. One school was an all-girls, three were all-boys and four were mixed. A Total of 574 science students responded to the questionnaires (table 4.1). The questionnaires were distributed across all years of Junior Certificate Science programme (Table 4.2).

Table 4.1. Gender of student respondents to questionnaires.

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Students</td>
<td>418</td>
<td>156</td>
</tr>
<tr>
<td>Percentage of Students</td>
<td>72.8</td>
<td>27.2</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n = 574)

Table 4.2. Number of student respondents in each year of the Junior Certificate Cycle.

<table>
<thead>
<tr>
<th></th>
<th>First Year</th>
<th>Second Year</th>
<th>Third Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Students</td>
<td>247</td>
<td>122</td>
<td>205</td>
</tr>
<tr>
<td>Percentage of Students</td>
<td>43</td>
<td>21.3</td>
<td>35.7</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n = 574)

4.2 Investigations in Junior Science

This section investigates how students engage in learning, understanding and investigating science at Junior Certificate level. Information was sought on research questions such as: what are the current methods used in practical work and experimental procedure and do students write up their laboratory reports individually or in groups?

Students were asked what they used when they wrote up their experiments and the results shows that 76.8% of students use their own laboratory manuals while 22.5% use a
laboratory manual and textbook. Therefore the majority of students were allowed to design and develop their own investigation write up, instead of following a step by step laboratory manual which may or sometimes may not promote scientific inquiry skills and higher order thinking for example including headings for predictions, analysis and interpretation of results and synthesis of the information gathered. If teachers are allowing students to design their own write up, it is very important that inquiry based scientific process skills are encouraged and emphasised in their written work as well as their practical work.

The questionnaire asked science students how they write up their laboratory experiments and the results show that the majority (71.4%) write up their laboratory experiments on their own, while 28% engaged in group write ups and 0.5% said they did write ups both on their own and in groups. Therefore the majority of students did not engage in collaborative work when writing up their investigations.

Students were questioned further about experiments and asked how they carried out their experiments. The result shows the majority (52%) of students said they "follow step by step procedure", while 47% designed their own experimental steps.

4.3 Student innovation and questioning in the science classroom

This section investigates the opportunities students believe they are given to be innovative and to allow for questioning in science class.

![Figure 4.1. Opportunities given to students in the Junior Certificate science class (Results are represented as percentage of total participants n = 574).](image)

The majority of students said they get the opportunity to ask a question in science class (96.2%) (Fig. 4.1). The majority of students (83.2%) said that they do **not** work according to
their own design. However, the following results contradict these results. Many students stated that they do get the opportunity to design step-by-step procedures (50.7%), predict experimental results (72.8%), design how measurements are taken (49.8%), plan and design procedures on how to make observations (44.6%), use experimental results to make new predictions (47.9%), use new experimental techniques and create their own theory (38.5%).

Inquiry skills include predicting, designing, creating, experimenting and observing. It appears that the majority feel they get the opportunity to experience inquiry skills. However 83.2% of students do not work according to their own design, which is the underlying principle of inquiry based learning. These results are ambiguous. Further investigation into the students’ interpretations of working according to their own design and drawing their own conclusions is needed through qualitative data collection in the form of interviews.

Students were asked after they had carried out their experimental investigations if the laboratory booklets/write ups helped them to develop an understanding of the investigation.

Figure 4.2. Students opinions on whether writing up laboratory investigations help them to understand the investigation (Results are represented as percentage of total participants n=574).

Only 53% of students thought that writing up the laboratory experiments always helps them to understand the investigation whereas 44% think it sometimes helps them to understand the investigation and 2% think it never helps (Fig. 4.2). This practical aspect of an investigation can enforce the theory and also encourage the use of inquiry skills.
However the writing up of the investigation is a very important element or scientific inquiry in order for the student to analyse and interpret their results. It is possible that the overall 46% of respondents who said the writing up of experiment helps them to only sometimes/never understand the investigation, may not understand the experiment, the purpose of the experiment or the actual theory. These students may need guidance in their writing up of investigations to include higher order thinking including challenging questions allowing students to make sense of their results, applying the information learned to different situations.

The questionnaire asked science students what they use as their main sources of information or knowledge in science class (Fig. 4.3). A large majority of students (65%) identified the textbook the main source of knowledge used in the science class. Other resources such as handouts and the internet played a role, with 19% of students saying they use these as main sources of knowledge in science class. However with only 10% of students using the internet, there are very few opportunities for inquiry based learning and project work, with students following the text book, workbooks and teachers' handouts, they are not encouraged to gather further information for themselves.

Figure. 4.3. The main sources of knowledge students used in science class (n = 574).

![Bar chart showing the main sources of knowledge used in Science](chart.png)
Students were also asked in their opinion, how class time is proportioned in science class (Fig. 4.4).

Figure 4.4. How Class time is proportioned in science (Results are represented as percentage of total participants n = 574).

The majority of students (29.8% and 36.4%) felt that a very large proportion to a large proportion of class time is spent in discussion with the teacher. However, it can be suggested that a lot of this discussion time is teacher-led as the majority of students (27% and 50.7%) said a very large proportion to a large proportion of time is spent listening to the teacher talk. In contrast, the majority of students (32.1% and 29.1%) felt that a small proportion to a very small proportion of class time was spent in discussion among themselves thus limiting the amount of time spent on dialogue with peers and peer learning.

The majority of students (22.3% and 39.7%) said that a very large proportion to a large proportion of class time was spent working in groups. Over sixty percent of students (16.9% and 44.4%) felt that a very large proportion to a large proportion of class time was allocated to student laboratory work. However, the majority (20.4% and 25.8%) of students said a very large proportion to a large proportion of class time was spent watching teacher demonstrations. This suggests that the student laboratory work was teacher-led through teacher demonstrations as students (34% and 21.8%) also said a small proportion to a very small proportion of time was spent working alone.
4.4 Learning science – students’ perceptions of how they learn science

The research questions sought information on how students learn science. Do students learn by questioning the information, learning off a set of facts, trying to understand topics or just taking the information as a given? Students were asked to how often they question in science class.

<table>
<thead>
<tr>
<th>Question</th>
<th>Very Regular</th>
<th>Regular</th>
<th>Seldom</th>
<th>Very Seldom</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you ever question and investigate the theory being taught with the teacher?</td>
<td>8.4</td>
<td>22.6</td>
<td>22.3</td>
<td>16.9</td>
<td>27.4</td>
</tr>
<tr>
<td>Do you ever question the theory being taught?</td>
<td>10.1</td>
<td>28.4</td>
<td>21.1</td>
<td>16.4</td>
<td>22.1</td>
</tr>
<tr>
<td>Do you ask questions in science?</td>
<td>20.7</td>
<td>39.5</td>
<td>26.7</td>
<td>7.1</td>
<td>4.4</td>
</tr>
</tbody>
</table>

Figure 4.5. How often students question in science class (n = 574).

Sixty percent of students asked questions regularly/very regularly in science class (Fig. 4.5). A much smaller proportion (approximately 30%) questioned the teacher about the theory. This suggests that most of the questions asked by students, do not relate to the theory being covered in the lesson.

Similarly, the relatively high percentage of students (33.8%) who seldom/very seldom ask questions are likely to be included in those students (44.8%) who seldom/very seldom question the theory or students (39.5%) who seldom/very seldom question and investigate the theory being taught.

One of the principles of inquiry skills includes questioning. These results suggest that a large portion of science students do not possess this inquiry skill. Although students said they very regularly/regularly ask questions (60.2%), there is a large percentage of students (21.1% and 27.4%) who never question the theory and never question and investigate the theory being taught. Therefore we must ask the question is the syllabus limiting, and
restricting the use of questioning in the classroom? Does the syllabus allow time for questioning of theory and further deeper inquiry into the topics being taught?

The next question investigated how students learn science (Fig. 4.6).

![How Science Students Learn Science](image)

Figure 4.6. How science students learn science ($n = 574$).

A large percentage of students (58.9%) said they always try to learn by trying to understand the topic. A smaller percentage of students (29.3%) said that they did this only sometimes. One might expect similar levels of response to the question “you learn by questioning the theory being taught”, but in fact relatively few (25%) responded positively to this question. A suggestion for this could be a misinterpretation of the question by the student or a lack of clarity regarding the meaning of the question.

Inquiry-based learning involves the use of problem solving skills and critical thinking. Students (28% and 49.3%) said they always and sometimes take information as a given without ever questioning it. Similar proportions of students (30% and 48.1%) said they always and sometimes learn by learning off a set of facts and a large portion of students (43.4%) said they never do their own research at home. These results suggest that students are not engaging in inquiry skills. Rote memorisation and acceptance of theory appears to take preference among students over questioning, critical thinking or project work.
4.5 Survey and Interview Results of Biology Students

4.5.1 Background Information

The questionnaires were distributed to eight second level schools. A total of 202 biology students (89 of these were male (44.1%) and 113 were female (55.9%)) responded. Of the students that responded, 96 were fifth year students and 106 were sixth year students. Two of these schools were an all girls, two were an all boys and 4 were mixed. Three 6th year Biology students (two females, one male) from the pilot intervention school were interviewed. Only the main findings from the interviews will be reported, full transcripts, can be seen in Appendix 5 on attached CD.

4.5.2 Investigations in Biology

This section investigates the current methods used in practical work and experimental procedures in Leaving Certificate biology classroom. It investigates the opportunities given to students to ask questions, create a theory, design methods of measurements, work according to their own design and writing up their laboratory report individually or collaboratively.

The biology students were first asked about investigations in biology and what aid they used in their experimental write ups in Biology class. 62% of the biology students stated that they use their own laboratory copies and 38% used the laboratory workbook and textbook.

Comments from the Biology student interviewees were very similar to the above results. Some of the interviewees’ comments included;

→ “I use the biology (text)book and ask my neighbour what they did” (Biology student interviewee 1)

→ “The laboratory copy and sometimes we get extra handouts” (Biology student interviewee 2)

→ “I use my laboratory copy and my (text)book” (Biology student interviewee 3)

For all comments see Appendix 5.

Similar to the findings from the Junior Certificate Science Class, the majority of students use their own laboratory copies to write up experiment. As discussed previously there are both advantages and disadvantage to this method. Teachers must ensure that laboratory write ups
encourage the practice and development of inquiry based scientific process skills i.e. questioning, prediction, design of materials, measurement procedures, data analysis, analysis and interpretation of results and application of results.

Students were then asked how they write up their laboratory experiments.

Figure 4.7 How laboratory results are written up in biology class (Results are represented as percentage of total participants \( n = 202 \)).

Surprisingly 83% of students write up their laboratory investigation individually, 13% write it up in groups and 4% write up investigations both in groups and individually. All three of the biology student interviewees responded as writing up the laboratory results “individually” (See Appendix 6).

These are similar to the findings from the JC Science students’ questionnaire, students do not write up investigations collaboratively. Collaborative and peer learning are key aspects in inquiry based learning.
The questionnaire also asked biology students what experimental procedure they followed when carrying out their Biology Experiments.

![How Is Experimental Procedure Followed](image)

Figure 4.8 How is experimental procedure followed (Results are represented as percentage of total participants n = 202).

A large percentage of students (77%) followed a **step by step procedure from their textbook**, 21% of students **design their own procedure steps** and 2% engage in **both** step by step procedures and get to design their own steps (Fig. 4.7). Similar to the findings in the JC Science classroom (section 4.2), over three quarters of the students are not involved in the planning and designing of investigations in Biology lessons.

Responses from the biology student interviewees confirmed that they received a lot of help from their teachers who wrote the procedure on the board and shows them how to do the experiment firstly. Some of their comments included:

→ "We go through the steps of the experiment on the board, get handouts and look to the PowerPoint to know what to do" (Biology student interviewee 1)

→ "We get a good bit of help, like the teacher would go through the caution and methods, showing us first and then letting us off to do it then" (Biology student interviewee 2)
I try not to get help, only when I get stuck but the teacher generally goes through it first then lets us off to do it and during the experiment not much help is given which is great because I think it is up to us to do it” (Biology student interviewee 3).

It is obvious from the comments above that their teachers do not allow the students the independence in developing their own procedures. However, this is due to the constraints of the curriculum and also because practical skills are not assessed in the summative leaving certificate examination. Due to practical skills not being assessed, teachers are not required and will not allocate a lot of time in developing students’ scientific process skills. Teachers are under pressure also to try and cover an extensive amount of theory in the Biology syllabus in the time allocated.

When interviewees were pressed on whether they would feel comfortable designing their own steps, many did not feel comfortable with this:

→ No because I don’t think I would know what to do or where to start, or how to go about it” (Biology student interviewee 1)

→ No because I wouldn’t know what I was doing” (Biology student interviewee 2)

→ No because I like doing experiments on my own after they have been explained, I wouldn’t know what to do or I think I would do it wrong” (Biology student interviewee 3)

It can be seen from their comments above, because this culture of scientific inquiry is a concept new to them (Section 4.3), they would not feel confident in themselves to design and plan an investigation themselves.
Students were asked to select from options relating to the opportunities for Inquiry Based Learning they experience in biology class.

<table>
<thead>
<tr>
<th>Percived Opportunities Given to Students in Biology Class</th>
<th>Apply new experimental techniques</th>
<th>Work according to your own design</th>
<th>Create new questions</th>
<th>Create a theory</th>
<th>Experimental results - used to explain...</th>
<th>Use your experimental results make predictions</th>
<th>Design experimental procedures</th>
<th>Design how measurements are taken</th>
<th>Design how to make observations</th>
<th>Predict experiment results</th>
<th>Ask a question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>23.3</td>
<td>26.2</td>
<td>29.2</td>
<td>39.1</td>
<td>43.6</td>
<td>44.6</td>
<td>44.6</td>
<td>53</td>
<td>55.4</td>
<td>86.1</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>48.5</td>
<td>51.5</td>
<td>49</td>
<td>23.3</td>
<td>28.7</td>
<td>26.2</td>
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<td>30.2</td>
<td>19.8</td>
<td>4.8</td>
<td>100</td>
</tr>
<tr>
<td>I don’t know</td>
<td>26.2</td>
<td>21.3</td>
<td>19.8</td>
<td>35.1</td>
<td>24.8</td>
<td>27.2</td>
<td>14.4</td>
<td>15.3</td>
<td>23.3</td>
<td>8.9</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 4.9. Opportunities given in biology class (Results are represented as percentage of total participants n = 202).

Over half of the respondents (51.5%) felt they do not get the opportunity to ‘work according to your own design’. However a large proportion of these students also stated that they felt they get the opportunity to design experimental procedures (44.6%), design how to make observations (55.4%), how measurements are taken (53%) and create a theory (39.1%). These results are ambiguous. These results are similar to that of the JC science students (Figure 4.1).

Inquiry skills include designing, experimenting, predicting, observing, and creating. It appears that the majority of biology students feel they get the opportunity to experience inquiry skills. To ‘work according to their own design’ is the underlying principle of inquiry based learning. Again these results are ambiguous and further investigation into the students’ interpretations of working according to their own design and drawing their own conclusions is needed through qualitative data collection in the form of interviews.

The high percentage of students responding ‘I don’t know’ for the initial nine questions that highlight inquiry-based skills shows a confusion or at least an uncertainty among students towards some opportunities for inquiry-based learning they should be engaging in as specified in the aims and objectives of the Leaving Certificate Biology Syllabus.
The majority of the biology student interviewees stated that they were not being provided with the opportunities to design experimental procedure, work according to their own design or create theory. The interviewees gave their reason for this. Some of the comments included:

→ “Not create theory no, but we do get to do experiment to look at the theory. No, never design own experiment, there always so much to do, I doubt we would get the time to do that because of exams coming up” (Biology student interviewee 1)

→ “No never. Definitely don’t get to design own experimental especially this year cause we have the leaving cert. coming up” (Biology student interviewee 2)

→ “Eh no, like we do experiments to tell us if what we learned in class is real but we don’t get to plan and design an experiment. We know how to do the experiment because the teacher goes through it” (Biology student interviewee 3)

The majority of interviewees felt they were provided with some opportunity to practice the key scientific inquiry skills of discussion and prediction of results before they begin the investigations. Some of the comments included:

→ “Yes we do, the teacher asks us what we think will happen and we can guess or think about it, but generally it is very obvious and you know what the results should be” (Biology student interviewee 1)

→ “I suppose we do. We know what to expect like we talk about what we should be seeing or getting as a result and then we know if we were right or wrong with the experiment” (Biology student interviewee 2)

→ “Yes, we talk about the results before doing the experiment and think about what we think we would get but we kind of know what we should be getting” (Biology student interviewee 3).

During the interviews, all of the biology students stated that they ask questions in class. Some of their reasons for asking questions and comments included:

→ “I ask questions. Well if I don’t understand then I ask” (Biology student interviewee 1)

→ “Yes because I want to know the answer” (Biology student interviewee 2)

→ “Yes because I need to know” (Biology student interviewee 3)
These answers highlight that the students are questioning the teacher to develop a greater understanding of the theory being covered. However it does not indicate if the students ever question the actual theory being covered, i.e. do they just take all theory as fact and never question what is being said.

Students were asked their opinion on what skills can be developed using the textbooks and workbooks after they have done their experiments.

![Figure 4.10. Textbooks and workbooks promote skills after experimentation.](Results are represented as percentage of total participants n = 202).

Based on the results above, it is clear that the majority of students think the textbook and workbook promotes certain inquiry-based skills after experimentation (Fig. 4.9). The majority of students felt scientific knowledge (82%), scientific understanding (79.2%), to think and reason logically (78.7%), observational skills (76.2%), promoted by workbooks and textbooks (74.3%), problem solving skills (61.9%) and critical thinking skills (56.4%) were all being promoted in their textbook and workbooks.

Fewer but still a significant proportion of students felt that problem solving (61.9%) and critical thinking (56.4%) skills were promoted in their text and workbooks. All the above mentioned scientific process skills are examples of inquiry-based skills that students should be allowed to practice as part of the Leaving Certificate Biology Syllabus. It must be taken into considerations however that the students may not understand the meaning of these skills and therefore have assumed that the workbook/textbook should promote these skills.
Students were then asked if they thought the textbooks or laboratory booklets allowed for the development of a meaningful explanation of the experiment.

![Figure 4.11. Biology Students opinion on whether laboratory booklets and textbooks promote the development of meaningful explanations after experimentation (Results are represented as percentage of total participants \( n = 202 \)).](image)

Some students (19%) felt that the laboratory booklets and textbooks *always* allow development of meaningful explanations after the experiment. A large majority of students (74% and 6%) disagreed and felt that the booklets *sometimes* and *never* helped in developing a meaningful explanation after the experiment.

The interviewees from the biology student interview all had different opinions on whether the laboratory booklets or textbooks allow for the development of meaningful explanations after experimentation. One interview disagrees and said they do not, while the two other interviewees agree they do, but to different extents. Some of their comments included:

→ "*They help, yes because we use them to help us do and understand the experiments. Like most of the time the results and conclusions are given in the book so it is easy to develop explanations"* (Biology student interviewee 1).

→ "*No I would prefer diagram form with space to write and explain what I did, as I doing the actual experiment but we would probably need more time for this"* (Biology student interviewee 2)
The students were asked about what the main sources of knowledge they use in biology class.

The majority of students (66%) use their textbook only as their main source of knowledge (Figure. 4.11). A large percentage of students (21%) said they are given extra handouts by the teacher and a small percentage of students (4%) use the internet as a source of knowledge. These results are similar to those of the junior certificate science students’ in Figure 4.3. These use of the textbook and handouts as main sources of knowledge do not entice the student to be active in their own learning and encourage fewer opportunities for inquiry-based learning. Both science and biology students are not encouraged to gather further information for themselves because it appears to be handed to them by the teacher in the form of notes, handouts and power points.

The majority of interviewees also responded as using their (text)book as main source of knowledge. They also said they use other sources of knowledge such as PowerPoint notes and handouts designed and given to them by the teachers. Some of their comments included;

→ „We use our book but we do get lots of Notes, power points and handouts” (Biology student interviewee 1)

→ „We use a lot of Power point and get given handouts. We do use our book as well but only as a reference really” (Biology student interviewee 2).
We go through topic on Power point and are given notes and handouts” (Biology student interviewee 3)

The students were then asked to give their opinions on the proportion of time they think is allocated to different activities and tasks during biology class.

Figure 4.13. Proportion allocation of time in biology class (Results are represented as percentage of total participants n = 202).

Students (16.8% and 43.1%) felt that classroom discussions with their teacher and other students take up a very large to a large proportion of class time (Figure. 4.12). Students (16.8% and 43.1%) also felt that teacher demonstration receive a very large to large proportion of class time. It could be suggested that all of these activities are very much teacher led and can be further emphasised by the results showing students (28.2% and 59.9%) believe teacher talk takes up a very large to large proportion of time in biology class.

The results also show that the majority of students (40.6%) think that time for discussion among students is small. Small percentage of students (27.8%) also felt that working alone took up either a very large or large proportion of the class time. It can be suggested that the reason for this is due to students (41%) feeling that a very large to a large proportion of class time is spent on teacher demonstration and a large majority of students (55%) saying a small to very small proportion of class time is spent on experimental work. This can also be reflected in the majority of students (39.6% and 17.8%) felt they spent a small to very small proportion of class time on group work.

Some teachers seemed to place less emphasis on teacher demonstration. Some students (36.6% and 14.4%) said they had a small to very small proportion of time spent engaged in teacher demonstration. It can be suggested that more time may then have been
allocated to students (38.6%) who engaged in very large to large proportion of experimental work. The same can be said for students (7.9% and 30.2%) who engaged in a very large to large proportion of group work.

The interviewees’ responses are quite similar to the responses from the questionnaires. Overall, the interviewees felt they spent a lot of their time working alone. Their comments and reasons for this included;

→ “Fairly often, like doing notes, answering exam questions, you kind of have to do it on your own at this stage because you have to do the exam on your own” (Biology student interviewee 1)

→ “Most of the time we work alone” (Biology student interviewee 2)

→ “A lot of the time... like taking down notes, listening, doing questions” (Biology student interviewee 3)

When interviewees were asked about how often they got to discuss topics among themselves, they all responded similarly to the results of the questionnaire i.e. that they did not get time to do this.. Some comments from the interviewees included;

→ “Not really. We have to discuss results together after experiment but not actual topics” (Biology student interviewee 1)

→ “No, not really. As a class yes but not in groups or anything” (Biology student interviewee 2)

→ “No we do not. The teacher tells us about topic, we learn it. That’s how it is” (Biology student interviewee 3)

The interviewees responded that they engaged in group work only through experiments which would coincide with the results from the questionnaire above. Some interviewee comments included;

→ “Yes for the experiments” (Biology student interviewee 1)

→ “We get to work in groups for experimental. But generally no, it is all business when we are in class, get the stuff covered, no messing!” (Biology student interviewee 2)
The interviewees’ responses are very similar to the results from the questionnaire regarding teacher talk time. All of the interviewees felt that teacher talk takes up a lot of the class time. Some of the comments included;

→ “All of the time! It is really boring sometimes because have to constantly listen” (Biology student interviewee 1)

→ “Very often, but I suppose she has to because she is telling us about things, but yes a lot” (Biology student interviewee 2)

→ “The teacher talks a lot!! All the time, we listen... she talks!” (Biology student interviewee 3)

4.5.3 How Students Learn Biology

Students were asked how often they question the theory being taught in the biology class and how often in general they ask questions.

![The Frequency at which Students Question in Biology Class](image)

Figure 4.14 The frequency at which students question in biology class (Results are represented as percentage of total participants n = 202).

It can be seen that the majority (57.9%) of students ask questions regularly in biology, either very regularly or regularly (Figure 4.13). However, a disappointing total of 41.6% of students seldom, very seldom and never ask questions in biology. There are students (16.3%) who do question the theory either very regularly and regularly and students (17.4%) who do question
and investigate the theory being taught both very regularly and regularly.

Inquiry skills include questioning and investigating. From these results, it appears that students do not possess these inquiry skills as surprisingly, 76.7% of the students responded that they seldom, very seldom and never question the theory being taught and 81% of students seldom, very seldom and never question and investigate the theory being taught by the teacher.

All of the biology student interviewees stated that they ask questions in biology class. However, interestingly all of the interviewees stated that they never question the theory they are being taught. Some of their comments included;

→ “No because I take it as it is, because I wouldn’t have any previous knowledge so I have nothing to compare it to as being right or wrong!” (Biology student interviewee 1)

→ “No because I don’t want to” (Biology student interviewee 2)

→ “No I don’t because if it is written there I believe it is true, they hardly going to tell us lies are they”. (Biology student interviewee 3)

22.3% of student in the questionnaire stated they question the theory, however the findings from the interviews would suggest otherwise. Further investigations into the students‘ interpretation of this question are needed. Students may have thought it just meant asking questions in class rather than questioning the actual theory being taught.
The next question asked students to give their opinion on how they learn or understand biology.

A large percentage of students always try to learn by understanding the topic (65.8%) (Figure. 4.14). It could be suggested that the majority of students begin by trying to understand the topic but due to the nature of the Leaving Certificate Biology Examination, 50.5% of students said they find they have to sometimes learn off sets of facts and 67.8% of students said they sometimes just take information as a given without ever questioning it. 44.1% of students said they sometimes learn by questioning the theory being taught. This result appears to contradict the results in Figure 4.14 were the majority of students (81%) said they seldom, very seldom and never question the theory being taught.

52% of students said they never do research in biology at home. This suggests that the majority of students are being ‘spoon fed’ all of the work and students may feel there is either no purpose or need to do research at home. It also suggests a lack of encouragement for inquiry based projects where students would have to do their own research. Issues such as time restraints, teaching to the exam, rote learning seems to be factors that affect how students learn biology. Surprisingly, only a small percentage of students (11.9%) said they always learn by questioning the theory being taught. Some students (4.5%) said never learn by learning of sets of facts and other students (8.4%) said they never learn by taking information as a given without questioning it.
Interestingly all of the interviewees’ responses seem to focus on learning off facts as their primary method of learning biology. Some of their comments and reasons included:

→ “By studying my notes and learning off the definitions and diagrams. It is really hard because there is so much to learn” (Biology student interviewee 1)

→ “I try to organise my notes throughout the year then learn the main points of a topic and practice drawing the diagrams. I learn the main definitions and then try and answer exam questions” (Biology student interviewee 2)

→ “Learning the notes off as much as I can... I try to think up ways to remember the definition or remember shape of diagrams by thinking of something else like... say the shape of bacteria looks like a solpadine capsule. Things like that. Most of the time though, I have to just learn it off because it is kind of specific so you need to get the answer exactly right which is annoying” (Biology student interviewee 3)

The next question asked students if they think they were good at writing or thinking up conclusions for the experiments they had completed. 5.5% of students felt they were very good at writing and thinking up conclusions after an experiment and 29.7% of students said they were good. The majority at 53% of students said they were only average, 9.4% said they were poor and 2.5% said they very poor. Interpreting evidence and drawing conclusions from data is a very important feature of inquiry based learning. It is significant that 64.9% felt that they were average to very poor in drawing conclusions. Therefore this is a very important aspect to Inquiry based learning that needs attention in the biology classroom.

4.5.4 The Biology Syllabus

This section reports on the students’ opinion of the biology syllabus. It also investigates what biology students think they have to do in order to achieve good grades in Leaving Certificate biology, i.e. memorise scientific facts or study in order to be able to answer past exam questions or understand every topic or develop the scientific skills
The majority of students said the biology emphasised experimentation (73.8%), ready-made answers for students to accept (53.4%), explanations being changed to fit the data collected during the experiment (33.7%) and an emphasis on the data that is collected being changed in order to fit the explanations (35.6%).

The results show that 44.6% of students think the biology syllabus emphasises investigating and questioning the theory being taught. However, in the Figure 4.15 a much smaller percentage of students (11.9%) said they always question the theory being taught. These findings are contradictory. If students think the biology syllabus emphasises investigating and questioning the theory being taught, then why are they not putting this into practice?

Overall, there appears to be a large number of students who said that they don’t know if the biology syllabus emphasises experimentation in order to find answers (13.4%), ready-made answers for students to accept (23.3%), investigating and questioning the theory being taught (28.7%), the data being changed/re-collected in order to fit explanation (36.6%) and explanations being changed to fit the data collected during the experiment (33.7%). A reason for this could be a misinterpretation of the question or confusion regarding the assigned answers given as a choice. It also highlights the possibility that students are not aware of what the biology syllabus is and they were answering with what they think the biology syllabus should emphasise.

Interviewees responded differently to the results shown in the questionnaire on what they believe the biology syllabus places an emphasis on. The interviewees believed that
certain topics get focused on more with a large volume of material to learn. Some of their comments included; (See Appendix 6 other comments)

→ “Some of the topics are too detailed and it is hard to understand the question let alone try to answer it. Some topics are very detailed whereas others are easy. There has to be a way to learn the topics with larger volume!” (Biology student interviewee 1)

→ “A lot of learning and writing and a lot of plant related chapters which is weird because I like Human biology and would love more of that to be in it” (Biology student interviewee 3)

Students were asked if they thought the laboratory activities matched closely to what they were learning on the biology course and 56.4% of students think that the laboratory activities always closely match the topics on the biology course, while 40.6% of students think it sometimes matches and 2.5% think it never matches.

Students were asked to rank in order of importance what they believed they had to do in order to be successful and achieve good grades in the leaving certificate biology exam.

![Figure 4.17 Students opinions on what has to be done to be successful in biology (Results are represented as percentage of total participants n = 202).](image-url)
A majority of students (43.6% and 29.7%) thought that it is very important and important to understand every topic. A smaller proportion of students (16.8% and 9.4%) felt that memorising scientific facts and studying in order to answer past exam questions (11.4% and 9.4%) is less important or least important factor in being successful in biology. This means students who want to understand the topic don’t feel the need to place an emphasis on memorising scientific facts or studying past exam questions.

But this seems to contradict the findings discussed in Figure 4.15 where the majority of students seem to focus on learning off sets of facts, taking information as a given and never question the theory being taught and in Figure 4.16 students said they think the biology syllabus places an emphasis on ready-made answers for students to accept.

It can be suggested that when students were answering this question, it is possible they assumed what they must do to be successful in their Leaving Certificate Biology Examination. The majority of students placed a very important to important emphasis on understanding every topic, memorising scientific facts and studying in order to answer past exam papers. Students placed the less importance and least importance on developing scientific skills. It can be suggested that students may focus on the three previous areas as they think it may help them to be successful in their Leaving Certificate Biology Examination and so place more emphasis on them. It appears students engage in little development of scientific skills or else may not have understood this term as it is not assessed in their Leaving Certificate Examination.

The interviewees’ responses were similar to the results found above from the questionnaire. The overall responses focused on being able to learn off the material and do past exam questions. Some of their comments include:

→ _Know lots of stuff!! Be in class to do the experiments because if you miss them you, you miss that experiment and it might come up in exam. Eh... study a lot and learn the stuff off”_ (Biology student interviewee 1)

→ _Practice by doing the exam papers because it shows me what I know and what I don’t know so I better go back and study that harder. Mainly study because you need to answer the exam questions!”_ (Biology student interviewee 2)

→ _Have a photographic memory!! It so hard to do well because you have to know so much and the only way to know it for me is to learn it off, we get weekly topic exams_
in class that show me what I need to go back over which helps home in on what I good and bad at” (Biology student interviewee 3)

The final question asked the biology students did they think the current biology syllabus promoted good future Scientists. The students responded and the data was analysed and the results are shown below.

![Bar chart showing student opinions on whether the current syllabus promotes good future scientists.](image)

Figure 4.18. Students opinions on whether the current syllabus promotes good future scientists (Results are represented as percentage of total participants n = 202).

The bar chart shows that 21% of students said ‘yes’, they think the current biology syllabus promotes good future scientists. The majority at 53% said ‘no’, they do not think the current biology syllabus promotes good future scientists and 26% of students said they don’t know if the current biology syllabus promotes good future scientists.

The responses from the interviews show a division of opinion. Two interviewees said they do think the biology syllabus promotes good future scientists while one interviewee disagrees and said it does not. Their comments included;

→ *Yes kind of, I suppose because we do a lot of experiments and we go through topics in detail. Maybe some more experiments on specific topics”* (Biology student interviewee 1)

→ *No not really... I think we would need to do other things that need more freedom in class but we don’t need it because we need to pass the Leaving Certificate exam and we don’t really have time for it”* (Biology student interviewee 2)
Yes it does prepare you for being a scientist because you carry out experiments a lot and you have to look up stuff relating to it, get results and form conclusions. I think it prepares for the experimental skills” (Biology student interviewee 3)

4.6 Survey and Interviews results of Biology teachers

4.6.1 Background information

Questionnaires were completed and analysed by eight biology teachers. Seven of the biology teachers were female and one was male. Two of the teachers taught in an all boys, two in all girls and four in a mixed post primary school. Four science/biology teachers were interviewed. Two teacher interviewees were male and two teacher interviewees were female. The main findings from the interviews will be reported and the full transcripts are available in Appendix 6 on attached CD.

The biology teachers taught in a variety of schools of different sizes (Table 4.3).

Table 4.3 The Size of the schools teachers taught in.

<table>
<thead>
<tr>
<th>Numbers in students</th>
<th>&gt;1500</th>
<th>&gt;1000</th>
<th>&gt;800</th>
<th>&gt;600</th>
<th>&gt;400</th>
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<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

(Total participants n = 8)

The teaching experience of the teachers varied from 1-20 years experience (Figure 4.19).

Figure 4.19. Number of Years Teaching Biology (Results are represented as percentage of total participants n = 8).
4.6.2 Investigations in biology

The next section displays the results when teachers were asked how their students performed various investigations in biology. The questionnaire was used in order to gather information on how investigations are being carried out in the classroom and what are the current methods used in practical work and experimental procedure?

Teachers were asked how their students completed their laboratory reports.

![Bar Chart: How Do Students Write Up Their Laboratory Reports](image)

Figure 4.20. How do students write up their laboratory reports *(Results are represented as percentage of total participants n = 8).*

Five teachers get students to write up the laboratory reports individually (63%), one teacher get students to write the laboratory reports in groups (13%) and 2 of the teachers get the students to write up the reports in groups and individually (25%). The results from the interview show that three out of four teachers get their students to write up laboratory reports individually with only one teacher getting them to do it in groups. Some of their comments include;

→ *Individually, it’s chaos in groups!*” (Teacher interviewee 2)

→ *Individually but do diagrams and graphs together*” (Teacher interviewee 3)

When the teachers were asked what their students used when writing up the laboratory reports 50% of the teachers (n= 4) said they use pre-printed laboratory manuals and 50% of teachers (n=4) get students to use their own laboratory copies. No teacher got students to use workbook accompanying the textbook.
The next question investigated whether or not the students designed their own investigations.

Figure 4.21 Experimental procedure followed by students *(Results are represented as percentage of total participants n = 8).*

Interestingly 75% of teachers get their students to follow a step by step procedure whereas 25% of teachers allow students to design their own experimental steps (Figure 4.20).

The results from the interview shows an equal divide with two out of the fours teachers saying they get their students to design the experimental steps while the other two teachers said they would not veer away from the step by step procedure. Some of their comments include;

→ “No (I don’t get them to design their own experimental steps), because it won’t guarantee success of experiment or write up, which will knock confidence when I want to build their confidence in the subject” (Teacher interviewee 1)

→ “No, because the students wouldn’t know what to do” (Teacher interviewee 2)

→ “Yes, they know how to carry out experiments after so much training that it becomes second nature to them and they’re able to do it without steps. You would give out equipment and ask “how do you think you would use this” (Teacher interviewee 3)

→ “Yes, because the books that they have are outdated and old anyway. In the school they recycle book and reused them instead of buying new ones so a lot of the
experiments in the biology book are not mandatory and badly explained and laid out. To be honest I do not often use them and either do the students” (Teacher interviewee 4)

These responses show that some teachers do not want biology students to design their own experimental procedures for fear that they could misunderstand or misinterpret the task and perform an incorrect experiment. The understanding and purpose is lost along with any confidence the students may have had in the subject. Other teachers appear to get students to design experimental procedures out of necessity as the textbooks they use are of a poor and outdated nature.

4.6.3 Biology Textbooks Promoting Scientific Inquiry

The next section investigated teachers’ opinions on the use of textbooks in promoting different aspects of scientific inquiry among their students.

![Teachers' Opinions on the Biology Textbook](image)

Figure 4.22 Teachers’ opinions on the biology textbook in developing the students’ scientific process skills (Results are represented as percentage of total participants n = 8).

The textbook was reported as being the main source of knowledge used by both Junior Certificate science students (Figure 4.3) and Leaving Certificate biology students (Figure 4.12). Teachers were asked if they think the textbook promotes the following inquiry skills - formulating, designing, questioning, observing, experimenting and critical thinking. The results show that the majority of teachers (75%) think the biology textbook allows students to
pose a question. Overall, teachers do not think the biology textbook promotes inquiry skills such as formulating, designing, predict, observing or applying techniques (Figure 4.22).

Teachers (75%) do not think the textbook allows students to predict the experimental results and seem divided on the textbook (50% saying ‘yes’ and 50% saying ‘no’) encouraging students to use their experimental results to make new predictions or hypotheses. The majority of teachers said the textbooks do not encourage students to apply new experiment techniques (87.5%) and again appear divided regarding applying experimental results to explain applications of biology in industry and the medical area (50% saying ‘yes’ and 50% saying ‘no’). Teachers seemed divided equally (50% saying ‘yes’ and 50% saying ‘no’) on whether they thought the textbook got students to formulate new questions. The majority said that the textbook did not get students to formulate hypotheses (62.5%).

There appears to be an overall negative response towards textbooks promoting the inquiry skill of ‘designing’ among students. The majority of teachers felt that the textbook did not get students to design how to make observations (75%) nor to design how measurements are taken (75%). There are conflicting opinions between biology students (Figure 4.9) and teachers in the use of textbooks in allowing students the opportunity to design investigations.

To probe further into their opinions about the text books, questions were asked relating to inquiry based skills required by and promoted by the textbook.

![Inquiry Skills Promoted by Textbook](image)

Figure 4.23 Teachers’ opinions on the inquiry Skills promoted by the biology textbook

*(Results are represented as percentage of total participants n=8).*
The majority of teachers (87.5% and 87.5%) felt that the biology textbook promoted reasoning skills and observations skills (Figure 4.23). However, from Figure 4.22 that the majority of teachers do not think the biology textbook promotes inquiry skills such as formulating, designing, predict, observing or applying techniques (Figure 4.22).

The majority of teachers also believed that scientific methodology (62.5%), the skill to think and reason logically (50%) and critical thinking skills (63.5%) are all inquiry skills that get promoted by the biology textbook. The inquiry skill that teachers said is not promoted by the biology textbook is the ability to solve problems (62.5%). Problem solving is one of the skills associated inquiry-based learning. It is essential for students to be able to think critically, to become great future scientists and constant learners.

In contrast to the questionnaire results, when the interviewees were asked if they thought the biology textbook promotes inquiry skills, the majority of them said no. Their comments included;

→ “No, I don’t think it does. I don’t recall any area of the book promoting students ability to reason or problem solve because the book generally tells the student how to do it” (Teacher interviewee 1)

→ “No I don’t think they promote them – the book tends to focus on fact and telling students how to do the experiment. I don’t see where it promotes students to think creatively or understand how to do certain skills” (Teacher interviewee 2)

→ “No, I don’t think it does. I don’t recall any area of the book promoting students ability to reason or problem solve because the book generally tells the student how to do it” (Teacher interviewee 3)

→ “Definitely not if I do not know what inquiry skills are!” (Teacher interviewee 4)

The responses in the interviews appear to contradict the results in Figure 4.23 but are similar to those in Figure 4.22. One interviewee claims she does not even know what inquiry skills are. In light of these responses and the results in Figure 4.23, it could be suggested that some teachers may have answered this question with the expectation or assumption that the textbook has these inquiry skills already incorporated.
The next question investigated teachers’ opinions on how time is allocated in a biology class.

![Teacher Opinions on Time Allocation In Biology Class](image)

Figure 4.24 Teachers’ opinions on the time allocated to different teacher and pupils activities in the biology class (Results are represented as percentage of total participants n = 8).

Interestingly teachers think less than 20% of biology class is allocated to **teacher demonstration**. This equates to a very small proportion of time and contradicts results from Figure 4.4 where science students think a very large to large proportion of class time is taken up with teacher demonstrations. However, in Figure 4.13 the majority of biology students (36.6% and 14.4%) said a small to a very small of time is placed on teacher demonstrations. It could be suggested that at Senior Cycle, there is less of an emphasis on experimental work and therefore demonstrations are not necessary. Also teachers may not do more than the necessary mandatory experiments at Senior Cycle and therefore there may not be a need to demonstrate other experiments.

The majority of teachers (75%) said less than 40% of time was allocated to **experimental work**. This equates to a small proportion of time. This corresponds to the biology students results in Figure 4.13 where students (42.6% and 12.4%) said a small to very small proportion of time is allocated to experimental work. The results from above show some teacher allocate less than 60% which corresponds to the science students results in Figure 4.4 where science students (16.9% and 44.4%) said they have a very large to a large of time allocated to experimental work.
The majority of teachers (50%) felt that oral interaction among students received less than 20% of class time. This result corresponds to both the science and biology students' results. In Figure 4.4 science students (60.2%) said they had a small to very small time allocation for oral interaction among themselves. In Figure 4.13, the biology students (40.6% and 27.2%) also said they got a small to very small time allocation. Some teachers allowed their students a greater length of time engaged in oral interaction. Some teachers (37.5%) said their students spent less than 40% and other teachers (12.5%) said their students spent less than 60% of class time. It could be suggested that this results could be related to time students spent interacting orally with one another during the student experimental work.

The majority of teachers (62.5%) said that less than 80% and less than 60% of class time is allocated to teacher talk. This equates to a very large to large proportion of time and corresponds with both the science and biology students' results. In Figure 4.4 science students (27% and 50.7%) said a very large to large proportion of time was spent listening to the teacher talk. In Figure 4.13 biology students (28.2% and 59.9%) also said a very large to large proportion was allocated. The teachers (50% and 37.5%) who responded their students spent that less than 60% and less than 40% of time listening to the teacher talking seems to contradict the science and biology students' results in Figure 4.4 and Figure 4.13.

A minority of teachers (12.5%) answered less than 80% of class time is allocated to classroom discussion with teacher and students. This equates to a very large/large proportion of time and corresponds again with the both the science and biology students' results in Figure 4.4 and Figure 4.13. The other teachers allocate less than 40% and less than 20% to classroom discussion seem to contradict the science and biology students' results. It could be suggested that teachers think less time is allocated to classroom discussions with teacher and students because it is generally teacher led and therefore could be perceived as teacher talk.

The majority of teachers (50%) said their students get less than 20% of class time allocated to group work. Other teachers (37.5%) said their students got less than 40% of class time engaged in group work. According to teachers (50% and 50%) a small to very small proportion of class time is allocated to student individual work with results ranging from less than 20% to less than 40% of class time. These results correspond to the biology results in Figure 4.13 for both group work and student individual work. However, the science students (23.3% and 39.7%) said they are allocated a very large to large proportion of group work. It could be suggested that at Junior Cycle there is not as much pressure on getting the course covered or time restraints and so more time can be allocated to group work.
All of the interviewees responded as saying they talk a lot during class time. Some of their comments include;

→ “I talk quite a lot of the time” (Teacher interviewee 1)

→ “I talk the majority of the time to guide and tell the students what to do” (Teacher interviewee 2)

→ “I talk a lot during a 40 minute class period. Sometimes it can depend on the topic but generally it is me who does the majority of the talking” (Teacher interviewee 3)

→ “I would talk a lot during class time” (Teacher interviewee 4)

When the interviewees were asked about group work and experimental work, three out of the four interviewees said they do not engage in a lot of group work while only one teacher allows group work as much as possible. These results appear similar to the ones above from the questionnaire with 50% of teachers saying they allocate less than 20% of class time to group work. All of the interviewees said their students engage often in experimental work. Some of the interviewee comments include;

→ “They do the mandatory experiments so over the two years that’s 23. Group work is generally not done too often, probably only during experiments” (Teacher interviewee 1)

→ “At least once a week maybe every two weeks depending on the topic we are doing. Group work is kept to a limit because they are quite a big class and it gets a big chaotic” (Teacher interviewee 2)

→ “They do experiments often, like once a week. The group work depends on the topic but often I would get them to quickly in groups brainstorm or put down their previous knowledge regarding a topic” (Teacher interviewee 3)

→ “They would do an experiment often enough like once a week I try to do an experiment to get them bit more active. Group work generally does not happen because the course doesn’t really allow for it, so much to cover that sometimes I think group work just wastes time because they end missing the point and just talk about their life when they should be doing work in the groups” (Teacher interviewee 4)
All interviewees responded that their students work alone quite often but one interviewee stressed that they prefer their students to be more active and so tries to engage in group work. Their comments include;

→ “Most of the time they work on their own” (Teacher interviewee 2)

→ “A lot of the classes the students work alone because they are taking notes down, filling in their workbooks or experiment books. But I try to get them to do group work or experiments to break the monotonous routine” (Teacher interviewee 3)

Opportunities for both types of discussions are given to their students but the classroom discussions compared to group discussion seem to be more favoured among the interviewees. Three out of the four interviewees favoured the class discussion the most while one interviewee favoured both class and group discussions. Some of their comments and reasons include;

→ “We discuss the experiment results when students have finished and come up with conclusions. Group discussions don’t happen that often” (Teacher interviewee 1)

→ “After experiment or for some exam questions class Discussions go on” (Teacher interviewee 2)

→ “Yes they are given time to discuss in their groups at end of experiments and then we would have a class discussion. Some topics are great for class discussions and I like it because it gives the students a chance to talk and get their opinions heard” (Teacher interviewee 3)

→ “Class discussion probably more so than group because they tend to go off task in groups” (Teacher interviewee 4)

4.6.4 Learning Biology – Teachers opinions on how students learn biology

This section of the questionnaire investigated the teachers’ opinions on how they think students learn biology. The first question sought teachers’ opinions on how often students ask questions in the biology class.
Figure 4.25 Teachers’ opinions on students questioning theory being taught on the Biology Syllabus (Results are represented as percentage of total participants n= 8).

The results show that all teachers said their students (50% and 50%) ask questions either very regularly and regularly. These results correspond to the science and biology students results found in Figure 4.5 and Figure 4.14 were the science students (20.7% and 39.5%) said they ask questions very regularly and regularly and the biology students (17.3% and 40.6%) said they ask questions very regularly and regularly.

The majority of teachers (62.5%) felt their students seldom questioned the theory being taught. This also seems to correspond with the results found in Figure 4.5 where science students (28.4% and 21.1%) said they seldom to never question the theory. The biology students’ results are also quite similar as students (28.7% and 22.8%) said they seldom to never question they theory being taught (Figure 4.14). The majority of teachers said their students seldom (62.5%) questioned and investigated the theory being taught but some teachers (37.5%) said their students regularly did. The results in Figure 4.5 and Figure 4.14 show the majority of the science and biology students seldom questioned and investigated the theory being taught with quite a high percentage of science students (27.4%) and biology students (26.7%) saying they never do.

There seems to be a culture of acceptance of learning off scientific facts among the participating science and biology students. They seldom or rarely question theory and thus are not practicing the key underlying principle of scientific inquiry.

The next question investigated teachers’ opinions on how the think students learn biology.
Figure 4.26 Teachers’ opinions on how students learn Biology (Results are represented as percentage of total participants n= 8).

The majority of teachers (37.5% and 50%) think that students seldom or never do their own research at home. This corresponds to Figure 4.6 and Figure 4.15 where science students (43.1%) and the majority of biology students (50%) said they never do their own research.

The results show that majority of teachers (62.5%) believe students seldom learn by trying to understand the topic. This result seems to contradict the science results in Figure 4.6 where nearly 60% of science students and in Figure 4.15 nearly 66% of biology students’ results said they always try to understand the topic. It could be suggested that because the majority of science students (65.9%) and biology students (76.6%) seldom, very seldom or never question the theory being taught (Figure 4.5 and Figure 4.14) teachers perceive this as a lack of understanding or at the very least a lack of trying to understand the theory.

A large majority of the teachers (87.5%) believe that students seldom take information as a given without ever questioning. This suggests that teachers think their students ask questioning before accepting the information. This contradicts the science and biology students’ results. In Figure 4.6 the majority of science students (77.3%) and the majority of biology students (89.1%) said they always/sometimes take information as a given without question. All of the interviewees’ responses showed they think students do not learn by questioning the theory being taught and are similar to the results from the questionnaires shown above. Their comments included;
→ “On a whole, no but there is always one or two students who are quite bright and what to know more, know why but these are few and far between. Then you have students who just want the notes to learn for exam so there not interested in questioning the theory, just learning it off” (Teacher interviewee 1)

→ “You get the why do we have to learn this question but nothing specific” (Teacher interviewee 2)

→ “They do not question the theory because they are so used to taking things as they are and not questioning” (Teacher interviewee 3)

Interestingly only 12.5% of teachers said they think students learn by the memorisation of facts, with 87.5% of teachers thinking that students ‘seldom’ learn by memorisation. In Figure 4.5 science students (48.1%) they sometimes learn off sets of facts and in Figure 4.14 biology students (50.5%) said they too sometimes will learn off sets of facts.

In the interviews, only one out of the four teacher interviewees mentioned that their students ask questions to clarify and help with their understanding. Their comment included;

→ “They ask questions in most classes. If it’s a topic they find hard, they will ask more questions to help them understand a little better” (Teacher interviewee 4)

When teacher interviewees were asked how they think their students learn a lot of them commented that the problem with just learning topics off is that the students miss the point of actually understanding the topics. Some of their comments include;

→ “All students are different, there are some who try to understand and once they understand they know the answer and the others who don’t understand and just try to learn it off like rote learning”(Teacher interviewee 1)

→ “They study and try to learn off definitions to give it back in exams. They look at the exam questions and try giving the correct answer from memory” (Teacher interviewee 2)

The interviewees’ responses highlight that the summative examination promotes rote learning for the regurgitation of facts and definitions required in the examination questions.
Teachers were asked if they thought the laboratory activities help students confront and change any misconceptions they may have with a biology topic. The results are displayed below.

Figure 4.27 Teachers’ opinions on whether laboratory activities help students confront and change any misconceptions they have on a topic (Results are represented as percentage of total participants n = 8).

Four of the teachers felt that laboratory activities help students confront and change any misconceptions they have on a topic. Two of the teachers felt experimentation does not allow for this and could be the reason why some teachers do not place an emphasis on experimentation in biology class. It is interesting that two of the teachers answered ‘I don’t know’.

The next question investigated teachers opinions on how good are their biology students at drawing conclusions from experiments they have carried out.
Some teachers (12.5%) think that their biology students are "very good" at drawing conclusions from the experiments they have carried out, while other teachers (25%) think their students are "good". A large majority of teachers (63%) said they think their students were "average" at drawing conclusions from experiments. This corresponds with the biology students results were the majority of biology students said they were only average at writing and thinking up conclusions after an experiment.

4.6.5 Inquiry Based Learning in the Current Leaving Certificate Irish Biology Syllabus

This next section investigated teachers' opinions on inquiry based learning in the current biology leaving certificate syllabus. It also investigated the teachers' opinions on the biology syllabus placing an emphasis on investigating and questioning the theory being taught or experimentation in order to find answers or on readymade answers for students to just accept.

Regarding the biology examination paper, the questionnaire investigated what do teachers think biology students have to do in order to achieve good grades in Leaving Certificate biology and do teachers think the current syllabus promote good future scientists.
Some teachers (25%) think the biology syllabus does place an emphasis on inquiry based methods whereas the majority of teachers (75%) felt that they do not think it emphasises inquiry based methods.

The results from the interviews were similar. The interviewees were asked if they think the biology syllabus places an emphasis on inquiry methods and they all responded with a resounding no. Some of their comments included:

→ “I don’t think it does because I would be using inquiry if it did” (Teacher interviewee 1)

→ “No it doesn’t and there is nothing to really enforce the use of inquiry, like if I don’t use inquiry my students will still be able to sit the leaving certificate exam and do well in it” (Teacher interviewee 2)

→ “Definitely not. There are aims and objectives in the syllabus that talk about inquiry based skills and methods but that it. The books, the teaching methods, the exams they all point towards the traditional approach because at the end of the day the student has to sit a 100% exam and our job is make sure the student has all the necessary knowledge to do well but they will just be basically asked to regurgitate the information. There is not testing of their skills” (Teacher interviewee 3)
Teachers were then asked what they think the biology syllabus emphasises.

<table>
<thead>
<tr>
<th>Teacher Opinions on What the Biology Syllabus Emphasises.</th>
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<tbody>
<tr>
<td>Ready made answers for students to accept.</td>
</tr>
<tr>
<td>The data collected is changed/re collected in-order to fit theoretical explanations.</td>
</tr>
<tr>
<td>The data collected during experimentation is interpreted and explanations are changed</td>
</tr>
<tr>
<td>Experimentation in order to find answers.</td>
</tr>
<tr>
<td>Inquiry-based methods.</td>
</tr>
<tr>
<td><strong>Yes</strong></td>
</tr>
<tr>
<td>87.5</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>37.5</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>25</td>
</tr>
</tbody>
</table>

Figure 4.30 Teachers‘ opinions on what aspects of scientific inquiry the biology syllabus places and emphasis on *(Results are represented as percentage of total participants n = 8).*

The majority of teachers (87.5%) think the biology syllabus emphasises readymade answers for students to accept. This corresponds to the results shown in Figure 4.16 where the majority of biology students (53.4%) also said the biology syllabus emphasises readymade answers for students to accept.

A division of opinion appears in the results with 50% of teachers saying ‘yes’ and the other 50% saying ‘no’ to data collected being changed/recollected to fit theoretical explanations. The majority of teachers (62.5%) do not believe that explanations are changed when data collected during experimentation is interpreted. From the results above, the majority of teachers (50%) said they do not think experimentation in order to find answers is emphasised by the biology syllabus. This result contradicts the biology students‘ responses in Figure 4.15 where the majority of students (73%) said they do think it is emphasised.

Most significantly the majority of teachers (75%) said that the Leaving Certificate Biology Syllabus does not emphasise Inquiry based methods. It could be suggested that because the teachers feel it is not emphasised then the need to engage in and encourage inquiry-based methods diminishes as teachers know their students will not be assessed on them. Due to time constraint and pressure to cover the course, areas like inquiry-based methods can be perceived as a luxury as opposed to necessity.
The interviewees responded with similar results to those from the questionnaires. The interviewees feel that the biology syllabus has promoted a generation of student that are impatient and unable to learn and instead have become rote learners. Some of their comments include:

→ "The exam... the 100% written exam” (Teacher interviewee 1)

→ "I think rote learners, students being unable to think for themselves... there is content emphasis with little rewards for students who are good at experimentation and showing other skills” (Teacher interviewee 2)

→ "Rote learners – they are not able to decipher or answer any questions that veer off the main path. They are unable to think for themselves. It is very frustrating” (Teacher interviewee 3)

→ "They have all the answers and knowledge given to them. They answers are ready made almost that they don’t have to develop an understanding... they start at the bottom and they should be working up a step each time but it is like they get a free ride straight to the topic because they can just go to their book and tell you the answer instead of thinking about it” (Teacher interviewee 4).

The biology teachers were asked to give their opinion on whether they think the laboratory activities coincide with the course topics. The results show that 62.5% of teachers said they think the laboratory activities are always closely parallel with course topics and 37.5% said that the laboratory activities are sometimes parallel.
Teachers were asked what they think students have to do in order to be successful in leaving certificate biology.

Figure 4.31 Teachers’ opinions on what students need to do to be successful in the leaving certificate biology examination (Results are represented as percentage of total participants n = 8).

These results show that 100% of the teachers think that in order to be successful in the leaving certificate biology examination, it is most important that students are able to answer past exam questions and also most important for students to memorise scientific facts. Interestingly, it could be suggested that majority of teachers seem to focus on ‘rote learning’ due to the high importance they appear to be placing on memorising and answering past exam questions.

Surprisingly, nearly half of the teachers (37.5% and 12.5%) said that it is less important and least important for students to understand every topic. Therefore this highlighted that teachers may teach towards the requirements of the examination i.e. the memorisation of facts. The development of scientific skills appear to rate quite low as the majority of teachers (50% and 25%) said it is less important and the least important factor in being successful in leaving certificate biology. This is due to the fact that there is no practical assessment in biology, with no emphasis on practical inquiry skills on the examination paper.

The interviewees responded similarly to the results found above from the questionnaire. All interviewees said they think students need to understand all aspects of the units in biology but also have an ability to learn large volumes of material. It is unfortunate
they feel, but because of the 100% written exam, students only get examined on what they know and show on the page in the exam. Some of their comments include;

→ “For the current Leaving Certificate exam, the students must knowledgeable in all areas of the units but especially unit 3. They need to understand the topics and the experiments, be rehearsed in the questions from the exam papers and practice, practice, practice…” (Teacher interviewee 1)

→ “Understand the material…answer what they ask… not what you think they asking because the exam marking scheme is very specific at higher level so you have to actually understand and know your stuff to do well” (Teacher interviewee 2)

→ “Be present and attentive and start studying in 5th year. Try to get to grips with some topics in 4th year and maybe do some of the harder experiments but overall, be present, be attentive and ask in order to understand” (Teacher interviewee 3)

→ “A rote learner with an ability to memorise and regurgitate… because that is what this exam and syllabus advocates” (Teacher interviewee 4)

4.6.6 Inquiry Based Learning

In this section, the biology teachers understanding of what is inquiry based learning was investigated. When asked, all the teachers said “yes” to understanding the meaning of Inquiry Based Learning. Table 4.4 The results in percentage format, when teachers were asked to tick the appropriate box to indicate what they think inquiry based learning involves.

<table>
<thead>
<tr>
<th>Please indicate below what you think Inquiry based learning involves:</th>
<th>Yes</th>
<th>No</th>
<th>I don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Making Observations</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Posing Questions</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Accessing and using relevant information</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Planning and carrying out investigations</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Using tools and technology to collect, analyse and interpret data</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Proposing answers | 100 | 0 | 0
Proposing explanations and predictions | 100 | 0 | 0
Communicate findings | 100 | 0 | 0

(Results are represented as percentage of total participants n = 8).

The interviewees were asked during the interview if they know what inquiry is and what it involves. One interviewee said no and three out the four interviewees said ‘yes’. Some of their responses include;

→ "Yes. Posing questions and leading them to a conclusion by asking questions and getting responses” (Teacher interviewee 1)

→ "Yes you have to mention something, plan a topic, the students tell you about the concept, give their understanding or meaning” (Teacher interviewee 2)

→ "Yes. It involves developing students critical thinking by using alternative methods to the traditional class like developing students scientific skills by getting them to analyse, conceptualise, predict... there are lots of skills” (Teacher interviewee 3)
Teachers were asked if they believed Inquiry based learning requires students to carry out experiments.

![Figure 4.32 Inquiry based learning is getting students to carry out experiments (Results are represented as percentage of total participants n = 8).](image)

The majority of teachers (75%) agreed that inquiry based learning is getting students to carry out experiments. 13% of teachers disagreed, while the other 13% did not know.

It could be suggested most teachers then believe they are engaging in inquiry-based learning because they are carrying out experimentation because of the mandatory biology experiments.
The next question investigated teachers’ views on the process of scientific inquiry and the steps that investigations should follow.

Figure 4.33. Teachers’ opinions on the order of scientific inquiry (Results are represented as percentage of total participants n= 8).

Six out of the eight teachers (75%) listed the stages for scientific inquiry differently and two out of the eight teachers (25%) managed to list the same order.

The variety of responses given could suggest that there is a lack of understanding among teachers regarding scientific inquiry. Alternatively, some teachers may have confused scientific inquiry with scientific method and therefore based their response on this. This highlights a need for teachers to engage in continuous professional development (CPD) to keep up to date on innovative teaching methods.

The majority of teachers (n=6) said they use inquiry based learning in their teaching and in some classes. Feedback on how they incorporate inquiry based learning is varied and is displayed in a pie chart below.
Teachers gave a variety of responses when asked to explain how they would incorporate inquiry into their teaching. The responses teachers mentioned included using project work, getting students to engage in experimentation, prediction and higher level questioning. Some teachers proposed problems and got their students to formulate the answers. All of these skills encourage inquiry-based learning. However, there were two teachers (25%) that gave no response to how they incorporate inquiry into their teaching suggesting that they do not use inquiry-based methods in their teaching.

During the interviews, one out of the four interviewees responded that they never incorporate inquiry into their teaching; one other interviewee said they sometimes incorporate it and two out of the four said they incorporate it into most classes. When three of the interviewees were asked how they incorporate inquiry into their teaching, the interviewees gave varied responses that included:

→ "Asking questions, doing group work, let them come up with the reasons” (Teacher interviewee 1)

→ "Give them word and do a bubble diagram and give their understanding” (Teacher interviewee 2)
“By letting them come up with their own understanding, worksheets, brain storms, setting achievable goals that boosts confidence and the concept is not out of their reach” (Teacher interviewee 3).

When Teacher interviewee 4 was asked why she did not incorporate inquiry methods in her class and her response included;

“Because there are a lot of hurdles to get over... I would really like to because it would be great for the students, but realistically I cannot and it won’t happen. In college it’s pushed onto you and you had to learn quick. Maybe if we started earlier in college and then in teaching then the students wouldn’t need as much help and it would become second nature to them” (Teacher interviewee 4)

The interviewees who used inquiry methods were questioned further and were asked if they encountered any difficulties when incorporating inquiry into their lessons. The difficulties varied from students misinterpreting or misunderstanding the topic, student ability and mixed ability classes to classroom management issues. Some comments include;

Them (the students) coming to the wrong conclusion or wrong answer they remember those so it is important to lead questions to ensure that they understand concept, it is hard to break that attachment to incorrect concepts” (Teacher interviewee 1)

Shouting out and they say some off the wall stuff that is not relevant and misses the point completely” (Teacher interviewee 2)

“If the concept is too abstract and they go too far, it is confusing and difficult to get them back. Using too small groups or weak groups together are difficult because they need to be told what to do!” (Teacher interviewee 3)

When interviewees were pressed on the benefits associated with inquiry for students, three out of the four interviewees responded with relevant benefits that included;

Makes concepts or topics more accessible and the students understand at their own pace and ability or concept level” (Teacher interviewee 1)
They are in control of their learning, they remember more because they came up with themselves” (Teacher interviewee 2)

“Improve critical thinking, improves retention of knowledge – I see, I learn – I do and I inquire” (Teacher interviewee 3)

The interviewees who used inquiry methods were asked if they saw any improvement in exam results and three out of the four interviewees responded that their students‘ results were better. Some comments include;

“Yes, my students in the inquiry class seemed to do better in the exam result” (Teacher interviewee 1)

“Exam results were better in the inquiry classes” (Teacher interviewee 2)

“They did improve, they were able to give better explanations” (Teacher interviewee 3)

Interviewees were then asked how they think inquiry based learning could be better incorporated by teachers. Their responses ranged from the need for inquiry resources and a change in assessment to less pressure to complete syllabus and more time for discussion. Some of their comments include;

“Particular resource pack on chapters with questions or experiment questions to help lead the discussion on topics, worksheets” (Teacher interviewee 1)

“More time in class for experiments and discussions and less pressure of syllabus completion” (Teacher interviewee 2)

“Assessment…Teachers are too didactic because we have no other option because we are tied to the assessment. Change the assessment and you change the way things are taught” (Teacher interviewee 3)

“Having some pre and post worksheets to help with hammering home the point of the topic and experiment because a lot of the time in biology they miss the point of doing the experiment and compartmentalise the topics instead of linking them” (Teacher interviewee 4).
From the interviews, it can be seen that the teachers who use inquiry-based methods know of the benefits and advantages it has for student learning. This does not seem to overcome the numerous issues such as continuous professional development, resources, time constraints and assessment that are at the forefront of why more teachers say they do not readily engage in inquiry-based methods.

### 4.6.7 Implementing Inquiry Based Learning in the Classroom

Teachers who engaged in the interviews were asked to give opinions on factors that they think may cause implications for using inquiry based methods in the classroom. Teachers who participated in the questionnaire were asked to tick a factor they considered to be an implication for incorporating inquiry. The results from the interviews and the questionnaire are displayed below.

![Figure 4.35](image)

From the interviews, it can be seen that the teachers who use inquiry-based methods know of the benefits and advantages it has for student learning. This does not seem to overcome the numerous issues such as continuous professional development, resources, time constraints and assessment that are at the forefront of why more teachers say they do not readily engage in inquiry-based methods.

The results show that 100% of teachers do not think poor textbooks are a factor that can cause implications. It could be suggested that the reason for this is the dependence that students and teachers appear to have on the textbook. The majority of science students in Figure 4.3 and biology students in Figure 4.12 have reported that they use the textbook as the source of knowledge and in Figure 4.8 the majority of biology students (77%) said they use textbook to help write up their experiments. In Figure 4.21, the majority of teachers (75%) said their
students follow step by step procedures from the book for experimental procedure. There appears to be some conflicting results regarding the meaning of inquiry-based learning which could cause an implication. Figure 4.35 shows 87.5% of teachers said there is no confusion about its meaning. But results in Figure 4.22 show the majority of teachers think inquiry skills are not emphasised in the textbooks while in Figure 4.23 results showed that teachers do think certain inquiry skills such as reasoning and observing are promoted by textbooks. It could be suggested that this shows some misunderstanding towards inquiry-based learning.

Teachers (87.5%) said that being unprepared for students’ questions would not cause implications for inquiry based methods. A reason for this is because the majority of science and biology students seldom, very seldom or never question the theory being taught (Figure 4.5 and Figure 4.14). Teachers were asked if difficulties with group work could cause implications and 87.5% said ‘no’. The science students (22.3% and 39.7%) reported that a very large to large proportion of class time is allocated to group work. However, the biology students (39.6% and 17.8%) reported that only a small proportion to very small proportion of class time is allocated to group work, with some students (3%) saying they never do group work. There appears to be a difference between the Junior Cycle and Senior Cycle regarding group work. It could be suggested that as students move into Senior Cycle more emphasis is placed less on group work and more on the theory, getting the course completed and examinations.

This appears to be the case as the majority of teachers (87.5%) said ‘yes’ when asked if they think getting the course covered for examinations restricts using inquiry based learning. This is also highlighted in Figure 4.17 by biology students (53% and 27%) who responded that the most important and important factor for being successful in Leaving Certificate Biology is to study in order to answer past exam questions.

Teachers were also asked if a lack of time causes implications for inquiry based methods and 87.5% of teachers said ‘yes’, that inquiry methods are time consuming. It could be suggested that this is the reason why teachers do not engage in inquiry-based skills during experimentation such as designing, formulating, observing and why in Figure 4.21, a large majority of teachers get their biology students (75%) to follow a step by step procedure for experimental procedure.

100% of teachers think the syllabus content restricts using inquiry based learning. The majority of biology students (53.4%) in Figure 4.16 and biology teachers (87.5%) in Figure 4.30 said they think the biology syllabus promoted ready-made answers for students to accept. In Figure 4.29 the majority of teachers (75%) said that the biology syllabus does not
place an emphasis or promote inquiry-based learning.

Surprisingly, 62.5% of teachers said ‘no’ that they don’t think the challenge of the assessment could cause implications for inquiry-based methods and a large majority of teachers (75%) thinks inquiry lack a clear definition would not cause any implications for inquiry based methods. It could be suggested that all of these factors would not cause implication as students are not assessed on inquiry-based skills. With regards to assessment, interviewees were asked during the interview why they thought more teachers were not adopting inquiry methods and one out of the four interviewees said he thought it was because of how teachers were taught themselves and because of the challenge of assessment. His comments include;

→ “Teachers teach how they were taught. No matter what work you do it comes down to what they can deliver on the day of exam. It’s about what they know. There is not enough questions that test their scientific knowledge, critical thinking, and until that changes then there will be no change in assessment and therefore no change in the way teachers teach. There is too much recall and a definite need to change questions towards more scientific questions” (Teacher interviewee 3)

The results from the questionnaire (Figure 4.35) mirror the responses from the interviewees when they were asked why they think inquiry methods are not adopted by all teachers. Three out of the four interviewees’ responses emphasised ‘time’ and ‘pressures of the syllabus’ as factors that causes implications. Teacher interviewee 4 responded in detail to this question because she does not use inquiry methods. Some of their comments include;

→ “Time restraints and pressure of syllabus are important ones” (Teacher interviewee 1)

→ “Need longer class time and the pressure of syllabus” (Teacher interviewee 2)

→ “I think (it is because of) time restraints, students lacking capability and pressures of syllabus that definitely contribute. If the ability of the student is not there then it is very difficult to use inquiry in class. They won’t get it and you will waste time trying to achieve one understanding of one topic. It would take too long especially in LC biology where you have a course to cover and little time to revise, under a lot of pressure and as a teacher you will be given out to by students if you don’t get things covered quickly. In college you left on your own in labs and you just have to get on
with it and do it or fail. There needs to be more scientific skills incorporated to develop their ability to think without constant help” (Teacher interviewee 4).

21% of biology students reported handouts as a source of knowledge used in their biology class (Figure 4.12). This shows the researcher that teachers make and use their own resources. If a new method of teaching is to be successfully implemented teachers would require suitable resources as making their own would be time consuming. The majority of teachers (87.5%) said ‘yes’ they would require resources for inquiry based methods (Figure 4.35) as not having them could cause implications for inquiry-based learning.

Other results include 50% of teachers who said they would need support and need to be trained and professional development provided while the other 50% said ‘no’ to both factors. Interestingly though, one of the final questions in the questionnaire asked teachers would they like to receive training and information on inquiry based learning and 100% of teachers responded with ‘yes’.

The interviewees responses sheds some light on the issue of professional development and support when interviewees were asked how they think teachers could develop their understanding of inquiry. All of the interviewees’ responses were comparable and ranged from the need for hands on training and in services to being supplied with resources.

→ More training to get teachers up to speed and teach them how to ask leading questions without giving too much away because posing questions is difficult” (Teacher interviewee 1)

→ Maybe we could go to in-services or become more of a prominent feature in college course so we learn as we go what we should be doing in a classroom… like when new methods come on board, teachers are just expected to implement them and we are the problem why it is not working. But the need to be up skilled seems to be a second thought” (Teacher interviewee 2)

→ “There needs to be more training for teachers, packs given to teachers, expose it to teachers by other people who have practiced and used it and seen benefits, show teachers why they should use this method, should be teacher leadership instead or going against it and not motivating” (Teacher interviewee 3)
→ “With In services and maybe get someone to come to school and teach a class in inquiry method and I can copy them and see how it suppose to look and to see if they have any resources I could use” (Teacher interviewee 4)

The next question investigated teachers’ opinions on the type of control they would have in the classroom if they engage in inquiry based methods. 100% of the teachers (n=8) thought that inquiry based lesson meant the teacher has part control.

Teachers were then asked if they thought the biology syllabus allowed for the introduction of scientific inquiry and 50% of teachers (n=4) said ‘yes‘ they believe the biology syllabus allows for the introduction of scientific inquiry, 25% said ‘no‘ and 25% said ‘I don’t know. However, the majority of teachers said they do not think the biology syllabus promotes inquiry-based methods (Figure 4.29). Teachers may have been confused the term scientific inquiry with scientific method.

The next question investigated if teacher think the current biology syllabus promotes good future scientists. The bar chart summaries the results.

Figure 4.36. Teachers’ opinions on whether the current biology syllabus promotes good future scientists (Results are represented as percentage of total participant’s n= 8).

This bar chart shows that 25% of teachers said ‘yes‘ the current biology syllabus promotes good future scientists and a large majority (75%) of teachers responded by saying ‘no‘, they
do not think this is the case.

Interviewees’ responses were all very similar when asked if the current biology syllabus promotes good future scientists. Three out of the four interviewees responded with definite a _no_ while one interviewee commented that there is potential for it to but due to a number of constraints it has not happened. Their comments include;

→ _Potentially it could but the deliverance is just not practiced in the right way because we focus on the end product being the exam. It has great topics, you could really use inquiry but there just seems to be a lot of constraints that it doesn’t happen all of the time. It’s easier to just teach for the exam”_ (Teacher interviewee 1)

→ _No, it’s not great because of the constraints of assessment and the focus and pressure on the Leaving certificate exam. Like in transition year there is great opportunity to do real scientist stuff because of the freedom they generally have”_ (Teacher interviewee 2)

→ “No, how would it be when all we can do is teach to the exam and we want the students to get good results so they can get their points for their course and go to college. I could do inquiry lessons – lovely and spend ages preparing and deliver the lesson and then go to exam paper and the questions will still ask the facts and not the skills they used to gathering this knowledge. There is no assessment of scientific skills even though they are promoted in the syllabus”_ (Teacher interviewee 3)

→ _No, it prepares the student for the exam”_ (Teacher interviewee 4)

Teachers were then asked what ability of student they thought inquiry based learning methods suited best. The results show that 25% of teachers (n=2) said they think inquiry based learning was most suited to higher ability of students, while 75% of teachers (n=6) said that inquiry based learning is suitable to both higher and weaker ability students.

Interviewees were asked what ability of student do they feel inquiry based methods would be suitable for. Three out of the four interviewees felt that higher ability students would be better at doing inquiry methods, with one interviewee saying she thought it would suit all abilities. Some of their comments include;

→ _Higher ability would be better at doing inquiry but it can be used with all ability of students I think”_ (Teacher interviewee 1)
→ "It would probably suit all ability student... like there are different benefits for the different abilities" (Teacher interviewee 2)

→ "I think the high ability kids will always plough ahead and get it wrong or right, average ability kids waiting to see what other lads are at and then the weaker ability are doing nothing. So probably suit higher/average ability” (Teacher interviewee 3)

→ “Higher ability because I don’t think the lower ability would be capable of understanding and doing tasks without being told exactly how, it would go over their head and they would miss the point of the lesson” (Teacher interviewee 4)

Finally, teachers were asked how well they think their students are or would take to learning through inquiry based methods. 50% of teachers (n=2) said students would take to learning though inquiry based methods ‘well’, 13% of teachers (n=1) said the students would do ‘very well’ and surprisingly 38% of teachers (n=5) said their student would not do so well being taught through inquiry based methods.

4.7 Summary

This chapter presented the results from questionnaires give to science students, biology students and biology teachers. The main findings from the biology students’ and biology teachers’ interviews were also presented and full transcripts can be viewed in Appendix 5 and 6 on the attached CD.

Some of the main findings include;

- The majority of both science students and biology students use their own laboratory manuals.
- Most teachers use pre-printed manuals while other get students to use own laboratory copies.
- The majority of both science and biology students write up their laboratory experiments on their own.
- The majority of science and biology students said they ‘follow step by step procedure from their textbook and teachers get their students to follow a step by step procedure. The teacher interview responses showed that some teachers do not want biology students to design their own experimental procedures for fear that they could misunderstand or misinterpret the task and perform an incorrect experiment.
The majority of science and biology students do not get to work according to their own design, which is the underlying principle of inquiry based learning. However both science and biology students said they got the opportunity to design experimental procedures, design how to make observations, how measurements are taken and create a theory, which is contradictory.

A large majority of science and biology students identified the textbook the main source of knowledge used in class.

Biology students said they thought scientific knowledge; scientific understanding, to think and reason logically, observational skills, problem solving skills and critical thinking skills were all being promoted in their textbook and workbooks. Teachers do not think the biology textbook promotes inquiry skills such as formulating, designing, predict, observing or applying techniques but felt the biology textbook promoted reasoning skills and observations skills. The responses in the interviews appear to contradict the results - some teachers may have answered this question with the expectation or assumption that the textbook has these inquiry skills already incorporated.

A large majority of both science and biology students said a very large proportion to a large proportion of time is spent listening to the teacher talk in class. Teacher results correspond to these results.

The majority of science students said a very large proportion to a large proportion of class time was spent working in groups and allocated to student laboratory work.

The majority of biology students said the opposite, spending a small to very small proportion of class time is spent on experimental work and a small to very small proportion of class time on group work. The teachers‘ results regarding experimental work also correspond to those of the science and biology students.

The science and biology students‘ results show that they very regularly/regularly ask questions in class. The teachers‘ results correspond.

A large majority of science and biology students seldom, very seldom or never questioned the theory and never questioned and investigated the theory being taught. The majority of teachers felt their students seldom questioned the theory being taught or questioned and investigated the theory being taught.

The majority of science and biology students seem to always or sometimes take information as a given without ever questioning it. Similar proportions of science and
biology students said they *always* or *sometimes* learn by learning off a set of facts. A large majority of the teachers believe that students seldom take information as a given without ever questioning and seldom learn off sets of facts. This contradicts the science and biology students’ results.

- A large portion of science and biology students said they never do their own research at home. The majority of teachers think that of students seldom or never do their own research at home
- The majority of biology students and teachers said the biology emphasised ready-made answers for students to accept experimentation. Teachers said that the Leaving Certificate Biology Syllabus does not emphasise Inquiry based methods.
- The majority of biology students placed a very important to important emphasis on understanding every topic, memorising scientific facts and studying in order to answer past exam papers. Students placed the less importance and least importance on developing scientific skills.
- Teachers think that in order to be successful in the leaving certificate biology examination, it is most important that students are able to answer past exam questions and also most important for students to memorise scientific facts. half of the teachers said that it is less important and least important for students to understand every. Most teachers agreed that inquiry based learning is getting students to carry out experiments.
- The majority of teachers said that poor *textsbooks, the meaning of inquiry-based learning and group work* are not factors that can cause implications.
- They think *getting the course covered for examinations; lack of time and syllabus content* restricts using inquiry based learning. The results from the questionnaire mirror the responses from the interviewees when they were asked why they think inquiry methods are not adopted by all teachers. Three out of the four interviewees’ responses emphasised _time_ and _pressures of the syllabus_ as factors that causes implications.
- The majority of both biology students and biology teachers think the current biology syllabus does not promote good future scientists.
Chapter Five
Results from the Intervention Programme

5.0 Introduction

This chapter presents the results of intervention programme. The first section will display the main findings from the analysis of the inquiry-based teaching resources that were developed in part two of the research project. Before each inquiry lesson, the students completed a pre-lesson questionnaire. The students then engaged in the inquiry based lessons and completed a post-lesson questionnaire at the end of every lesson (see Appendix 8 for the complete Inquiry Based Biology Lesson Student Booklet). A sample of the students comments are also displayed and completed sample lessons and full comments from students’ folders can be found on the CD attached with this thesis. A pre and post questionnaires for each lesson were given to 24 students in the inquiry class over the 14 week period of the intervention programme. The main aims of the questionnaires were to;

- Assess transition year students’ achievements and attitudes in the two different classes towards biology.
- Investigate the effect Inquiry Based Learning on how students engage in the learning process and their overall understanding in science.

Students were asked to tick boxes of pre-determined answers in the pre- and post-lesson questionnaires. These responses were coded and analysed in SPSS version 18. Some questions required students to respond freely. Space was allocated to students for answers given to open-ended questions. These responses were also coded and analysed.

The second section focuses on part three of the aims of this research project and will report the main findings from the six student interviews that were undertaken. The entire student interviewee responses reported in this chapter were free responses. A pre- and post-interview was conducted with four students who engaged in the inquiry lessons and with two students that were taught biology in a traditional style of teaching i.e. that did not take part in the intervention programme. The responses were coded, analysed and used as qualitative data. These interviews probed deeper into the attitudes and opinions and gain a better insight and understanding of the students who engaged in both the inquiry and traditional science/biology classes. Interviewees’ comments from the inquiry class are then compared to the two interviewees from the traditional science/biology class who were also interviewed.
The inquiry and traditional interview transcripts can be seen in full in Appendix 7 on attached CD.

5.1 Lesson One – Introduction to Inquiry

The following section summarises student responses and sample comments made by students from the pre- and post-lesson questionnaires. The Inquiry Based Biology Lesson Student Booklet can be seen in Appendix 8. For all comments or viewing of completed pre- and post-questionnaires, see accompanying CD.

Table 5.1 The feedback and responses given by participants in the pre and post questionnaire when they were asked what they think a scientist is.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>83%</td>
<td>A person that tries to find out things and how things work.</td>
<td>21% A person that tries to find out things and how things work.</td>
</tr>
<tr>
<td>4%</td>
<td>Does Experiments</td>
<td>8% Does Experiments</td>
</tr>
<tr>
<td>8%</td>
<td>Really Smart</td>
<td>13% Really Smart</td>
</tr>
<tr>
<td>0%</td>
<td>Scientific/inquiry Skills</td>
<td>56% Scientific/inquiry Skills</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n = 23).

The pre-lesson questionnaire shows that the majority of students have limited knowledge of what a scientist is i.e. they think it is a person who finds out things and how they work. A significant difference between the pre- and post lesson questionnaire is the use of term scientific/inquiry skills. A large majority of students responded that scientists use various inquiry skills such as experimentation, problem solving, formulating and analysing.

Table 5.2 The change in comments when a sample of inquiry students’ when they were asked what a scientist is.

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Knows facts, equations and definitions</td>
<td>Uses logic, communicates, works things out and solves problems</td>
</tr>
<tr>
<td>2</td>
<td>Is smart, inventive and knows lots about how things work</td>
<td>They analyse, think and come up with new ideas and experiment.</td>
</tr>
</tbody>
</table>
They calculate and present.

They have logical thinking, communication skills, they experiment and collect data.

(Results are represented as percentage of total participants n = 23).

The next question questionnaire asked students about how they are taught science/biology in school. The answers participants gave in both the pre and then post questionnaire are as follows;

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety skills</td>
<td>8%</td>
<td>0%</td>
</tr>
<tr>
<td>Safety Skills</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Being smart and</td>
<td>21%</td>
<td>Being smart and</td>
</tr>
<tr>
<td>knowledgeable</td>
<td></td>
<td>knowledgeable.</td>
</tr>
<tr>
<td>Challenge beliefs</td>
<td>4%</td>
<td>0%</td>
</tr>
<tr>
<td>Challenge beliefs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimentation skills</td>
<td>29%</td>
<td>33%</td>
</tr>
<tr>
<td>Experimentation skills</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inquiry skills</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>Inquiry skills</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logical thinking</td>
<td>87%</td>
<td></td>
</tr>
<tr>
<td>Problem solving</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Prediction</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Observation</td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td>Data collection</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Mathematical skills</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Analysis</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>Formulating hypothesis</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>Pattern seeking</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>Research</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>Design of experiments</td>
<td>4%</td>
<td></td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n = 23).
Students developed a deeper understanding and awareness of the scientific process skills (predicting, analysing, problem solving, formulating hypothesis). This can be clearly seen in the Table 5.3 above and also in the students’ comments (Table 5.4).

Table 5.4 The changes in student opinion between the pre- and post questionnaire when asked what scientific skills scientists should have.

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Be able to think on their feet…smart.</td>
<td>Have good common sense, logic and good problem solver.</td>
</tr>
<tr>
<td>2</td>
<td>Be able to carry out experiment and know how to actually do it.</td>
<td>Be able to communicate, analyse, collect data and come up with new ideas.</td>
</tr>
<tr>
<td>3</td>
<td>Be able to use their knowledge to think outside the box.</td>
<td>Be able to formulate, analyse, observe and make deductions.</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

The intervention programme got students in the inquiry class to use scientific and inquiry skills during their lessons in order to mirror the work of a scientist. Students’ responses in the post-lesson questionnaire show they have a greater understanding of what scientific skills a scientist should use.

Table 5.5 The percentage of participants who responded with specific comments and the change in these responses between the pre and post questionnaire when asked how they were taught science/biology in school.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>79%</td>
<td>From the teacher (teacher explanations, taking down notes, teacher power point, listening to teacher, teacher demonstrations).</td>
<td>0% From the teacher (teacher explanations, taking down notes, teacher power point, listening to teacher, teacher demonstrations).</td>
</tr>
<tr>
<td>0%</td>
<td>Learn from each other and in groups.</td>
<td>44% Learn from each other and in groups.</td>
</tr>
<tr>
<td>21%</td>
<td>Talking through experimental</td>
<td>0% Talking through experimental</td>
</tr>
</tbody>
</table>
method and then doing it. method and then doing it.

0% Designing and carrying out experiments. 56% Designing and carrying out experiments.

62% Using book, learning off notes and definitions 0% Using book, learning off notes and definitions

(Results are represented as percentage of total participants n = 23).

The majority of students commented (79%) that they are taught science/biology through their teacher which suggests that the majority of class time is very teacher lead (Table 5.5). A strong comparison can be made with the students in the intervention programme who were taught through inquiry-based methods, where all students commented that they either learned from each other through group work or group discussion or designed and carried out their own experiments. These results are also highlighted in the students’ comments below.

Table 5.6 shows the change in students’ opinions when asked how they are taught.

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>By learning things and then doing an experiment</td>
<td>By doing everything ourselves and coming up the conclusion ourselves too</td>
</tr>
<tr>
<td>2</td>
<td>By taking down notes and learning things off.</td>
<td>We are taught to do it ourselves and not depend on others to tell us.</td>
</tr>
<tr>
<td>3</td>
<td>Take down notes and learn them off.</td>
<td>We have to plan the experiment ourselves and do it.</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n = 23).

The next question asked related to carrying out experiments.

Table 5.7 The responses given in the pre and post questionnaire when students were asked if they are told to carry out the experiment.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>96%</td>
</tr>
<tr>
<td>No</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n = 23).
Students said they get told how to carry out experiments in a traditional science/biology class. After completing the intervention programme, students said they are not and some students commented that they had to think about carrying out the experiment. There is a stark difference in the results (Table 5.7) and are emphasised by the students' comments in Table 5.8 below.

Table 5.8 The change in students’ responses when asked how they carry out experiments.

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes, we are told the steps and are prepared before doing it.</td>
<td>No, we had to come up and use our own methods and procedures; we had way more freedom… that was good.</td>
</tr>
<tr>
<td>2</td>
<td>Yes by the teacher</td>
<td>No, we had to do it ourselves. It was fun and interesting.</td>
</tr>
<tr>
<td>3</td>
<td>Yes we are told how to carry them out.</td>
<td>No, we had to make up experiments to answer the task question.</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

Table 5.9 The pre and post questionnaire responses given by participants when asked if they know the result before doing the experiment.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

In traditional science/biology classes, students said they know the results of their experiments beforehand. After doing the intervention programme, all students said they did not. During the intervention programme, students designed and carried out several experiments with less emphasis been placed on knowing the result and more on the scientific inquiry method used.

Table 5.10 The results of the pre and post questionnaires when participants were asked how they write up their experiments;

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory copy</td>
<td>Laboratory copy</td>
</tr>
<tr>
<td>Laboratory manuals</td>
<td>Laboratory manuals</td>
</tr>
</tbody>
</table>
Power Point presentations | 75%  
Posters | 38%  
Worksheets | 38%  
Handouts | 21%  
Project | 4%  

(Results are represented as percentage of total participants n =23).

The striking difference between the pre- and post- is the variety of ways students presented their results in the intervention programme. The students said traditionally they just use their laboratory copy or manuals. Students in the intervention programme said they used technology and other innovative methods to display their results when compared to the traditional forms of teaching. These results are also emphasised in student‘s comments seen below in Table 5.11.

Table 5.11 The change in students‘ responses when asked how they write up their experiments;

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Step by step instruction of what we did in the laboratory copy</td>
<td>On the task sheets.</td>
</tr>
<tr>
<td>2</td>
<td>How it started and how it finished.</td>
<td>I would present them in PowerPoint presentations.</td>
</tr>
<tr>
<td>3</td>
<td>We write about how we started, what we did during and the results in our laboratory copy.</td>
<td>We put our results in poster or PowerPoint forms.</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

Table 5.12 The difference in students‘ responses in the pre and post questionnaire when they were asked what aspect of science/biology they enjoy.

<table>
<thead>
<tr>
<th>Pre</th>
<th>54%</th>
<th>33%</th>
<th>4%</th>
<th>8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiments</td>
<td>Freedom of Experiments</td>
<td>83%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biology topics</td>
<td>Biology topics</td>
<td>4%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outdoor experiments</td>
<td>Outdoor experiments</td>
<td>0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I don't know if I like any aspect</td>
<td>I don't know if I like any aspect</td>
<td>0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In both the pre- and post- questionnaires, ‘experiments’ were regarded as the most enjoyed aspect by students. However, a noticeable difference between a traditional class and the intervention programme was the freedom students said they had doing the experiments. Some of the student’s comments are shown in Table 5.13 below.

Table 5.13 The change in students’ comments made in the pre and post questionnaire towards the aspect of science/biology they enjoy.

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>The experiments</td>
<td>Finding out things I never knew before.</td>
</tr>
<tr>
<td>3</td>
<td>Doing the experiments</td>
<td>Being actually allowed to do the experiments.</td>
</tr>
</tbody>
</table>

5.2 Lesson two: Experimentation

The following section displays the results from the pre-lesson and post-lesson questionnaires. To view an Inquiry Based Biology Lesson Student Booklet, see Appendix 8 on the attached CD. For all comments or viewing of completed pre- and post- questionnaires, also see accompanying CD.

Table 5.14 The results from the pre and post questionnaires when students were asked if they had ever done dissections before either on their own or teacher demonstrated.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>79%</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>21%</td>
<td>No</td>
</tr>
</tbody>
</table>

Of the 79% said ‘yes’;

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissection</td>
<td>42%</td>
<td>Dissection</td>
</tr>
<tr>
<td>Dissection Demo</td>
<td>29%</td>
<td>Other</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).
The pre questionnaire revealed that a large proportion of students have engaged in dissection/dissection demonstration. The experimentation lesson in the intervention programme called for all students to participate in dissections so hence all of the students in the post questionnaire responded “yes”. Noticeably in traditional classes, less than half of the students said they got to dissect themselves while quite a large proportion viewed a demonstration of a dissection.

Table 5.15 The results when students were asked if they got the opportunity to choose the organ for dissection.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th></th>
<th>Post</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>23%</td>
<td>Yes</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>77%</td>
<td></td>
<td>No</td>
<td>0%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n = 23).

In traditional science/biology classes, the majority of students said they do not get to choose their organ. During the Design, Dissect and Presentation lesson (see Appendix 8) all students had to decide on an organ, video and take photos of the dissection and present through poster or Power Point format.

Table 5.16 The participants’ responses in the pre and post questionnaires when they were asked how they carried out their experiments.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th></th>
<th>Post</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Step by step instructions</td>
<td>100%</td>
<td>Step by step instructions</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>Developed own steps</td>
<td>0%</td>
<td>Developed own steps</td>
<td>96%</td>
<td></td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n = 23).

An important aspect of being a lifelong learner is the ability to think critically and for yourself. The traditional science/biology class does not encourage this as students said they followed step by step instructions when carrying out experiments. However, the inquiry lessons in the intervention programme encouraged students to design and develop their own steps to all their experiments and practice their inquiry skills.

Table 5.17 The students’ responses when they were asked which method they would prefer.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th></th>
<th>Post</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Step by step instruction</td>
<td>63%</td>
<td>Step by step instruction</td>
<td>35%</td>
<td></td>
</tr>
</tbody>
</table>
It is interesting to note that after completing the inquiry lesson, more students said they would prefer to develop their own steps for the experiments. In a traditional science/biology class students would have preferred the step by step instruction method. However, once students engaged in the inquiry lessons through the intervention programme, the students favoured developing their own steps. Students were pressed further to explain how they knew what to do when they were not told.

Table 5.18 The responses when students were pressed further to explain how they knew what to do when they were not told.

<table>
<thead>
<tr>
<th>In the post questionnaire students were asked how they knew what to do in the experiment?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Thought about steps in detail</td>
<td>6%</td>
</tr>
<tr>
<td>Discussed with fellow students</td>
<td>36%</td>
</tr>
<tr>
<td>Thought about it logically</td>
<td>67%</td>
</tr>
<tr>
<td>Used previous knowledge</td>
<td>10%</td>
</tr>
<tr>
<td>I don’t know.</td>
<td>3%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

This result shows that the students’ scientific process skills are increasing with the majority of students (67%) saying they ‘thought about it logically’ (Table 5.18).

Table 5.19 The responses given by students in the pre and post questionnaires when asked how they wrote up their experiments.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>In groups</td>
<td>42%</td>
</tr>
<tr>
<td>Individually</td>
<td>50%</td>
</tr>
<tr>
<td>Both</td>
<td>8%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

The pre questionnaires reveal that the majority write up their experiments ‘individually’ (50%) while in the post questionnaires, all students said they do their write ups ‘in groups’.
(100%). All the inquiry lessons in the intervention programme contained large proportions of group work which promoted collaboration and peer learning among the students.

Table 5.20 The results of students’ responses when asked how they display their experimental result.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment Copy</td>
<td>92%</td>
<td>Experiment Copy</td>
</tr>
<tr>
<td>Experiment Manual</td>
<td>8%</td>
<td>Experiment Manual</td>
</tr>
<tr>
<td>Worksheets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poster and presentations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(Results are represented as percentage of total participants n =23).*

The results from the pre questionnaires show that the large majority (92%) use their experiment copy (laboratory copy). In comparison, the post questionnaire revealed a variety of approaches to presenting their results with poster and presentations (96%) being the most common. Students developed scientific process skills as well as presentation, social and computer skills.

Table 5.21 The responses of students when they were asked how they would prefer to display their results.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>59%, Poster</td>
<td>42%</td>
<td>Poster</td>
</tr>
<tr>
<td>31% Experiment copy</td>
<td>4%</td>
<td>Experiment copy</td>
</tr>
<tr>
<td>17% Video</td>
<td>0%</td>
<td>Video</td>
</tr>
<tr>
<td>5% Project</td>
<td>0%</td>
<td>Project</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>PowerPoint Presentation</td>
</tr>
<tr>
<td></td>
<td>12%</td>
<td>Worksheets</td>
</tr>
<tr>
<td></td>
<td>16%</td>
<td>Handouts Worksheets</td>
</tr>
</tbody>
</table>

*(Results are represented as percentage of total participants n =23).*

The results show in both the pre- and post- lesson questionnaire students preferred displaying their results is in poster format. Surprisingly still one third of students said they prefer using an experiment copy (30%) in the pre-lesson questionnaire. However, this figure decreases
greatly in the post-lesson questionnaire. The post questionnaire revealed the PowerPoint presentations (42%) and a poster format (30%) as the most favoured suggesting students prefer engaging in group work with collaboration among their peers. The students in the post questionnaire were pressed further to explain why they liked doing dissections.

Table 5.22 The participants’ responses when students were pressed to explain why they liked doing dissections.

<table>
<thead>
<tr>
<th>Post Lesson Question: Why did the students like dissection?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>More interesting &amp; fun</td>
<td>75%</td>
</tr>
<tr>
<td>More freedom</td>
<td>33%</td>
</tr>
<tr>
<td>More responsibility</td>
<td>20%</td>
</tr>
<tr>
<td>Had input into learning</td>
<td>16%</td>
</tr>
<tr>
<td>Like doing a different method</td>
<td>8%</td>
</tr>
<tr>
<td>Found it easy</td>
<td>8%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

The responses given by students varied but the majority (38%) of students said they liked dissections because it was more interesting and fun. It is important that students find the subject interesting and fun in order to keep the numbers up for Senior Cycle Science (Leaving Certificate Biology) and for the development of good future scientists.

This last question for lesson two was an open ended question and students responded freely.

Table 5.23 The scientific skills students said they used in the pre and post questionnaires.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>17% Making comparisons and pattern seeking</td>
<td></td>
</tr>
<tr>
<td>8% Team work</td>
<td></td>
</tr>
<tr>
<td>25% Reasoning</td>
<td></td>
</tr>
<tr>
<td>4% I don’t know</td>
<td></td>
</tr>
<tr>
<td>87% Communication</td>
<td>86% Communication</td>
</tr>
<tr>
<td>79% Logical thinking</td>
<td>74% Logical thinking</td>
</tr>
<tr>
<td>4% Research</td>
<td></td>
</tr>
<tr>
<td>8% Investigations</td>
<td>74% Investigations</td>
</tr>
<tr>
<td>4% Observations</td>
<td>57% Observations</td>
</tr>
</tbody>
</table>
From the table, it can be seen that even in the pre questionnaire, students listed actual scientific skills as skills they think they would need for this lesson. This shows an improvement in the students' understanding of scientific skills and the application of them when a comparison is draw between the scientific skills students said they used in table 5.3 and table 5.23 above.

5.3 Lesson three: Enzymes

Students were asked if they remember using the term enzyme during Junior Certificate Science. 52% of students said ‘yes‘ and surprisingly just under half at 48% said ‘no‘. After the enzyme lessons, 100% of students responded they knew what an enzyme was. For the remaining eight questions, students were given predetermined response boxes to tick.

Table 5.24 The responses given by students when they were asked if they can define the term enzyme.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>48%</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>52%</td>
<td>No</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

Over half of the students said they could not define the term ‘enzyme‘. On completing the inquiry lesson in the intervention programme, 100% of students said they could define it.

Table 5.25 The responses given by students when asked if they can give an example of an enzyme.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>38%</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>62%</td>
<td>No</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).
These results show that the majority of students (62%) were not able to give an example of an enzyme compared to 100% of students who participated in the intervention programme and who responded *yes* in the post questionnaire.

Table 5.26 The students responses when asked if they know what a substrate means.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>10%</td>
</tr>
<tr>
<td>No</td>
<td>90%</td>
</tr>
<tr>
<td>Yes</td>
<td>92%</td>
</tr>
<tr>
<td>No</td>
<td>8%</td>
</tr>
</tbody>
</table>

*(Results are represented as percentage of total participants n =23)*.

Before engaging in the intervention programme a large proportion of students did not know what the word substrate meant. Once the students completed the inquiry lesson, 92% said they knew what the word meant and could give an explanation.

Table 5.27 The results from the pre and post questionnaires when students were asked if they understood the meaning of a *control*.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>43%</td>
</tr>
<tr>
<td>No</td>
<td>57%</td>
</tr>
<tr>
<td>Yes</td>
<td>88%</td>
</tr>
<tr>
<td>No</td>
<td>12%</td>
</tr>
</tbody>
</table>

*(Results are represented as percentage of total participants n =23)*.

The result from the pre-lesson questionnaire shows that the term appeared familiar to just under half of the students, while still a large majority (57%) of students did not know what *control* meant. Once the inquiry lesson was completed, all of students responded in the post questionnaire to knowing what *control* means.

Table 5.28 The results from the pre and post questionnaire when students were asked if they think an enzyme can be influenced.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>14%</td>
</tr>
<tr>
<td>No</td>
<td>86%</td>
</tr>
<tr>
<td>Yes</td>
<td>100%</td>
</tr>
<tr>
<td>No</td>
<td>0%</td>
</tr>
</tbody>
</table>

*(Results are represented as percentage of total participants n =23)*.

Before the inquiry lesson, students said they do not think enzymes can be influenced. In comparison, the students who completed the inquiry lesson on enzymes revealed that *yes*
they can be influenced. During the intervention programme and in this inquiry lesson, students were given the opportunity to firstly discuss ‘enzymes’ and using the task sheet design an experiment around enzymes to help broaden their understanding of how they work.

Table 5.29 The responses given by students in the pre and post questionnaire when asked if they can name a factor that can influence an enzyme.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>5%</td>
</tr>
<tr>
<td>No</td>
<td>95%</td>
</tr>
</tbody>
</table>

*(Results are represented as percentage of total participants n = 23).*

A large percentage of students could not name a factor in the pre-lesson questionnaire. Students engaged in the inquiry lesson and completed the inquiry task and this resulted in all of the students being able to name a factor that influences an enzyme.

Table 5.30 The responses given by students when asked if they were shown how to do the experiment beforehand.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>100%</td>
</tr>
<tr>
<td>No</td>
<td>0%</td>
</tr>
</tbody>
</table>

*(Results are represented as percentage of total participants n = 23).*

All students said they are shown how to do experiments beforehand in traditional science/biology classes. In the inquiry lessons students are shown an example initially so as to ‘engage’ them in the lesson. This is the first E step in the 5 E’s learning cycle that was used when developing the lesson plans. The 35% of students may have mistook this initial stage as being shown how to the experiment beforehand. A large majority of students (65%) said they did not know how to do the experiment beforehand as students had to design and develop the majority of their experimental procedures during the intervention programme.
Table 5.31 The responses given by students when asked if they were shown how to do the experiment beforehand.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>0%</td>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
<td>100%</td>
<td>No</td>
</tr>
</tbody>
</table>

*(Results are represented as percentage of total participants n =23).*

According to the pre-lesson questionnaire, traditional science/biology classes do not give students the opportunity to develop their own experimental steps. It can be suggested that traditional science/biology classes do not encourage students to engage in the process of scientific inquiry or use inquiry skills. 92% of students said they got opportunities to develop their own experimental steps during the intervention programme. Inquiry skills such as designing, developing, formulating and analysing were used throughout the inquiry lessons during the intervention programme.

Table 5.32 The results from the pre and post questionnaire when students were asked how they show their results.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Laboratory copy/ Experiment copy/laboratory manuals</td>
<td>80%</td>
</tr>
<tr>
<td>Poster</td>
<td>10%</td>
<td>Poster Presentations</td>
</tr>
<tr>
<td>PowerPoint presentation</td>
<td>10%</td>
<td>PowerPoint presentation</td>
</tr>
<tr>
<td></td>
<td>Experiment worksheets</td>
<td>14%</td>
</tr>
<tr>
<td></td>
<td>Experiment task sheet</td>
<td>47%</td>
</tr>
</tbody>
</table>

*(Results are represented as percentage of total participants n =23).*

The majority of students (80%) answered in the pre questionnaire that they show their results in their laboratory copy. The post questionnaire reveals the experiment task sheet as the most common method (47%) of showing their work. Other methods such as poster and PowerPoint presentations were other innovative ways of showing their results.
Table 5.33 The results of the pre and post questionnaire when students were asked how they determine their conclusion.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th></th>
<th>Post</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I look at the results</td>
<td>67%</td>
<td>I look at the results</td>
<td>42%</td>
<td></td>
</tr>
<tr>
<td>I look at results and relate my previous knowledge</td>
<td>10%</td>
<td>I look at results and relate my previous knowledge</td>
<td>38%</td>
<td></td>
</tr>
<tr>
<td>I think about the results and give my opinion.</td>
<td>5%</td>
<td>I think about the results and give my opinion.</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>results, relate previous knowledge, look at graph, patterns</td>
<td>5%</td>
<td>look at results, think about results, look at graph, patterns</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>think about results and give my opinion</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I use all of these ways.</td>
<td>5%</td>
<td>I use all of these ways</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>I don’t know how to describe it</td>
<td></td>
<td></td>
<td></td>
<td>4%</td>
</tr>
</tbody>
</table>

The students in the pre questionnaire said they look at their results to make a conclusion. The post questionnaire reveals various methods used by students to make a conclusion. The most common method includes looking at their results and using their previous knowledge.

Table 5.34 The responses given by students when asked about the scientific skills they used;

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th></th>
<th>Post</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication.</td>
<td>94%</td>
<td>Communication</td>
<td>96%</td>
<td></td>
</tr>
<tr>
<td>Collecting Data</td>
<td>57%</td>
<td>Collecting Data</td>
<td>88%</td>
<td></td>
</tr>
<tr>
<td>Experimentation</td>
<td>86%</td>
<td>Experimentation</td>
<td>88%</td>
<td></td>
</tr>
<tr>
<td>Predicting</td>
<td>57%</td>
<td>Predicting</td>
<td>29%</td>
<td></td>
</tr>
<tr>
<td>Logical Thinking</td>
<td>57%</td>
<td>Logical Thinking</td>
<td>56%</td>
<td></td>
</tr>
<tr>
<td>Observation</td>
<td>71%</td>
<td>Observation</td>
<td>42%</td>
<td></td>
</tr>
<tr>
<td>Formulating</td>
<td>33%</td>
<td>Formulating</td>
<td>88%</td>
<td></td>
</tr>
<tr>
<td>Analysing</td>
<td>33%</td>
<td>Analysing</td>
<td>84%</td>
<td></td>
</tr>
<tr>
<td>Presenting</td>
<td>38%</td>
<td>Presenting</td>
<td>17%</td>
<td></td>
</tr>
<tr>
<td>Designing</td>
<td></td>
<td></td>
<td></td>
<td>8%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).
Students noted in their pre-questionnaire scientific skills that they had developed and used in previous inquiry lessons. The skills are similar for both pre- and post- questionnaire but with an increased emphasis placed on ‘analysing’, ‘collecting data’ and ‘formulating’ skills due to the nature of the task in this inquiry lesson. Students developed and practiced their inquiry and scientific skills in each inquiry lesson.

5.4 Lesson four: Osmosis

This section displays the pre- and post- questionnaire responses given by students. The students were asked to tick a predetermined answer box that represented their response.

Table 5.35 The results from the pre and post questionnaire when students were asked if they can define the term ‘osmosis’.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>4%</td>
</tr>
<tr>
<td>No</td>
<td>96%</td>
</tr>
</tbody>
</table>

Yes 96%  
No 4%  

(Results are represented as percentage of total participants n =23).

The pre-questionnaire results show 96% students said they could not define ‘osmosis’. After students participated in this inquiry lesson, 96% of students said ‘yes’ they could. Through experimentation, students developed an understanding of what ‘osmosis’ is and therefore were able to define it.

Table 5.36 The results of the students’ responses when asked if they can give an example of osmosis.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>9%</td>
</tr>
<tr>
<td>No</td>
<td>91%</td>
</tr>
</tbody>
</table>

Yes 96%  
No 4%  

(Results are represented as percentage of total participants n =23).

There is a striking difference between the pre- and post- questionnaire responses. The pre-questionnaire results show that 91% of students could not give an example of ‘osmosis’ while a large percentage of students on completion of the inquiry lesson, were able to give an example.
Table 5.37 The results from the pre and post questionnaire when students were asked if they can list some steps they took in their experiment.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>48%</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>52%</td>
<td></td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

Over half of the respondents to the pre questionnaire said ‘no’ they could not list some of their experimental steps. Students who engaged in the inquiry lesson had to design and develop their own steps. It can be suggested 96% of students said they could list steps they took because the students designed the steps themselves and could remember them in greater detail because it was their own work.

Table 5.38 The results from the pre and post questionnaire when students were asked if they know what a dilute solutions means.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>52%</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>48%</td>
<td></td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

Over half of Students in the pre questionnaire said ‘yes’ they did know its meaning while compared to 91% of students in the post questionnaire said ‘yes’.

Table 5.39 The responses given by students when asked if they know how to make a dilute solution.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>70%</td>
<td></td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

70% of students in the pre questionnaire said they do not know how to make a dilute solution and the post questionnaire reveals 78% of students said they know how to make it.
Table 5.40 The students responses when asked if they know what a concentrated solution means.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>35%</td>
</tr>
<tr>
<td>No</td>
<td>65%</td>
</tr>
<tr>
<td>Yes</td>
<td>87%</td>
</tr>
<tr>
<td>No</td>
<td>13%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

The pre questionnaire revealed 65% of students said "no” they did not know what it is while after engaging in the inquiry lesson 87% of students knew what a concentrated solution.

Table 5.41 The results to the pre and post questionnaire when students were asked if they knew how to make a concentrated solution.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>17%</td>
</tr>
<tr>
<td>No</td>
<td>83%</td>
</tr>
<tr>
<td>Yes</td>
<td>77%</td>
</tr>
<tr>
<td>No</td>
<td>23%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

The majority of students in the pre questionnaire said "no” while 77% of students in the post questionnaire answered "yes”. The inquiry task for this lesson asked students to make up both concentrated and dilute solution (see Appendix 8). The students who participated in the inquiry class were able to explain what the term meant as they would have carried it out during the experimental task.

Table 5.42 shows the responses given by students in the pre and post questionnaires when asked if they knew a term(s) that best described what happened to the cells.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>3%</td>
</tr>
<tr>
<td>No</td>
<td>97%</td>
</tr>
<tr>
<td>Yes</td>
<td>92%</td>
</tr>
<tr>
<td>No</td>
<td>8%</td>
</tr>
</tbody>
</table>

The students in the pre-questionnaire did not understand the terms associated with osmosis with 97% saying "no”, while 92% of students in the post questionnaire answered "yes”. Students who answered the post-questionnaire would have undergone the osmosis onions lesson. Students saw and explained what happened to their onions and through group and class discussions terms and definitions were explained.
Table 5.43 The responses students gave in the pre and post towards the scientific skills they said they used.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th></th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>55%</td>
<td></td>
<td>80%</td>
</tr>
<tr>
<td></td>
<td>75%</td>
<td></td>
<td>28%</td>
</tr>
<tr>
<td></td>
<td>43%</td>
<td></td>
<td>37%</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td></td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>56%</td>
<td></td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td>44%</td>
<td></td>
<td>75%</td>
</tr>
<tr>
<td></td>
<td>35%</td>
<td></td>
<td>51%</td>
</tr>
<tr>
<td></td>
<td>31%</td>
<td></td>
<td>80%</td>
</tr>
<tr>
<td></td>
<td>21%</td>
<td></td>
<td>23%</td>
</tr>
<tr>
<td></td>
<td>10%</td>
<td></td>
<td>75%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Formulating</td>
<td>5%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n = 23).

There are a variety of skills mentioned by students in both the pre- and post-questionnaires. Students are using their previous knowledge from previous inquiry lessons to answer this question. The post-questionnaire results show that students felt they used their communication, recording, experimentation and observation skills the most during the inquiry class. The tasks in this inquiry lesson merited these skills being used as students had to record and observe what happened during their experiments in the *Osmosis Onions* and *Egg Mayhem* lessons.

### 5.5. Lesson five: Mitosis

The final lesson investigated students‘ previous knowledge of mitosis, whether they knew the stages involved in mitosis or any examples of mitosis. Students then carried out the inquiry lesson task (see Appendix 8) and explanations were the given by students explaining how they sequenced their stages. Sample worksheets and completed questionnaires can be found on the CD attached to this thesis. All questions in the pre-questionnaire were predetermined with students choosing a box to tick while; the post-questionnaire allowed students to freely respond as well as tick predetermined answer boxes.
Table 5.44 The results when students were asked if they knew what mitosis means;

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>35%</td>
<td>Yes</td>
<td>83%</td>
</tr>
<tr>
<td>No</td>
<td>65%</td>
<td>No</td>
<td>17%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

The pre- questionnaire shows that the majority of students said ‘no’. The inquiry lesson encouraged students to discuss mitosis and participate in the inquiry lesson task to help them understand what mitosis is. As a result, the majority of students (83%) understood what mitosis means.

Table 5.45 The results from the pre and post questionnaires when students were asked if they could give an example of mitosis displays the results from the pre- and post-questionnaires.

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>13%</td>
<td>Yes</td>
<td>78%</td>
</tr>
<tr>
<td>No</td>
<td>87%</td>
<td>No</td>
<td>23%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

Before the students did the intervention programme, 87% of them said they could not give an example of mitosis. Having completed the inquiry lesson, 78% of the students said they could. Through discussion, peer tutoring and collaboration students forged an understanding of mitosis and where it happens in their everyday lives.

The students who knew what ‘mitosis’ meant in the pre-questionnaire (23%) were pressed further on where they had heard of mitosis before.

Table 5.46 The responses students gave when they were asked in the pre questionnaire where they heard of mitosis before.

<table>
<thead>
<tr>
<th>In science class</th>
<th>13%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science class/teacher</td>
<td>13%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).
Table 5.47 The responses students gave when they were asked if they knew how a cell undergoes mitosis.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th></th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>4%</td>
<td>Yes</td>
<td>76%</td>
</tr>
<tr>
<td>No</td>
<td>96%</td>
<td>No</td>
<td>24%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

The majority of students (96%) did not know how a cell undergoes mitosis. After engaging in the inquiry lesson task and worksheet, working collaboratively and using the scientific process skills and inquiry skills they developed throughout the intervention programme, the majority of students (76%) understood how cells underwent mitosis.

Table 5.48 The responses students gave when they were asked if they knew the names of any of the stages in mitosis.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th></th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>0%</td>
<td>Yes</td>
<td>76%</td>
</tr>
<tr>
<td>No</td>
<td>100%</td>
<td>No</td>
<td>24%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

All of the students in the pre questionnaire said “no” while the majority of students (76%) said they could list the stages of mitosis. These students were pressed further on how they remembered the names of the stages involved in mitosis.

Table 5.49 The students’ responses in the post questionnaire when asked how they remembered the steps involved in mitosis.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I number them</td>
<td>32%</td>
</tr>
<tr>
<td>A rhythm ‘I party Mondays and Tuesdays’</td>
<td>41%</td>
</tr>
<tr>
<td>I cannot remember</td>
<td>3%</td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

Table 5.50 The responses students gave when asked how they decided on their sequence of cell division.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion among peers</td>
<td>46%</td>
</tr>
<tr>
<td>Follow the shapes</td>
<td>86%</td>
</tr>
</tbody>
</table>
Look at the pattern 56%
Use Logic thinking 78%
Cut out the shapes and arrangement 92%

(Results are represented as percentage of total participants n =23).

This question allowed students to respond freely. When students were asked how they displayed their sequence the majority said they took to cutting out the shapes and physically arranging them (see CD attached for samples). Students used various ways with some combining both discussions among peers with using their logical thinking or discussion among peers and cutting out the shapes and arranging them. This inquiry task encouraged students to use all the inquiry and scientific skills used in the previous lessons and most importantly to think critically and for themselves.

Table 5.51 The students’ responses when they were asked what scientific skills did they use.

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pattern forming</td>
<td>55%</td>
</tr>
<tr>
<td>Communication</td>
<td>37%</td>
</tr>
<tr>
<td>Observation</td>
<td>33%</td>
</tr>
<tr>
<td>Logical thinking</td>
<td>37%</td>
</tr>
<tr>
<td>Recording data</td>
<td>15%</td>
</tr>
<tr>
<td>Analyse</td>
<td></td>
</tr>
<tr>
<td>Prediction</td>
<td></td>
</tr>
<tr>
<td>Experimentation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Results are represented as percentage of total participants n =23).

The pre-questionnaire results show students thought they would be using certain inquiry skills that they had used in the previous inquiry lessons. However, on completion of the inquiry lesson, students said they used prediction skills, logical thinking skills, communication and pattern forming skills the most which reinforces students comments made in Table 5.50 when asked how they completed their mitosis sequence. These scientific skills were used more frequently in this lesson due to the nature of the task.

5.6 Main findings of the Transition year interviews

The following tables represent the change in pre and post responses of students who engaged in inquiry classes. Responses of two transition year students who were in a traditional biology
class will also be reported on for comparison. Only the main findings of the interviews for both traditional and inquiry students will be reported on in this results chapter. The full transcripts can be found in Appendix 7.

Table 5.52 The overall responses in the pre and post interview when interviewees where asked to explain in their own words what they think a scientist is. The table 5.52 also displays the interviewees’ comments (n=4) and the change between the students‘ pre and post responses when asked what they think a scientist is.

<table>
<thead>
<tr>
<th>Interviews</th>
<th>Pre Interview Responses</th>
<th>Post Interview Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td>What is a scientist?</td>
<td></td>
</tr>
<tr>
<td>Overall responses</td>
<td>Basic understanding of what a scientist does.</td>
<td>Clear understanding of what scientist is and the skills they use.</td>
</tr>
<tr>
<td>Student</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>1</td>
<td>It is someone who explores things, does experiments and dissections</td>
<td>They are someone who discovers, explores, investigates… like someone who works at finding out how things work, they present their findings and experiment to see if they are correct.</td>
</tr>
<tr>
<td>2</td>
<td>They people who mix up substances and stuff and find out new things and try to invent new things and experiment</td>
<td>He has knowledge, works things out, solves problems, experiments and communicates.</td>
</tr>
<tr>
<td>3</td>
<td>Comes up with definitions, knows facts and proves things.</td>
<td>He has knowledge, works things out, solves problems, experiments and communicates.</td>
</tr>
<tr>
<td>4</td>
<td>Someone who does experiments</td>
<td>Someone who uses different</td>
</tr>
</tbody>
</table>
Students in intervention showed a clear understanding of what a scientist is and how s/he practices as a scientist. Students were comfortable in expressing the different skills a scientist may have. In contrast, the two interviewees from the traditional class expressed the basic understanding of a scientist. They felt a scientist was a ‘smart’ person who works and experiments in a lab. Some of their comments included;

→ “He is a smart guy, someone who has been to college, who is inventive knows how to do experiments” (Traditional student 1)

→ “I think it is someone who wears white coats and works in labs and investigates things. They find cures and use machines to find out weird things by experimenting” (Traditional student 2) (For all comments see Appendix 7)

Table 5.53 The overall responses interviewees gave when asked what they think scientific skills are. Also displayed are the changes in the interviewees’ responses towards scientific skills.

<table>
<thead>
<tr>
<th>Interviews</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td>What are scientific skills</td>
<td></td>
</tr>
<tr>
<td>Overall responses</td>
<td>Two out of four interviewees said ‘I don’t know’. The other two responded ‘they involve doing experiments’</td>
<td>All interviewees responded with a list of skills.</td>
</tr>
<tr>
<td>Student</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>1</td>
<td>Doing experiments</td>
<td>They are skills that you need to be a scientist. Like important skills. They are more than just the basic skills we use doing an experiment like problem Logic, pattern forming, comparison, communication, analysing.</td>
</tr>
</tbody>
</table>
I don’t know … they should be really brainy
They involve analysing, deduction, formulating, observation and graphing

Doing experiments
They are the skills we used in class like Communication, logic, problem solving, experimenting and thinking.

I don’t know
The skills you need to use to figure stuff out like observation, predicting, communication.

(Interviewee participants n=4)

In contrast all of the interviewees from the traditional class responded as either not knowing or related it to experiments.

Some of the responses include; (For all comments see Appendix 7)
→ “I think it means how you carry out experiments and the actual knowing of how to do experiments” (Traditional student 1)
→ “I don’t know at all”. (Traditional student 2)

Table 5.54 The overall responses of interviewees when asked how they were taught science in their school. It also shows the change in the interviewees’ responses both before and then after they engaged in inquiry based lessons in science/biology class.
experiment and we got to present our data in a different way to how we normally did.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>We take down notes and learn them off</td>
<td>By experiments and discussions and thinking about stuff a lot more than normal.</td>
</tr>
<tr>
<td>3</td>
<td>Learn a method the teacher tells us and put it into practice by doing an experiment</td>
<td>By doing everything ourselves and coming up the conclusions ourselves.</td>
</tr>
<tr>
<td>4</td>
<td>Through books and experiments and taking notes down</td>
<td>In a different way than in normal class</td>
</tr>
</tbody>
</table>

(Interviewee participants n=4)

The interviewees from the traditional class all responded similarly to the _pre interview responses_ of the students in the inquiry class. They said they take down notes, learn them off and then do the experiment. Their comments include; (For all comments see Appendix 7)

→ _By learning notes and taking down notes and doing experiment_ (Traditional student 1)

Table 5.55 The interviewees overall responses when asked how they carry out their experiments in science/biology class and the change in the interviewees’ responses towards experiments in science/biology class.

<table>
<thead>
<tr>
<th>Interview</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td>How Do you carry out experiments in science/biology class?</td>
<td></td>
</tr>
<tr>
<td>Overall response</td>
<td>They are told a step by step procedure.</td>
<td>They have to come up with the experimental procedure</td>
</tr>
<tr>
<td>Student</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>1</td>
<td>We carry them out step by step that are given to us and told how to do it.</td>
<td>Yes we did…We would get the question from the teacher and task worksheet. Then we have to get on with the experiment on our own. Like you get the basic information</td>
</tr>
</tbody>
</table>
and then you explore ways of finding the answer using experiment. We had the opportunity to think a lot about how we would do the experiment.

2

| We are told how to carry it out in and go through the steps on the board | Yes we have to make up an experiment to answer a question and experiment different ways and see if we get the answer… |

3

| Yes we like go through stuff on the board and its in a step by step way and then we might read it as well to make sure we know what we are doing and what results to look for. | Yes we would come up with and make up our own procedures to experiments, talk about the topics and using our own methods for each topic. We got to carry out experiments in our own way. |

4

| Yes the procedure is normally laid out on the board and we go through it and then do the experiment. | Yes they were different and fun we were given the basic information and had to do it then ourselves |

*(Interviewee participants n=4)* (For all comments see Appendix 7)

In stark contrast the students in the traditional class responded in the interview that they were told exactly what to do and would go through the steps together with the teacher. Some of their comments include;

→ *We were told how to. The teacher would go through it on the board and then we get to do it”* (Traditional student 1)

→ *“Usually the teacher gets us to read the procedure and then she would put up steps on board with diagrams to help us follow the procedure, then we go through it and safety stuff and then put our coats on and set up the equipment. We follow what is on the board”* (Traditional student 2)
Table 5.56 The overall responses in the pre and post interviews when students were asked if they were told how to carry out the experiments and the change in their responses when asked are they told how to carry out their experiments.

<table>
<thead>
<tr>
<th>Interviews</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td>Are you told how to carry out experiments?</td>
<td></td>
</tr>
<tr>
<td>Overall responses</td>
<td>Four out of four interviews said ‘yes’</td>
<td>Four out of four interviewees said ‘no’</td>
</tr>
<tr>
<td>Student</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>1</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>Yes step by step and prepared beforehand.</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Yes</td>
<td>No we have to have a bit of cop on and do it ourselves</td>
</tr>
</tbody>
</table>

(Interviewee participants n=4)

All of the students in the traditional class responded ‘yes’ when asked if they were told how to carry out the experiments (see Appendix 7 for comments).

Table 5.57 The overall responses given by interviewees when they were asked if they knew the results before doing the experiment.

<table>
<thead>
<tr>
<th>Interviews</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td>Do you know the results beforehand?</td>
<td></td>
</tr>
<tr>
<td>Overall responses</td>
<td>Two interviewees responded saying sometimes and two interviewees responded ‘yes’</td>
<td>Four of the interviewees said ‘no’</td>
</tr>
</tbody>
</table>

(Interviewee participants n=4) (For all comments see Appendix 7).

All the responses from the interviewees in the traditional class said ‘yes’. Their comments include;

→ ‘We knew what we should be getting yes’ (Traditional student 1)
→ ‘Yes sometimes but most of the time we knew what to look for in the result’ (Traditional student 2)
Table 5.58 The overall responses interviewees gave when asked where they write up their experimental results and then the change in the interviewees’ responses between the pre- and post- lessons analysis.

<table>
<thead>
<tr>
<th>Interviews</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td>Where do you write your results?</td>
<td></td>
</tr>
<tr>
<td>Overall responses</td>
<td>Four out of four interviewees said in their ‘laboratory copies’</td>
<td>Four out of four interviewees said ‘task sheets’</td>
</tr>
<tr>
<td>Student Pre</td>
<td>Post</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>In laboratory copy</td>
<td>We had a task worksheet and recorded our data on results tables.</td>
</tr>
<tr>
<td>2</td>
<td>In our Lab copies</td>
<td>On our task sheets…</td>
</tr>
<tr>
<td>3</td>
<td>In the lab copy</td>
<td>Using the task sheets.</td>
</tr>
<tr>
<td>4</td>
<td>In our lab copy</td>
<td>We had to fill them out in our task and worksheet</td>
</tr>
</tbody>
</table>

(Interviewee participants n=4) (For all comments see Appendix 7)

All of the interviewees in the traditional class responded in their ‘experiment copy’.

Table 5.59 The overall responses interviewees gave in the pre and post interviews when asked how they came up with conclusions. The change in interviewees’ responses from the pre and post interview are also displayed.

<table>
<thead>
<tr>
<th>Interviews</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td>How do you come up with conclusions?</td>
<td></td>
</tr>
<tr>
<td>Overall response</td>
<td>Four out of four interviewees said in class with their teacher</td>
<td>Four out of four interviewees said they think and discuss the results in their groups</td>
</tr>
<tr>
<td>Student Pre</td>
<td>Post</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>In class with teacher</td>
<td>Well we were in groups so we kind of just looked at the results and talked about them… We talked about the results… it was hard sometimes but it’s grand because you’re in a group so someone always has an idea.</td>
</tr>
</tbody>
</table>
Talk among ourselves and then the teacher talks and we come up with the conclusion... its normally very obvious so not rocket science or anything.

Think and try to relate what we did in the experiment to the question and see if it worked or not, and if it did then we say why we think. We work in groups like so someone always comes up with something.

Teacher talks through experiment and we come to a conclusion as a class

By thinking and discussing the results with each other.

In class with teacher

We talked in our groups and asked other groups what they came up with and talked to them as well

(Interviewee participants n=4) (For all comments see Appendix 7)

According to the interviewees, the tradition class discussed results in a class discussion and all wrote the same thing into their laboratory copies. Some of their comments include;

→ “We talked in class and then got to write it down in experiment copy together”
   (Traditional student 1)

→ “The teacher would take all of our results and put up on board and then put heading of conclusion and then we would have to give answers. Then we put it down in our copies” (Traditional student 2)

Table 5.60 The overall pre and post interview responses and the change in the interviewees' responses when they were asked how they display their experimental results.

<table>
<thead>
<tr>
<th>Interviews</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td>How do you display your results</td>
<td></td>
</tr>
<tr>
<td>Over all responses</td>
<td>Four out of four interviewees responded in their laboray copy</td>
<td>Four out of four interviewees responded that they used poster or Power Point presentations.</td>
</tr>
<tr>
<td>Student 1</td>
<td>In my lab copy</td>
<td>Using PowerPoint mostly. We</td>
</tr>
</tbody>
</table>
would have to transfer what we did, how we did it, what we used, what results we got, a conclusion…to PowerPoint slides. We… add pictures of the experiment… which was cool.

(Experiment participants n=4) (For all comments see Appendix 7)

All of the interviewees in the traditional class responded they display the results in their ‘laboratory copy’:

Table 5.61 The overall responses interviewees gave and the changes in the responses interviewees gave in the pre and post interviews when asked what they liked most about science/biology class.

<table>
<thead>
<tr>
<th>Interviews</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td>What do you like most about science/biology?</td>
<td></td>
</tr>
<tr>
<td>Over all responses</td>
<td>Doing experiments especially outside of classroom and biology topics.</td>
<td>Interviewees responded they liked a variety of things such as they freedom they had, they got to think differently and understand previous topics better and also design experiments</td>
</tr>
<tr>
<td>Student</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>1</td>
<td>The experiments</td>
<td>I like designing my own experiments</td>
</tr>
</tbody>
</table>
2. Doing biology. Sometimes we get onto the body which is interesting. Getting the experiments set up and using chemicals... accidental burning of tables with acid...

3. Getting out of the class for a while to do something other than write.

4. Finding out about my body and stuff that goes on inside that I don't know about.

Being able to think differently about things... like if that's not working then why like?

Just the freedom really. The lack of note taking, the talking about topic, doing the experiments ourselves, trying different things in the experiment.

Understanding stuff that I didn't when I was in third year

(Interviewee participants n=4) (For all comments see Appendix 7)

There were some similar responses from the interviewees in the traditional class when compared with the pre interviews of the inquiry students. The similarities include students wanting to find out about how their body works and doing experiments. Some of their comments include;

→ “I like talking about biology and the body because I play sport and I like to know how my body works” (Traditional student 1)
→ “I like doing experiments about biology” (Traditional student 2)

Table 5.62 The overall responses interviewees gave and the change in the interviewees' responses towards the aspect of science/biology they enjoy the most.
said she liked the "biology topics" done in class.

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Doing the biology experiments</td>
<td>I liked the biology topics</td>
</tr>
<tr>
<td>2</td>
<td>Doing the experiments</td>
<td>I like planning the experiments in our groups because we do have fun and we get to use chemicals and mix them together and see if a reaction happens… you don't know what will happen!</td>
</tr>
<tr>
<td>3</td>
<td>The experiments or doing ecology because we get to go outside.</td>
<td>Designing the method - I found I was thinking more about it than I would normally have.</td>
</tr>
<tr>
<td>4</td>
<td>I enjoy biology aspect and experiments</td>
<td>I loved doing the biology experiments different because we could like plan it and do what we felt was the right way.</td>
</tr>
</tbody>
</table>

*(Interviewee participants n=4)*

Table 5.63 The overall interviewees responses and also the change in interviewees responses towards the part they least enjoyed in science/biology class.
The students in the traditional class responses included the lack of time devoted to experiments and the amount of teacher talk as being the aspects they least enjoyed. Their comments include;

→ “I suppose when we don’t get to do experiments every week the writing and listening gets kind of boring” (Traditional student 1)

→ “Just sitting and having to listen to the teacher talk more than us... I mean I know she has to but it gets kind of annoying because I thought science was more practical like we actually do some experiments or something” (Traditional student 2)

Table 5.64 The interviewees overall responses and highlights the changes in interviewees’ responses when asked what they like doing most in science/biology class.

<table>
<thead>
<tr>
<th>Interviews</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall responses</td>
<td>All of the interviewees said they enjoyed doing the experiments the most</td>
<td>Three out of the four interviewees said they enjoyed designing the experimental method the most and one interviewee said being able to think differently.</td>
</tr>
<tr>
<td>Student</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>1</td>
<td>Doing experiments</td>
<td>I enjoyed doing the experiments and learning new things. It was fun and</td>
</tr>
</tbody>
</table>
challenging doing things a different way
Doing biology. I like sport and sometimes we get onto the body which is interesting getting the experiments set up and using chemicals… accidental burning of tables with acid…
Being able to think differently about things… like if that’s not working then why like?
Designing the method - I found I was thinking more about it than I would normally have.
Being able to have freedom to get up and go over to the other group and ask what you guys doing or just being able to do the experiment our way.

**Table 5.65 The overall responses interviewees gave and the changes in the interviewees’ responses towards the scientific skills they think they developed in science/biology class.**

<table>
<thead>
<tr>
<th>Interviews</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td>What scientific skills do you think you developed in science/biology class?</td>
<td></td>
</tr>
<tr>
<td>Overall responses</td>
<td>Three interviewees responded ‘I don’t know’ and one interviewee linked the skills to experiments.</td>
<td>All interviewees responded with a list of skills.</td>
</tr>
</tbody>
</table>
All of the interviewees in the traditional class associated the scientific skills they developed to the experiments. Some of their comments include;

- → *Well, I think I developed my experimental skills like doing the experiment and taking notes and results*” (Traditional student 1)
- → *Eh I dunno, maybe experiment skills like taking readings, and making up some chemicals... I dunno*” (Traditional student 2)

Table 5.66 The overall responses given by interviewees and the change in their responses in the pre and post interview when asked what lesson they enjoyed the most.
The Junior Certificate science practicals were good. The enzyme experiments were different.

The distillation experiment was class because there was so much assembly that took a while...
The dissection. Because we could pick whatever organ we wanted.

I suppose Ecology

I enjoyed the enzyme lesson and the experiment

The design and dissection and presentation… I liked it because we got to present our stuff in groups and in posters and it was interesting because we didn't just have to do a written report.

In comparison, the interviewees' responses from the traditional class included the enzyme and dissection experiments. Their comments include;

→ “I liked doing the enzyme experiment. There were chemicals we had to mix up and you could see the reaction happening” (Traditional student 1)

→ “I like doing the dissection. It is fun and it’s not every day you get to cut up a heart” (Traditional student 2)

Table 5.67 The overall responses given by interviewees and the change in their responses when asked in the pre- and post- interview to explain any term they understood in a science/biology lesson.
I remember using litmus paper that goes red if something is an acid. I suppose the word catalyst. That's something that speeds up or slows down reactions but don't ever get used up in the reaction… like the disc being propelled up because of the hydrogen peroxide breaking down to oxygen.

Eh well distillation separates two things like water and alcohol and it is because of their boiling points. The eye has this cool liquid in it I think the fluid is called vitreous humour that keeps it round and when you take it out its clear and fluidy looking but it has a membrane around it to hold shape but you can pierce it and it goes everywhere…

We use a quadrat to calculate the percentage of flowers and plants in an area. I chose the heart. I learnt about the different chambers, the way heart beats and the atrium contracts and then the ventricles contract.

That an enzyme can cause things to happen like react and we could see that happening because we could test the substance I learnt a lot about my heart from dissection… like the aorta is the main artery and it is massive at the top opening of the heart and it pumps blood like away from the heart.

(Interviewee participants n=4) (For all comments see Appendix 7)

The interviewees from the traditional class gave short and basic explanations of coronary artery and catalase, which appear to be basic recall answers to simple questions. Some of their responses included:

→ *Eh... we have to find the coronary artery which is the artery that gives blood to the actual heart*” (Traditional student 1)
→ “*I know that the enzyme in celery is called catalase*” (Traditional student 2)
Table 5.68 The overall interviewee responses and the change in their responses towards the part of a science/biology lesson they found most interesting or beneficial.

<table>
<thead>
<tr>
<th>Interviews</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td>What part of a science/biology lesson did you find most interesting/beneficial?</td>
<td></td>
</tr>
<tr>
<td>Overall responses</td>
<td>Interviewees’ responses varied from the experiments, building knowledge and not finding anything beneficial or interesting.</td>
<td>Two out of four interviewees found the presentations most beneficial. One interviewee found picking and planning his own dissection most enjoyable and the other interviewee said trying new things was beneficial.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Doing experiments are always interesting.</td>
<td>I loved the way the little paper discs just rose up at first and we didn’t know why. We had to investigate hydrogen peroxide and how it was causing the discs to float. Then we had to see if we could cause the discs to rise quicker by changing the solution. It was different, and I never did anything like that before.</td>
</tr>
</tbody>
</table>

*(Interviewee participants n=4) For all comments see Appendix 7)*

The interviewees in the traditional class said they found the experiments to be the most beneficial part of a science/biology lesson. Some of their comments include:

→ *Doing experiments and dissections*” (Traditional student 1)

→ *Doing the experiments because we got to work in groups and together which is good*” (Traditional student 2)
Table 5.69 The overall responses interviewees gave and the change in interviewees’ responses when asked if they plan to take Leaving Certificate Biology.

<table>
<thead>
<tr>
<th>Interviews</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Question</strong></td>
<td>Do you plan on taking Leaving Certificate Biology?</td>
<td></td>
</tr>
<tr>
<td><strong>Overall responses</strong></td>
<td>Two interviewees responded ‘probably not’ and two interviewees said ‘yes’</td>
<td>Three out of the four interviewees said ‘yes’ and one interviewee said ‘I don’t know’</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes I think I will.</td>
<td>Yes I liked the topics so I will</td>
</tr>
<tr>
<td>2</td>
<td>Yes, I probably will because I like it.</td>
<td>Yes I will be.</td>
</tr>
<tr>
<td>3</td>
<td>Probably not, I don’t know.</td>
<td>Yes, I think I would like to but</td>
</tr>
<tr>
<td>4</td>
<td>Probably not, there seems like there will be a lot of learning.</td>
<td>I don’t know, I liked the experiments but I don’t think it will be like that next year.</td>
</tr>
</tbody>
</table>

(Interviewee participants n=4) (For all comments see Appendix 7)

One interviewee from the traditional class said she would continue on to Leaving Certificate Biology and the other interviewee said he would not be taking Leaving Certificate Biology.

Table 5.70 The overall responses given by interviewees and the change in the interviewees’ responses when asked how they think they would find Leaving Certificate Biology.

<table>
<thead>
<tr>
<th>Interviews</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Question</strong></td>
<td>How do you think you would find LC Biology?</td>
<td></td>
</tr>
<tr>
<td><strong>Overall responses</strong></td>
<td>All interviewees said they think it will involve hard work with a lot of study, note taking and learning.</td>
<td>All interviewees expect it to be tough but feel they can handle it.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Student</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I think all subjects at leaving certificate are hard because my brother is doing the leaving certificate now and he seems to be always studying.</td>
<td>There probably is so much to do and learn but I enjoyed doing these lessons so I probably will find it ok.</td>
</tr>
</tbody>
</table>
2  | I think it will be hard because there will be new topics and I would say there is a load of it to learn as well. Exciting times ahead of me eh! | Yes but I think I be able to handle it. |
3  | It will involve more notes and learning no doubt! | It probably will be easier now I have some of it done in transition year and I know what I need to be able to do in experiments and stuff so maybe it won’t be too hard. |
4  | I think it will be very hard, load of writing and you have to know so much | We did some parts of it in transition year and they don’t look too bad. |

*(Interviewee participants n=4) (For all comments see Appendix 7)*

The interviewees in the traditional class have some of the same concerns as the inquiry interviewees in the pre interview. One interviewee is concerned that there is too much note taking and learning and not enough ‘doing’ even though it is considered a practical subject. The other interviewee feels she has to choose between biology or chemistry and think biology is the easier. Some of their comments include:

→ I would prefer to do something with less note taking or writing. I think I will probably take it because I have to and chemistry be bit harder. It will be a bit boring and I don’t get why we have to write so much. It gets annoying because there is fun stuff to do and we don’t seem to do it” (Traditional student 1)

→ I think I am going to do something a bit more practical because at least then I have a little more freedom and less note taking in class for a change” (Traditional student 2)
5.7 Overall Comments on the Intervention Programme

5.7.1 Improvement of communication skills
The researcher has noticed an improvement in the students’ communication skills. Initially the students would have been quite reserved and shy as speaking for long periods in front of their fellow students or presenting their posters and PowerPoint presentations would not have been done in a normal day to day class.

Figure 5.1 Inquiry students presenting their poster in class.

The results discussed in the previous section from the pre and post questionnaires show that students frequently said they used communication when asked about their scientific skills. The researcher feels that during the intervention programme period the students became more confident and articulate in expressing their views, opinions, knowledge and answering questions that their fellow students asked them during presentations. In order to view the presentations from the design, dissect and presentation lesson please refer to the CD attached to this thesis.

Some of the students’ comments include;

→ “We used communication skills to share our ideas” (Inquiry student 4)
→ “It was nice to interact with my fellow students in class time” (Inquiry student 20)

5.7.2 Student Ability
The researcher noticed that the students really got involved and embraced having to develop and design experiments. They forged group relationships and appeared to bounce ideas off one another and depend on one another for reassurance and confidence. One interviewee commented;
When someone is out in the group it is kind of annoying because you end up only being a pair or just you on your own” (Inquiry interviewee 2)

They were not afraid. The element of doubt was removed along with that feeling of if ‘I don’t get the same answer as everyone else I must be wrong’. The students expressed they had more ‘freedom’ to experiment in their own way and time and act like actual scientists. The transition year class is a mixed ability group with bright, enthusiastic, helpful students who have strong personalities. There are also some students who are dyslexic, shy, are at risk of being early school leavers, students who are considered weak academically and new students who joined the school. The researcher noticed that all of these students excelled throughout the 14 week intervention programme period. The researcher was astounded to see one particular dyslexic and shy student confidently stand and deliver a presentation and easily answer questions students asked. Most of the students appeared motivated and eager to participate regardless of their ability. However there were a few students who still depended on being told what to do either from the teacher or other members of their group. The researcher noticed a comment made by an inquiry student who was interviewed – “In my group I generally was the lead person and that got annoying sometimes because they looked to me for help or the answer nearly” (Inquiry Student interviewee 1).

The lesson requires students to do engage in many forms of practical and mental work. Some students did not feel like rising to the challenge and felt transition year was a time of rest for them. The lessons were designed to motivate and interest the students; however, the researcher feels the attitude of some students let them down more than their ability. During the teacher interviews, one teacher made the point that “the high ability kids will always plough ahead and get it wrong or right, the average ability kids will wait to see what the other lads are at and then the weaker ability are doing nothing” (Teacher interviewee 3).

Some of the inquiry students’ comments include;

→ “No we were not told how to carry out the experiments, we had to have a bit of cop on and do ourselves” (Inquiry student 12)

→ “For the experiments we had to think of how we could do the experiments ourselves” (Inquiry student 15)

→ “Yes I enjoyed doing this lesson because I liked the way it was puzzling and made me concentrate and think harder” (Inquiry student 2)
“I did enjoy this lesson because it made me think outside the box and to use my head” (Inquiry student 3)

Even students who are considered quite academically weak responded that he found the experiments to be “interesting and easy to understand” (Inquiry student 21)

“We make our own procedures and carry them out using our own methods. This is a good way I think. We had more freedom” (Inquiry student 1)

5.7.3 Scientific skills

The results in the above results section revealed the in the first pre questionnaire for the introduction to inquiry lesson, 38% of students said ‘I don’t know’ when asked what scientific skills should a scientists have and 25% of students thought it had something to do with experiments. When the students had completed this lesson, the students’ responses in the post questionnaire looked completely different. Students used lists of skills that included communication, logical thinking, problem solving, experimentation, using common sense, deduction, formulating, analysing, observing, designing, presentation and analysing. The researcher feels the most beneficial scientific skill developed by students was critical thinking.

The students’ comments below show how comfortable students got and the ease at which they used scientific skills. Some of their comments include;

“Listen to everyone’s theories, by using the process of elimination we assumed what was under the box” (Inquiry student 4)

“We communicated with each other to find out what numbers were on which side of the dice. We concluded and predicted what the number underneath then was” (Inquiry student 9)

“We used teamwork to see what numbers were on each side, we listened to each other, we communicated, we observed and we discussed what number may be at the bottom” (Inquiry student 12)

“We communicated with each other in our groups and made predictions of what the number might be. We used our previous knowledge of maths and listened to each other” (Inquiry interviewee 4)

One weak student commented “I used pattern forming and comparison skills” (Inquiry student 20)

I used the skills of logic and pattern forming to find the answers for both boxes” (Inquiry interviewee 1)
5.7.4 Critical thinking

The researcher thinks the development of critical thinking is one of the most necessary and important skills for science students. The inquiry lessons contained task sheets that encouraged students over the 14 week period to ask questions and problem solve. The inquiry lessons were designed in order to get students to take responsibility of their own learning and to take charge of their own thinking. The students rose to the challenges and seemed to enjoy being able to develop and design an experiment themselves. The researcher believes the students succeeded in developing critical thinking skills. One student commented "love dissections because it’s an organ in front of you and you can get in at it and I don’t like when in other science classes you can’t just do what you want. I planned how to dissect it; I did what I wanted to do” (Inquiry interviewee 3). Some other student comments from the inquiry class include;

- “Experimental skills, logical thinking... being able to just think for myself. Designing an experiment is a skill isn’t it? Yea, I liked doing that” (Inquiry interviewee 3)
- “The fact we had to make up our own experiment instead of doing one out of the book was most beneficial to me I think” (Inquiry interviewee 4)
- “Being able to create our own experiment was beneficial as a science student” (Inquiry student 8)
- “We are allowed do our experiments our own way without people telling us what to do” (Inquiry student 21)
- “The lessons were a more practical approach to science and I found I was thinking more than I would while doing previous experiments in science” (Inquiry student 1)

5.7.5 Computer and Presentation skills

Students were encouraged to use technology as often as possible throughout the intervention programme. The researcher felt there was a change in the students’ perceptions towards technology in school and their view that the computer existence is only for the accessibility of Facebook. Student used their cameras function on mobile phone or brought in cameras to take photos of some lessons and use them in the results for their presentations or posters. The computers were used for research, to create PowerPoint presentations and to show videos of
experiments students had chosen to record. Initially students were unsure and produced quite
reserved posters but as the lessons progressed the photographs, posters, presentations and
PowerPoint presentations became more elaborate and detailed. The researcher was surprised
that students had never being taught how to use PowerPoint presentation. All students
expressed at some point that using different research website on the internet and knowing
how to make a PowerPoint was one of the most beneficial skills they learned. Some of their
other comments included;

→ “In class we get to do some research and then we do the experiment on our own”
   (Inquiry student 10)
→ “The power point presentations were beneficial as I learnt how to present projects on
   PowerPoint… I never done that before” (Inquiry student 5)
→ “I learned how to use the power point presentation and that will be valuable to me in
   the future” (Inquiry student 6)
→ “Learning all about how to present and presenting made me grow in confidence”
   (Inquiry student 7)
→ “The presenting part because it would be good for me after school and give me
   confidence for the future” (Inquiry student 12)

5.7.6 Understanding of science topics covered
The researcher believes students demonstrated a great understanding of the topics covered.
This understanding can be visually seen and verbally heard. During experimental,
PowerPoint and poster presentations students displayed an understanding of the topic, a
purpose for engaging in certain experimental procedures as well as answering questions
posed by fellow students and the teacher. Time was given to students to develop their
understanding and to discover instead of theory being just thrown at them in the form of
notes, a common ritual they have encountered every day for three schools years. The students
commented that they learned an important factor during the intervention programme that
makes even abstract and hard topics doable and this was the ability to think for themselves.
An inquiry student interviewee commented that “I think I learned how to think a little for
myself. I am so used to teacher just telling me how to do things that when the teacher goes
right off you go and come up with a plan or procedure you are kind of sitting there for a bit
going what? I think I know how to change around an experiment if the results I getting are
not what I want as well” (Inquiry interviewee 1). Some other student comments include;
→ “I enjoyed understanding stuff that I didn’t when I was in third year” (Inquiry interviewee 4)

→ Enzyme lesson – →We noticed that the lower the temperature got, the longer it took for the disk to rise. As more heat was added, the time got quicker so more heat=quicker time” (Inquiry student 6)

→ →I will make the solution with cold water and I expect the reaction to slow down and the time it takes for the disk to rise was longer” (Inquiry student 8)

→ →A control is something that you need to compare your results to” (Inquiry student 9)

→ Mitosis lesson - →I looked at all the pictures and just made them get bigger and bigger and then put them into sequence and had to find a pattern in the pictures”.

→ Osmosis lesson: →To change the mass I could heat the egg as the egg mainly has water and the water could evaporate or freeze it and thaw it out and then mix egg with ketchup because that has high salt in it and that would draw the water out of the egg” (Inquiry student 11)

→ →The egg is mainly made up of water, so maybe if we freeze it or heat the egg it may shrink or expand if we freeze it” (Inquiry student 13)

→ “I numbered them in what I thought was the right order, then I cut them out and glued them to a sheet to get a look at the sequence in the right order” (Inquiry student 17)

→ →With logic and pattern forming, I realised that the numbers and names were significant and similar” (Inquiry student 19)

→ Mitosis lesson- →I chose mostly at random first, but then I looked for a pattern and looked the most natural to me” (Inquiry student 6)

5.7.7 Perception/attitudes towards science and scientists

The researcher looked at the pre questionnaires and found that students had a very basic understanding and vision of what a scientist is and does. As the students progressed through the intervention programme their understanding of what a scientist is, the scientific skills they think a scientist needs, the scientific skills they used and their critical thinking improved. A noticeable change can be seen in the students’ perceptions and attitudes towards scientists and science in the pre and post questionnaire results that were discussed in the above sections. One student commented in the pre questionnaire that a scientist is →someone who does experiments and makes discoveries and works in a lab” and in the post questionnaire the same student said that a scientist is →someone who uses different skills, who solves problems
and thinks logically about things” (inquiry student interviewee 4). The researcher thinks the inquiry lessons helped students to change their perception towards scientists by being able to give students the opportunity to mimic the skills of real scientists and understand certain aspects of their work. Each inquiry lesson enabled the students to build up their inquiry skills. These skills learnt in one lesson could then be used and benefit them in the next lesson. Some of the students’ comments from the post questionnaire when asked what they think a scientist is include:

→ “A scientist uses skills like prediction, observation, communication, calculations, previous knowledge, group work, experimentation, pattern forming…” (Inquiry student 14)

→ They communicate with each other, make predictions, use process of elimination, make estimations and use their previous knowledge” (Inquiry interviewee 4)

→ They use their communication skills and have to use their problem solving skills as well as their logic” (Inquiry student 18)

→ The scientist would use discussion, logical thinking, communication, pattern forming, concluding as their skills” (Inquiry student 2)
Chapter Six
Discussion of Findings, Conclusions and Recommendations

6.0 Introduction
This study attempts to gain an insight into the attitudes of students and teachers towards inquiry-based learning and teaching methods in Junior Certificate Science and Leaving Certificate Biology. An analysis of issues is drawn from the literature and research findings. The results will be discussed under the headings;

- The extent of which inquiry-based learning is used in the Leaving Certificate Biology classroom.
- Development of Resources
- Engagement in Inquiry Science.

This chapter will then conclude with a section listing main conclusions and recommendations arising from the results.

Inquiry is the basic learning process of "identifying a question, designing an investigation, collecting data, developing a hypothesis, answering and modifying the original question and communicating the results" (Flick, 2005). The critical skills developed by students include observing, hypothesizing, predicting, designing an investigation to solve a problem, measuring accurately, processing and interpreting data, drawing conclusions, inferring, generalizing, recognising assumptions, understanding limitations of scientific investigations, classifying, evaluating, making rational judgments based on information and explaining and applying knowledge to new situations" (Uno, 1990).

Science and biology students and biology teachers are not carrying out the true principles of scientific inquiry. The majority of science and biology students in this study said they do not work according to their own design which is the underlying principle of inquiry-based learning. According to students a large to very large proportion of class time is taken up by teacher demonstrations, discussions among the teacher and students and teacher talk. Kyriacou (1997) reported this as an increasingly worrying trend with teachers using direct teaching methods more frequently than active learning methodologies.

More class time was allocated to group work tasks in Junior Certificate Science than in Leaving Certificate Biology. Flick (2005) states the importance of allowing students to work...
in groups as they are able to learn from one another, which helps to promote good collaboration skills, communication skills and social skills as well as science learning. The results of this research indicate that the majority of science and biology students performed their experimental write-ups on their own and used their own laboratory manuals, following step-by-step procedures from their textbook. A teacher interviewee said a reason for this was teachers did not want biology students to design their own experimental procedures for fear that they could misunderstand or misinterpret the task and perform an incorrect experiment. Scientific inquiry encourages students to carry out their own investigations, especially open-ended investigations, where students pose the problem to be investigated and they design their own procedures to answer the questions (Flick, 2005). The use of inquiry-based laboratory activities and how biology is being taught to students has a considerable influence on students’ attitudes towards biology, which further affects their enthusiasm for the subject, uptake and achievement levels (Fensham, 2006). This research shows that opportunities for inquiry-based learning are not being encouraged during biology class time.

Science and biology students said that they ask questions very regularly in class. But the majority of science and biology students did not question the theory being taught which suggests that the theory does not relate to their everyday lives or students lack interest in the theory being taught. The majority said that they take information as a given without ever questioning it and learn by learning off a set of facts. The main sources of knowledge used by both science and biology students are the textbook and handouts given to them by the teacher. A large majority of students said they never do their own research at home emphasising that there are few opportunities where students are encouraged to work in an independent inquiry environment.

6.1.1 Conclusion/Recommendations

According to the NRC (1996) a constructivist and inquiry-based culture can be created by “_the conventional view of professional development for teachers shifting from technical training for specific skills to opportunities for intellectual professional growth_”. All of the biology teachers questioned said that they would like to receive training and information on inquiry-based learning. Powell, Short & Landes (2002) stress the importance of engaging participants in professional development programmes in inquiry-based learning and associated teaching methodologies. Hurd (1969) noted that the reaction of teachers to criticism over the way in which they taught high school science was that they were teaching what they were taught in their pre-service training. Continuous professional development will help teachers
to gain a greater understanding of inquiry-based learning and give them the knowledge and confidence to implement it in Junior Certificate Science and Leaving Certificate Biology classrooms. The interviewees’ responses shed some light on the issue of professional development and professional support. When interviewees were asked how they think teachers could develop their understanding of inquiry, responses were comparable and ranged from the need for hands-on training and in-services training to being supplied with resources to aid them in the classroom.


The decline in interest in science and the proportion of students taking science subjects at Senior Cycle is an international phenomenon (Frame, 1996; Francis & Greer, 1999; Task Force on Physical Sciences, 2002; Regan & Childs, 2003; Jenkins, 2006; Politis et al, 2007). A recent report by the National Research Council, (2010) emphasizes the importance of how students are taught i.e. how teaching and learning methodologies incorporated into the classroom, as well as the importance of the material being taught in courses (National Research Council, 2010). The results show that biology students are not given opportunities to work according to their own design or to engage in group work or group discussions among their peers. Biology students said they spend a small to very small proportion of class time engaged in experimental work, with a large proportion of time spent listening to the teacher talk or observing teacher demonstrations. The majority of teachers (75%) said that inquiry-based learning is getting students to carry out experiments. However, inquiry-based learning is more than just getting students to do experiments as discussed in the literature review. If teachers lack a clear understanding of what inquiry-based learning is, then it will be very difficult to get them to incorporate it into their teaching methodology. Students are not being given the opportunity to mirror the qualities that scientists use in research as discussed in the literature review. Future biology assessments may include a practical exam and students will need to develop their inquiry skills and develop the process of scientific inquiry. A lack of integration with inquiry-based methods means that students do not have these opportunities and may feel less confident about the subject and not continue with science to third level.

Teachers do not allow the students the independence to develop their own procedures because, due to the constraints of the curriculum, teachers are not required and will not allocate a lot of time in developing students’ scientific process skills, and because practical skills are not assessed in the summative Leaving Certificate Examination. Teachers are under
pressure to try and cover an extensive amount of theory in the Biology syllabus in the allocated time. Many educational researchers have also identified similar constraints among teachers (Abd-El-Kalick, 2002; Llewellyn, 2005; Timmerman, 2005; Volman & Abell, 2003). The textbook is the biology students’ main source of knowledge. Students are not encouraged to gather further information for themselves because it is handed to them by the teacher in the form of notes, handouts and Power Points. Llewellyn (2005) discusses how textbooks are the greatest single source of information from printed materials used in high schools today. Although many curricular materials bear the label ‘inquiry’, upon closer inspection what may be claimed to be inquiry falls short of the vision of inquiry put forth by the National Standards (NRC, 1996). There was an overall negative response towards textbooks promoting the inquiry skill of ‘designing’ among biology students. Biology teachers were asked if they think the textbook promotes the following inquiry skills - formulating, designing, questioning, observing, experimenting and critical thinking and the majority of teachers (75%) think the biology textbook allows students to pose a question.

Overall, teachers do not think the biology textbook promotes inquiry skills such as formulating, designing, predicting, observing or applying techniques. There is a lack of textbooks or other curriculum materials which really encourage inquiry learning. Many high school science teachers begin the school year by introducing the scientific method to students. The scientific method is so important to many textbook publishers that it is predominantly introduced in the first chapter of many secondary school science textbooks and it consists of rigid sequenced steps (Llewellyn 2004). The results also showed confusion among teachers regarding the difference between scientific inquiry and scientific method.

The majority of students (77%) said they followed a step-by-step experimental procedure. Hurd et al, (1980) found that whilst inquiry was a stated goal of biology programs, few biology activities (10%) stress independent inquiry. Biology teachers said they did not want their biology students designing their own experimental procedures for fear that they would perform the experiment incorrectly. The understanding and purpose is lost and this knocks any confidence the students may have had in the subject. Teachers who got students to design experimental procedures said they did so out of necessity as the textbooks they use got recycled within school and were of a poor and outdated nature.

The majority of students placed a very important to important emphasis on understanding every topic, memorising scientific facts and studying in order to answer past exam papers. Biology students and teachers rated the development of scientific skills as a least important factor in being successful in Leaving Certificate Biology. This is due to the
fact that there is no practical assessment in biology, with no emphasis on practical inquiry skills on the examination paper. Surprisingly, nearly half of the teachers said that it is less important for students to understand every topic. This highlights that teachers may teach towards the requirements of the examination i.e. the memorisation of facts. There is pressure on teachers to adequately prepare students for assessment tasks, and if teachers do not perceive inquiry techniques as being the best means of doing so, they will feel compelled to not use them, no matter how much they may believe in the greater value of such techniques. This tells the researcher that the current Leaving Certificate Biology Examination at present appears to encourage teacher to teach to the exam and favours students who are able to learn large volumes of material that they can regurgitate on the day of the exam. The LC Biology examination does not assess students’ scientific inquiry or scientific process skills and as a result, these skills are not being encouraged by the teacher.

Various responses appear in the results when interviewees were asked how they think inquiry-based learning could be better incorporated. Their responses ranged from the need for inquiry resources and a change in assessment to less pressure to complete the syllabus and more time for discussion. From the interviews, it can be seen that the teachers who use inquiry-based methods know of the benefits and advantages it has for student learning. This does not seem to overcome the numerous issues such as continuous professional development, resources, time constraints and assessment that are at the forefront of why more teachers say they do not readily engage in inquiry-based methods.

6.2.1 Conclusions/Recommendations

There is a need for a change in how biology is assessed at Senior Cycle. Tobin et al. (1990) reported that teachers felt constrained by the tests and exams and Tobin and Gallagher (1987) noted that academic work in high school classes was strongly influenced by the local assessment system. Gleeson (2000) agrees, stating that as long as the education system at second level is dominated by the Leaving Certificate examination and subjects are heavily content-laden, didactic methods will predominate.

For constructivist teachers to align their instructional goals with assessment goals, they need the flexibility to have students demonstrate their competencies using forms of assessment other than paper-pencil, objective type examination. A shift towards the use of journals, portfolios, performance tasks with rubrics and self-assessment becomes essential (Llewellyn, 2004). In 2004, the NCCA began reviewing the senior cycle syllabi. They envisioned a future where students are given more responsibility for their own learning and
teachers are the facilitators rather than then conveyors of knowledge as they presently are (McMorris, 2004). A consultation period opened by the NCCA for senior cycle syllabi is ongoing and will close in October 2011. If introduced, biology students will undergo a practical assessment using inquiry-skills worth 15%. An assessment will be carried out on the students’ abilities to conduct investigations, to communicate information and grasp an understanding based on the investigation they carry out.

6.3 Development of Resources

Teachers often state that a lack of equipment or resources is a barrier to using inquiry-based methods (Keys & Bryan, 2001; Welch et al., 1981). Biology students reported handouts as a source of knowledge used in their biology class. This shows this researcher that teachers make and use their own resources. The results show that the majority of teachers (87.5%) said they would require resources for inquiry based methods to help them implement inquiry-based methods. If an inquiry-based teaching methodology is to be successfully implemented and assessed, suitable inquiry resources would be needed by teachers as planning inquiry lessons and making their own resources would be time consuming. Teachers cited ‘lack of time’ as an implication of inquiry based methods with 87.5% of teachers saying inquiry methods are time-consuming. Hodson (2010) also explained that a problem with asking teachers to teach something that is both new and different to their familiar curriculum is that it makes the developed resources of an experienced science teachers irrelevant with the possibility of them reverting to just ‘telling’ students. This is reiterated by 87.5% of teachers who felt that the pressure of getting the course completed for examinations restricts using inquiry-based learning.

Transition year science class allows students to explore and experiment without time constraints or pressures of examination. As a result, 75% of teachers have reported that they use different approaches to teaching TY classes than senior classes (Smyth et al., 2004). Teachers gave a variety of responses when asked to explain how they would incorporate inquiry into their teaching. The responses included project work, getting students to engage in experimentation, prediction, higher level questioning, proposing problems and getting students to formulate the answers. All of these skills encourage inquiry-based learning. However, there were two teachers (25%) that gave no response to how they incorporate inquiry into their teaching, suggesting that they do not use inquiry-based methods in their teaching. It is important that science teachers are provided with resources that encourage teachers to implement inquiry methods as they may be the most influential party in
encouraging pupils and inspiring their pupils to pursue science-related careers (Carmicheal et al., 1988). If teachers have adequate resources the quality of learning for pupils will be improved greatly (Kyriacou, 2001).

6.3.1 Resources for Intervention Programme.

Many teachers do not have the time during school term or the skills to develop new modules for TY so they revert back to the old reliable textbook which in turn leads to dull, monotonous lessons (Childs, 2006). If teachers engaged in in-services or CPD relating to inquiry-based learning during school term then they could develop their own resources for inquiry lessons outside of the school term. The intervention programme was chosen to be implemented into Transition Year. The Inquiry Based Biology Lesson Student Booklet was developed for the teachers and given to teachers to encourage them to implement inquiry as they would not have to spend time developing resources or modifying current biology lessons. Five lesson plans, task sheets, worksheets, photos and videos would be given to teachers. The lesson plan would contain aims, objectives, time allocation, preparation, summary of lesson under the 5 E’s learning cycle and instructions of what the teacher could ask or do during lesson. A list of equipment accompanied each lesson plan and resources required for the experimental tasks could be found in most school science laboratories as they mirrored some of the mandatory experiments completed by Leaving Certificate Biology students or a local shop. A task sheet and worksheet based on each topic also accompanied the lesson plans. The availability of a computer room would be necessary for Power Point presentations. However, teachers would be shown how to adapt the lesson plans, resources and tasks to suit the needs of their students and availability of resources within their school.

The Inquiry Based Biology Lesson Student Booklet was very successful. The comments made by students on their pre- and post-lesson questionnaires were extremely positive. The students' worksheets and task sheets (see CD attached for sample Inquiry Based Biology Lesson Student Booklet) throughout the intervention programme showed the researcher how the students were progressing. The TY students who engaged in the Intervention programme thought the inquiry lessons were beneficial to them in the long term as they got to learn how to make and then present their Power Point presentation and make a photo-story board of their dissection with a poster presentation. Students liked that they got freedom to design and do their experiments while developing their scientific skills. Some students commented that they were delighted that they got to think differently and more than
normal about topics, think for themselves, try different things in the experiment and most importantly they had fun doing it.

6.3.2 Conclusions/Recommendations

The Inquiry Based Biology Lesson Student Booklet used for the intervention programme could be distributed to other teachers around Ireland and used as part of their TY biology module and where applicable, Senior Cycle Biology class. Continuous professional development will again be needed to show teachers how to modify their resources and current traditional teaching methodologies to be more inquiry-based. Future in-services could be conducted and the inquiry resources used during the intervention programme shown as a sample, and the experiments and topics based on the Biology Syllabus modified to become more inquiry-based.

Further development of the Inquiry Based Biology Lesson Student Booklet could be undertaken with more inquiry lesson plans added to coincide with the new Draft Biology Syllabus (2011) with more emphasis placed on the process of scientific inquiry and associated skills.

6.4 Engagement in Inquiry Science.

Transition Year Science the perfect opportunity to prepare and practice skills because there is lack of pressure and less time constraints generally felt by teachers during exam years. Freedom was given to Transition Year students to design and carry out investigations without the worry of time constraints. Innovative opportunities were given to students during the intervention programme that are not readily given during traditional classes. Students were initially apprehensive and unsure about designing their own experiments, engaging in group work and actively working without the direct guidance of the teacher. However, the students who participated in the inquiry classes during the intervention programme showed both an increased understanding of inquiry skills and became more responsible for their own learning. They showed motivation and eagerness to work according to their own design. Both low and high achieving students worked collaboratively and developed various skills. The researcher noted several changes in the attitudes of some students towards science and school in general. Throughout the intervention and after each inquiry lesson observational notes were taken by the researcher, who would circulate the room during the lesson and observe student participation and effort within their groups. The changes in attitudes were measured
by analysing the pre- and post-interviews.

The results from the pre- and post-lesson questionnaires show that all students who engaged in the inquiry classes when compared to the traditional class showed an increased understanding of inquiry skills; they exhibited confidence in the process of inquiry and designed successful experimental procedures. The inquiry student interviewees showed changes in their opinions, attitudes and understandings towards inquiry skills and biology topics in their pre- and post-lesson interviews. In a pre-interview with student interviewee one, she said scientific skills involved just “doing experiments”. In the post-interview her response changed dramatically. She said “they are skills that you need to be a scientist. Like important skills. They are more than just the basic skills we use doing an experiment. They are skills like problem solving, using logic, pattern forming, comparison, communication, analysing”. They gave more detailed statements regarding terms and displayed a greater understanding of what inquiry-based methods involved and the inquiry skills needed during each lesson while the traditional student interviewees did not.

6.4.1. Change in Attitudes

There was a noticeable change in the students’ perceptions and attitudes towards scientists and science in the pre- and post-lesson questionnaire results. The researcher believes that the inquiry lessons have helped students to change their perception towards scientists by being able to give students the opportunity to mimic the skills of real scientists and understand certain aspects of their work. There was a noticeable change in attitudes of some of the inquiry student interviewees who seemed unsure if they would take LC Biology but after doing the intervention programme appear more certain that they would. Students were given the opportunity to use everyday technology in science and the researcher also noticed a change in the students’ attitude towards technology in school and their view that the computer exists only for accessing Facebook.

6.4.2. Low and high achievers working together.

Biology Teachers were asked what ability of student they thought inquiry based learning methods suited best and 25% of teachers (n=2) said they think inquiry based learning was most suited to higher ability of students, while 75% of teachers (n=6) said that inquiry based learning is suitable to both higher and weaker ability students. Three out of the four interviewees felt that higher ability students would be better at doing inquiry methods, with
one interviewee saying she thought it would suit all abilities.

The researcher noted a relevant comment made by a teacher interviewee regarding student abilities. He said he thinks ‘the high ability kids will always plough ahead and get it wrong or right, the average ability kids will wait to see what other lads are at and then the weaker ability will be doing nothing’. One of the high achieving inquiry student interviewees reiterates this point as she found that she was the lead person and it got annoying sometimes because they looked to me for help or the answer nearly’.

Nonetheless, the intervention programme results show that both low and high achieving student can work well together. The researcher feels that there was a positive change in the way students understood science and was most evident among the weaker students. The researcher observed some students with learning difficulties, some that were shy, others at risk of being early school leavers, students who are considered weak academically and new students all excel throughout the intervention programme. Most of the students appeared motivated and eager to participate regardless of their ability.

6.4.3. Skills
The researcher observed the Transition Year students developed better communication skills, scientific inquiry skills, computer and presentation skills and social skills during the intervention programme.

6.4.4. Communication skills
The pre- and post- lesson questionnaires show that students frequently said they used communication when asked about their scientific skills. An inquiry student commented that they ‘used communication skills to share our ideas’. The researcher noted that students became more confident and articulate in their ability to communicate their scientific findings and answer questions during their presentations. Students are able to learn from others in the group which helps to promote good communication and people skills as well as lifelong science learning (Linn, 2000).

6.4.5. Scientific Inquiry Skills
When students were asked what scientific skills a scientist should have, the results in the pre-lesson questionnaire showed that the majority (38% and 25%) answered ‘I don’t know’ or thought it had ‘something to do with experiments’. The post-lesson responses looked
completely different with all students listing skills that included communication, logical thinking, problem solving and experimentation to name a few. The researcher feels the most beneficial scientific skill developed by students was critical thinking. The students commented that they learned an important factor during the intervention programme that makes even abstract and hard topics doable and this was the ability to think for themselves. The inquiry lessons were designed in order to get students to take responsibility of their own learning and to take charge of their own thinking. Scientific inquiry skills are skills that are relevant for a student’s everyday life and for developing problem solving and decision making skills (Bloom, 1956).

6.4.6. Computer and Presentation Skills

The most useful skill students said they learned was computer and a presentation skill with all students eagerly participating and commenting positively in the results. One inquiry student said ‘learning all about how to present and presenting made me grow in confidence’ while another inquiry student said ‘the Power Point presentations were beneficial as I learnt how to present projects on PowerPoint… I never did that before’. The results from the Transition Year student interviews show two out of the four inquiry student interviewees found the presentations very beneficial. This could be considered a cross-curricular skill as students will be able to use the knowledge learned here during subjects.

6.4.7. Social Skills

The Transition Year Students were engaged in a large proportion of group work, experimental work and discussion among themselves during the intervention programme. The researcher observed that they forged group relationships and appeared to bounce ideas off one another and depend on one another for reassurance and confidence. One inquiry student interviewee commented that ‘when someone is out in the group it is kind of annoying because you end up only being a pair or just you on your own’. Students are able to learn from one another in the group which helps to promote good collaboration skills, communication skills and social skills as well as science learning (Flick, 2005).
6.5 Final Conclusions and Recommendations

- This research has shown, that inquiry based learning is a highly effective pedagogy in supporting learning in the classroom. For inquiry-based learning to be successful at senior cycle a number of strategies and changes need to occur;
  
  1. In order for inquiry-based learning to be accepted widely it needs to be incorporated into the Junior Certificate Science and Leaving Certificate Biology assessment.
  2. A reduced curriculum with an emphasis on quality of theory and not quantity of theory and block scheduling would decrease the time constraint felt by the majority of teachers.
  3. The need for inquiry-based learning modules to be introduced to undergraduate teachers in Universities to teach them how to develop inquiry-based lesson plans and resources.
  4. More widespread availability of continuous professional development and inquiry resources for the current teaching profession.

- It would be recommended that every second-level biology teacher would incorporate an inquiry-based learning module similar to the Inquiry Based Biology Lesson Student Booklet attached to the intervention programme, into their Transition Year Science Module and then into Senior Cycle Biology.

- It is imperative that a change is made to the declining uptake of sciences at senior cycle. Inquiry-based learning influences students to be lifelong learners. It will prepare students for college science and for careers in science due to the practical nature involved and scientific process skill development. It also has the potential to increase the uptake of science subjects at senior level due to an increase in motivation and engagement in science.

- The NCCA opened a consultation period for the Senior Cycle Sciences Syllabi and will be closing in October 2011. This study will be relevant to the NCCA in informing them of future curricula.

6.6 Future Research and Conclusion

The benefits for further research in this area are sizeable. There would be merit to repeating an intervention programme on a wider scale with greater numbers of science and biology students and teachers and schools being used throughout Ireland. To assess the effectiveness
of inquiry based learning a future longitudinal study would be needed to assess students from first year to six year student consecutively. The NCCA consultation period for new Senior Cycle Sciences Syllabi closed in October 2011. If new Senior Cycle Syllabi and Assessments come into effect, an investigation maybe needed into teacher attitudes towards these new syllabi and if there is a willingness or necessity felt by teachers to use inquiry-based methods. In preparation for the introduction of a new draft Biology Syllabus, an investigation into a possible scientific skills gap between Junior Certificate Science and Leaving Certificate Biology could be needed. In order to build on skills students are perceived to have, it is imperative that research is done to clarify the skills being actually used by students during science class and the Junior Certificate Science Coursework B.

The intervention programme could be used for in-services on inquiry-based learning with the SLSS to help teachers design and develop their own resources. A further research project could involve the use of an inquiry-website for teachers to share their inquiry resources, have a forum to discuss lessons and get help from other teachers if continuous professional development is not readily available to them.
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Appendix 1

Information sheets and consent forms

Teaching Science and Biology through Inquiry at Senior Cycle in Irish- Post primary Schools.

Teacher and Parent/Guardian Information Sheet

Purpose: The purpose of this research is:

➢ To investigate inquiry based teaching methods in the Junior Certificate Science and Leaving Certificate Biology syllabus.
➢ To investigate teachers’ understanding of Inquiry.
➢ To get feedback on the Teachers’ Laboratory methods used in science and biology.
➢ To investigate the implementation of Inquiry in the science and biology classrooms.

Data Collection:

The research will use quantitative and qualitative data collection methods, distributing questionnaires to students and teachers of Junior Certificate Science and Leaving Certificate Biology around the country. Interviews will also be carried out with Biology teachers willing to get involved.

Confidentiality: Every effort will be made to ensure confidentiality of data. Data will be securely held in a locked filing cabinet and will be retained for 7-10 years (as required by UL Ethics Committee). All schools will be given a numerical code so no addresses or names will be used. Also each questionnaire will have a specific code so no participants will include their name.

Anonymity: Participants will be invited to view questionnaires and project outputs and will have opportunity to withdraw statements or data before publication.

Research Output: The research will contribute to a Masters in Science submission by the researcher.
Further information: Further information can be obtained from the principal investigators, Emma Ryan (emsinlimerick@hotmail.com) and Dr. Maeve Liston, University of Limerick (email maeve.liston@ul.ie). If you have concerns about this study and wish to contact someone independent, you may contact: The Chairman of the University of Limerick Research Ethics Committee, c/o Vice President Academic and Registrar’s Office, university of Limerick, Limerick, Tel (061) 202022.

The University of Limerick is subject to the Freedom of Information Act and all research procedures will adhere to the provisions of Data Protection legislation.
Teaching Science and Biology through Inquiry at Senior Cycle in Irish- Post primary Schools.

Teacher and Parent/Guardian Consent Form

You are invited to take part in the research, you may choose to take part as little or as much as you wish. You are under no obligation to participate in the research and may withdraw at any time. Should you agree to take part, and sign this consent form, you may still decide after data collection, that you do not wish for your data to be included for analysis.

Research will involve qualitative data collection in the form of questionnaires. The questionnaire data will be stored in a secured environment in UL, for a period of 7-10 years, as required by the UL Research Ethics Committee, and will only be accessed by the principal investigator Dr. Maeve Liston and a FYP student under the supervision of the principal investigator.

It is intended that the research will contribute to a Final Year Project submission by the researcher. Further information can be obtained from the principal investigator, Dr Maeve Liston University of Limerick (email maeve.liston@ul.ie). If you have concerns about this study and wish to contact someone independent, you may contact: The Chairman of the University of Limerick Research Ethics Committee, c/o Vice President Academic and Registrar’s Office, university of Limerick, Limerick, Tel (061) 202022. The University of Limerick is subject to the Freedom of Information Act and all research procedures will adhere to the provisions of Data Protection legislation.

“I have read and understand the Information Sheet Provided in relation to this research. I understand how the research will be conducted and disseminated. I know that participation is voluntary and that I can withdraw from the project at any stage without giving any reason”

Signed: _______________________________ Date: ________________
Teaching Biology through Inquiry at Senior Cycle in Irish - Post primary Schools.

Biology Student Information Sheet

Purpose: The purpose of this research is to:
- Investigate if Biology students are taught the current biology syllabus through inquiry based learning.
- Gather feedback from biology students on their attitudes towards the biology syllabus and the teaching methods used in biology class.
- Discover the students' perspective of how they are taught, on lab work, class work and examinations that they have undergone.

Data Collection: Information will be gathered by distributing questionnaires to teachers and students of Science and Biology around the country. These questionnaires will gather information on your experience of how Biology are taught to you in the classroom and how you learn these subjects.

Confidentiality: Every effort will be made to ensure confidentiality of data. Data will be securely held in a locked filing cabinet and will be retained for 7-10 years (as required by UL Ethics Committee).
Teaching Biology through Inquiry at Senior Cycle in Irish- Post primary Schools.

Biology Student Consent Form

You are invited to take part in the research, you may choose to take part as little or as much as you wish. You are under no obligation to participate in the research and may withdraw at any time.

“I have read and understand the Information Sheet Provided in relation to this research. I understand how the research will be conducted and disseminated. I know that participation is voluntary and that I can withdraw from the project at any stage without giving any reason”

Signed: ____________________________ Date: ________________
Teaching Science through Inquiry in Irish- Post primary Schools.

Science Student Information Sheet

**Purpose:** The purpose of this research is to:
- Investigate if science students are taught the current science syllabus through inquiry based learning.
- Gather information from science students on their attitudes towards the science syllabus and the teaching methods used in the science class.
- Discover the students' thoughts on how they are taught, lab work and class work.

**Data Collection:** Information will be gathered by distributing questionnaires to teachers and students of science around the country. These questionnaires will gather information on your experience of how science is taught to you in the classroom and how you learn these subjects.

**Confidentiality:** Every effort will be made to ensure confidentiality of data. Data will be securely held in a locked filing cabinet and will be retained for 7-10 years (as required by UL Ethics Committee).
Teaching Science through Inquiry Irish- Post primary Schools.

Science Student Consent Form

You are invited to take part in the research, you may choose to take part as little or as much as you wish. You are under no obligation to participate in the research and may withdraw at any time.

“I have read and understand the Information Sheet Provided in relation to this research. I understand how the research will be conducted and disseminated. I know that participation is voluntary and that I can withdraw from the project at any stage without giving any reason”

Signed: _______________________________ Date: ________________
Junior Certificate Science Questionnaire Structure: The science student questionnaire had three parts with thirteen specific questions. The purpose of these questions will now be discussed;

→ Part one: General Information
- **Question one**: The purpose of this question was to establish name of student.
- **Question two**: The purpose of this question to establish sex of student.
- **Question three**: The purpose of this question to establish year of student.

→ Part two: Investigations in Science
- **Question four**: The purpose of this question was to establish what students use when writing up their experimental reports
- **Question five**: The purpose of this question was to establish if students write up reports in groups or individually.
- **Question six**: The purpose of this question was to find out how they follow experimental procedure
- **Question seven**: The purpose of this question was to assess the opportunities given to science students in class
- **Question eight**: The purpose of this question was to investigate if laboratory booklets/textbooks allow students to understand the experiment.
- **Question nine**: The purpose of this question was to investigate the main sources of knowledge science students’ use in class.
- **Question ten**: The purpose of this question was to investigate students’ opinions on the allocation of time given to tasks in science class.

→ Part three: Learning Science
- **Question eleven**: The purpose of this question was to establish how often students’ question in science class
- **Question twelve**: The purpose of this question was to establish students’ opinions on how they learn science
- **Question thirteen**: The purpose of this question was to establish how good students’ are at writing and thinking of conclusions for completed experiments
JC Science Student Questionnaire

Instructions

This questionnaire is part of an effort to improve teaching and learning in Junior Certificate Science. Your answers are completely confidential and will not be seen by anyone only the research coordinators.

Part One: General Information
1. Name of Student: ____________________________________________

2. Please tick the appropriate boxes in the following questions below:
   - Male       - Female

3.           1st Year          2nd Year          3rd Year

Part Two: Investigations in Science

Please tick the boxes for the following questions below.

4. When writing up your laboratory experiments in Science, you use:
   - Laboratory workbook accompanying the text box
   - Your own laboratory copies

5. You write up laboratory reports:
   - On your own       - In groups

6. You follow the experimental procedures from/by:
   - Step by step from the text book
   - Designing your own experimental steps
7. Please tick the appropriate boxes from the following questions.

<table>
<thead>
<tr>
<th>In the science classroom are you given the opportunity to:</th>
<th>Yes</th>
<th>No</th>
<th>I don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask a question</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create your own theory (explanations in science)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predict the experiment results</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design how to make observations during an experiment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design how measurements are taken</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design the step by step procedures for an experiment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work according to your own design</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create new questions to be answered from the experiment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use new experimental techniques</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use your experimental results to make new predictions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rather than what it says in the book</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. Do the laboratory booklets/textbooks allow you to really understand what they have just investigated?

☐ Always  ☐ Sometimes  ☐ Never

9. The main sources of knowledge you use in science are:

☐ Text Book ☐ Workbooks ☐ Extra Handouts ☐ The internet ☐ Other

If other please specify: ____________________________________________

10. Please indicate below, by ticking the appropriate boxes what proportion of the classroom time in science is taken up by the following:

<table>
<thead>
<tr>
<th></th>
<th>Very Large Proportion</th>
<th>Large Proportion</th>
<th>Small proportion</th>
<th>Very Small Proportion</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher talk</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discussions among yourselves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Classroom discussions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with the teacher and the</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student working alone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student laboratory work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher demonstrations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part Three: Learning Science

11. Please tick the appropriate boxes from the following questions.

Do you ask questions in science? 
Do you ever question the theory being taught? 
Do you ever question and investigate the theory being taught with the teacher?

12. Please tick the appropriate boxes from the following questions.
A: Always S: Sometimes N: Never NS: Not Sure

You take information as a given without ever questioning it
You learn by trying to understand the topic
You learn by questioning the theory being taught
You do their own research in science at home

13. How good are you at writing and thinking of conclusions for experiments you have carried out?

Very Good Good Average Poor Very Poor
Leaving Certificate Biology Student Questionnaire Structure

The biology student questionnaire had four parts that contained eighteen specific questions. The purpose of these questions are described under each part:

→ Part one: General Information
  - Question one: The purpose of this question was to establish name of student
  - Question two: The purpose of this question was to establish sex of student
  - Question three: The purpose of this question was to the year of the student

→ Part two: Investigations in Biology
  - Question four: The purpose of this question was to investigate what students use when writing up their laboratory experiments
  - Question five: The purpose of this question was to find out if students write up their laboratory reports individually or in groups.
  - Question six: The purpose of this question was to investigate how students follow experimental procedure.
  - Question seven: The purpose of this question was to investigate students’ opinions on opportunities given to them in biology class
  - Question eight: The purpose of this question was to investigate if the questions at the end of the experiment procedure in textbooks/lab manuals adequately promote inquiry skills in students
  - Question nine: The purpose of this question was to investigate if laboratory booklets/textbooks allow students to develop meaningful understanding of the experiments
  - Question ten: The purpose of this question was to assess what main source of knowledge students use in biology class
  - Question eleven: The purpose of this question was to investigate what students’ opinions are on the proportion of time taken up by task in biology class.

→ Part three: Learning Biology

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• **Question twelve:** The purpose of this question was to investigate how often students question in biology class.

• **Question thirteen:** The purpose of this question was to investigate students’ opinions on how they learn biology.

• **Question fourteen:** The purpose of this question was to assess if students thought they were any good at thinking or writing conclusions to experiments carried out.

→ **Part four: The Biology Syllabus**

• **Question fifteen:** The purpose of this question was to investigate students’ opinions on what the biology syllabus emphasises.

• **Question sixteen:** The purpose of this question was to investigate if students thought the laboratory activities matched what they were covering on the course.

• **Question seventeen:** The purpose of this question was to investigate what students thought they had to do in order to achieve good grades in the leaving certificate biology exam.

• **Question eighteen:** The purpose of this question was to investigate if students thought the current biology syllabus promoted good future scientists.
Biology Student Questionnaire

Instructions

This questionnaire is part of an effort to improve teaching and learning in Biology. Your answers are completely confidential and will not be seen by anyone only the research coordinators.

Part One: General Information
1. Name of Student: ____________________________________________

2. Please tick the appropriate boxes in the following questions below:
   - □ Male  □ Female

3. □ Fifth Year   □ Sixth Year

Part Two: Investigations in Biology

Please tick the appropriate boxes for the following questions below.

4. When writing up your laboratory experiments in Biology, you use:
   - Laboratory workbook accompanying the text book □
   - Your own laboratory copies □

5. You write up laboratory reports:
   - □ Individually    □ In groups

6. You follow the experimental procedures from/by:
   - Step by step from the text book □
   - Designing your own experimental steps □

7. Please tick the appropriate boxes from the following questions.
In the biology classroom are you given the opportunity to:

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
<th>I don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask a question</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create a theory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predict experiment results</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design how to make observations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design how measurements are taken</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design experimental procedures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work according to your own design</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create new questions to be answered from the experiment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apply new experimental techniques</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use your experimental results to make new predictions (or hypotheses)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using the experimental results to explain applications of biology in industry and the medical area</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. Please tick the appropriate boxes from the following questions.

Y: Yes N: No IDK: I Don’t Know

Do the questions at the end of the experiment procedure in textbooks and/workbooks adequately promote the development of your:

<p>| Critical Thinking Skills (to be able to come up with conclusions on your own) |</p>
<table>
<thead>
<tr>
<th>Y</th>
<th>N</th>
<th>IDK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Solving skills</td>
<td></td>
<td></td>
</tr>
<tr>
<td>To think and reason logically</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific skills</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific understanding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific knowledge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observational skills</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9. Do the laboratory booklets/textbooks allow you to develop meaningful explanations of what they have just investigated?

Always   Sometimes   Never

10. The main sources of knowledge you use in biology are:

Text Books   Workbooks   Extra Handouts   The Internet   Other

If other please specify:__________________________________________________________________________________________________________________________
11. Please indicate below, by ticking the appropriate boxes what proportion of the classroom time in Biology is taken up by the following:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Very Large Proportion</th>
<th>Large Proportion</th>
<th>Small proportion</th>
<th>Very Small Proportion</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher talk</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discussions among students</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Classroom discussions with teacher and students</td>
<td></td>
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</tr>
<tr>
<td>Student working alone</td>
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</tr>
<tr>
<td>Group work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student experimental work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher demonstrations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part Three: Learning Biology

12. Please tick the appropriate boxes from the following questions.


<table>
<thead>
<tr>
<th>Question</th>
<th>VR</th>
<th>R</th>
<th>S</th>
<th>VS</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you ask questions in biology?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you ever question the theory being taught?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you ever question and investigate the theory being taught with the teacher?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13. Please tick the appropriate boxes from the following questions.

A: Always S: Sometimes N: Never NS: Not Sure

<table>
<thead>
<tr>
<th>Question</th>
<th>A</th>
<th>S</th>
<th>N</th>
<th>NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>You take information as a given without ever questioning it</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You learn by learning off a set of facts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You learn by trying to understand the topic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You learn by questioning the theory being taught</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>You do their own research in biology at home</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

14. How good are you at writing and thinking of conclusions for experiments you have carried out?

<table>
<thead>
<tr>
<th>Very Good</th>
<th>Good</th>
<th>Average</th>
<th>Poor</th>
<th>Very Poor</th>
</tr>
</thead>
</table>

Part Four: The Biology Syllabus

15. Please tick the appropriate boxes for each of the following questions.
The biology syllabus places an emphasis on:

<table>
<thead>
<tr>
<th></th>
<th>Y</th>
<th>N</th>
<th>IDK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigating and questioning the theory being taught.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimentation in order to find answers.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ready made answers for students to accept.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The explanations are changed to fit the data you collected when doing an experiment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The data collected is changed/re collected in-order to fit explanations.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

16. Do laboratory activities closely match what you are learning on the biology course?

☐ Always ☐ Sometimes ☐ Never

17. Rank the following in order of importance.

Circle the boxes 1-4.

1 = most important and 4 = least important. You can only circle a number once.

In order for you to successfully complete and achieve good grades in the leaving certificate biology syllabus, you must:

- Memorise scientific facts
- Study in order to be able to answer past exam questions
- Understand every topic
- Develop scientific skills

18. Do you think the current syllabus promotes good future scientists? (i.e. that the students engage in many of the same activities and thinking as true scientists)

☐ Yes ☐ No ☐ I don't know
Biology Teacher Questionnaire Structure

The teacher questionnaire had six parts with thirty-six specific questions being asked in total. The purpose of each question will now be discussed;

→ **Part one: General Information**
  - *Question one:* The purpose of this question was to ascertain the name of the school
  - *Question two:* The purpose of this question was to ascertain the name of the teacher
  - *Question three:* The purpose of this question was to investigate the sex of the teacher
  - *Question four:* The purpose of this question was to find out the type of school
  - *Question five:* The purpose of this question was to investigate the number of students in the school
  - *Question six:* The purpose of this question was to investigate the number of years teaching experience the teacher has.

→ **Part two: Investigations in Biology**
  - *Question seven:* The purpose of this question was to investigate what teachers instruct their students to use when writing up their experiments.
  - *Question eight:* The purpose of this question was to investigate if teachers instruct students to write up experiments individually or in groups
  - *Question nine:* The purpose of this question was to assess how teachers instruct students to follow experimental procedure.
  - *Question ten:* The purpose of this question was to assess if teacher would feel comfortable not using a step by step procedure for experiments
  - *Question eleven:* The purpose of this question was to investigated teachers opinion on if the textbook allows students to engage in inquiry based activities
  - *Question thirteen:* The purpose of this question was to seek opinions from teachers on whether they think the laboratory booklets/textbooks allow students to develop meaningful understanding of the experiment undertook.
  - *Question fourteen:* The purpose of this question was to investigate what the main source of knowledge teachers use in the biology class.
  - *Question fifteen:* The purpose of this question was to investigate teachers opinions on the proportion of class time allocated to certain tasks in biology class

→ **Part three: Learning Biology**
  - *Question sixteen:* The purpose of this question was to establish teachers view point on how often students question in biology class.
  - *Question seventeen:* The purpose of this question was to investigate how teachers think their biology students learn biology
  - *Question eighteen:* The purpose of this question was to investigate if teachers believe the experiment is beneficial in changing or confronting misconceptions a student may have with a topic
  - *Question nineteen:* The purpose of this question was to investigate how good teachers think their students are at drawing conclusions from experiments carried out.

→ **Part four: The Biology Syllabus**
• **Question twenty:** The purpose of this question was to investigate teachers’ opinions on what they believe the biology syllabus places emphasis on.

• **Question twenty-one:** The purpose of this question was to investigate if teachers think the laboratory activities run parallel with course topics.

• **Question twenty-two:** The purpose of this question was to investigate what teachers believe students must do in order to obtain successful grades in biology

→ **Part five: What is inquiry based learning?**

• **Question twenty-three:** The purpose of this question was to assess if teachers understand what inquiry means

• **Question twenty-four:** The purpose of this question was to assess if teachers understand what inquiry based learning involves.

• **Question twenty-five:** The purpose of this question was to investigate if teachers think inquiry based learning involves experiments.

• **Question twenty-six:** The purpose of this question was to investigate if teachers understand scientific inquiry.

• **Question twenty-seven:** The purpose of this question was to assess if teachers use inquiry based methods in their teaching.

• **Question twenty-eight:** The purpose of this question was to assess how often do teachers used inquiry based methods

• **Question twenty-nine:** The purpose of this question was to assess how teachers incorporate inquiry into their lessons

→ **Part six: Implementing inquiry-based learning in the classroom**

• **Question thirty:** The purpose of this question was to investigate what teachers believe are factors that cause implications for implementing inquiry based learning.

• **Question thirty-one:** The purpose of this question was to investigate what type of control teachers think they have when engaging in an inquiry lesson

• **Question thirty-two:** The purpose of this question was to investigate if teachers thought the current biology syllabus allows scientific inquiry to be introduced in to lessons

• **Question thirty-three:** The purpose of this question was to assess if teachers believe the current biology syllabus promotes good future scientists.

• **Question thirty-four:** The purpose of this question was to investigate teachers’ opinions on what ability of student inquiry based learning is most suitable for.

• **Question thirty-five:** The purpose of this question was for teachers to communicate whether they think they need further training

• **Question thirty-six:** The purpose of this question was to investigate how students are doing in classes where the teacher uses inquiry methods.
Biology Teacher Questionnaire

Instructions

General Information
This questionnaire is part of an effort to investigate the use of inquiry based teaching in the Senior Cycle Biology Syllabus in schools around Ireland. Information given on this document is highly confidential and will be kept secure at all times. The reason why we ask for your name is that we can collect a data base of biology teachers around Ireland which we can contact with information on different activities being run by and resources available at the NCE-MSTL that may be of interest to you.

Part One

1. Name of School: __________________________________________

2. Name of Teacher: __________________________________________

3. Please tick the appropriate boxes in the following questions below:
   - Male  □  Female  □

4. Type of School:
   - □ All boys  □ All girls  □ Mixed

5. Number of students in the school:
   - □ >1500  □ >1000  □ >800  □ >600  □ >400  □ >200

6. How many years have you been teaching Biology?
   - □ 1-5  □ 6-10  □ 11-15  □ 16-20  □ ≥20

Part Two: Investigations in Biology

Please tick the appropriate boxes for the following questions below.

7. In your classroom when the students are writing up their laboratory experiments in Biology, they use:
   - □ Pre-printed laboratory manuals
8. Students write up laboratory reports:

Individually  In groups

9. Students follow the experimental procedures from/by:

Step by step detailed instruction in the text book  
Designing their own experimental steps  

10. Would you feel comfortable NOT using the step-by-step experiment procedure?

Yes  No  
Please explain your answer below

11. Please tick the appropriate boxes from the following questions.

<table>
<thead>
<tr>
<th>Does the biology textbook allow the students to:</th>
<th>Yes</th>
<th>No</th>
<th>I don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pose a question</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formulate a hypotheses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predict experiment results</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design how to make observations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design how measurements are taken</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design experimental procedures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Work according to their own design</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formulate new questions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apply new experimental techniques</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use their experimental results to make new predictions or hypotheses</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Applying experimental results to explain applications of biology in industry and the medical area</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
12. Please tick the appropriate boxes from the following questions.

Y: Yes N: No IDK: I Don’t Know

<table>
<thead>
<tr>
<th>Do the questions at the end of the experiment procedure in textbooks and workbooks adequately promote the development of the students’?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical Thinking Skills</td>
</tr>
<tr>
<td>Reasoning Skills</td>
</tr>
<tr>
<td>Problem Solving skills</td>
</tr>
<tr>
<td>To think and reason logically</td>
</tr>
<tr>
<td>Scientific methodology</td>
</tr>
<tr>
<td>Observational skills</td>
</tr>
</tbody>
</table>

13. Do the laboratory booklets/textbooks allow students to develop meaningful explanations of what they have just investigated?

☐ Always   ☐ Sometimes   ☐ Never

14. The main sources of knowledge you use for the students in the biology classroom are:

☐ Text Book ☐ Workbook ☐ Extra Handouts ☐ The internet ☐ Other

If other please specify: _______________________________________

15. Please indicate below, by ticking the appropriate boxes what percentage of your classroom time in Biology is taken up by the following:

<table>
<thead>
<tr>
<th></th>
<th>≤ 20%</th>
<th>≤ 40%</th>
<th>≤ 60%</th>
<th>≤ 80%</th>
<th>≤ 100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher talk</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Oral interaction among students</td>
<td></td>
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</tr>
<tr>
<td>Classroom discussions with teacher and students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student individual work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student experimental work</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Teacher demonstrations</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Part Three: Learning Biology

16. Please tick the appropriate boxes from the following questions.

17. Please tick the appropriate boxes from the following questions.

A: Always S: Sometimes N: Never NS: Not Sure

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>S</th>
<th>N</th>
<th>NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students take information as a given without ever questioning it</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students learn by the memorisation of facts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students learn by trying to understand the topic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students learn by questioning theory being taught</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students do their own research at home</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

18. Do laboratory activities help students confront and change any misconceptions they have on a topic?

☐ Yes   ☐ No   ☐ I don’t know

19. How good are your students at drawing conclusions from experiments they have carried out?

☐ Very Good ☐ Good ☐ Average ☐ Poor ☐ Very Poor

Part Four: The Biology Syllabus

20. Please tick the appropriate boxes for each of the following questions.

<table>
<thead>
<tr>
<th>The biology syllabus places an emphasis on:</th>
<th>Y</th>
<th>N</th>
<th>IDK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inquiry-based methods.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimentation in order to find answers.</td>
<td></td>
<td></td>
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<tr>
<td>Ready made answers for students to accept.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The data collected during experimentation is interpreted and explanations are changed to fit the data.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The data collected is changed/re collected in-order to fit theoretical explanations.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

21. Do laboratory activities closely parallel with course topics?

☐ Always   ☐ Sometimes   ☐ Never

22. Rank the following in order of importance.

Circle the boxes 1-4.

1 = most important and 4= least important. You can only circle a number once.
In order for students to successfully complete and achieve good grades in the leaving certificate biology syllabus, they must:

Memorise scientific facts

Study in order to be able to answer past exam questions

Understand every topic

Develop scientific skills

Part Five: What is inquiry based learning?

Please tick the appropriate boxes for the following questions.

23. Do you know the meaning of inquiry based learning?

☐ Yes  ☐ No  ☐ I don’t know

24. Please indicate below what you think Inquiry based learning involves

Y: Yes  N: No  IDK: I Don’t Know

<table>
<thead>
<tr>
<th></th>
<th>Y</th>
<th>N</th>
<th>IDK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Making Observations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posing Questions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accessing and using relevant information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning and carrying out investigations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using tools and technology to collect, analyse and interpret data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proposing answers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proposing explanations and predictions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communicate findings</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

25. Inquiry based learning is getting the students to carry out experiments

☐ Yes  ☐ No  ☐ I don’t know

26. Put the following in step by step order (1-7) in which you think the process of scientific inquiry/investigations should occur?

Make observations

Ask questions

Formulate a hypotheses

Experimentation

273
Propose explanations  
Accept or reject hypotheses  
Ask questions  

27. Do you use inquiry-based learning in your teaching?
☐ Yes  ☐ No  ☐ I don’t know

If no please go to Question 30

28. How often do you teach inquiry-based methods?
☐ In most classes  ☐ In some classes  ☐ In no classes

29. How do you incorporate inquiry into your teaching?
___________________________________________________________________________
___________________________________________________________________________

Part Five: Implementing inquiry-based learning in the classroom

Please tick the appropriate boxes for the following questions.

30. Please indicate by ticking the boxes below the factors you think may cause implications for you in using inquiry based methods in the classroom:

<table>
<thead>
<tr>
<th>Time consuming</th>
<th>Requires resources</th>
<th>Need to be trained and professional development provided</th>
<th>Need support</th>
<th>The syllabus content restricts using inquiry based learning</th>
<th>Getting the course covered for examinations restricts using inquiry based learning</th>
<th>Poor textbooks</th>
<th>Difficulties with group work</th>
<th>Unprepared for students questions</th>
<th>Inquiry lacks a clear definition</th>
</tr>
</thead>
</table>
31. In an inquiry-based lesson the teacher has:

- [ ] Full control
- [ ] Part control
- [ ] No control.

32. Does the biology syllabus allow you to introduce scientific inquiry in your lesson?

- [ ] Yes
- [ ] No
- [ ] I don’t know

Please explain your answer below

___________________________________________________________________________

33. Do you think the current syllabus promotes good future scientists? (i.e. that the students engage in many of the same activities and thinking processes as scientists)

- [ ] Yes
- [ ] No
- [ ] I don’t know

34. In your opinion, Inquiry based learning is more suitable for students of

- [ ] Higher ability
- [ ] Weaker ability
- [ ] Both

35. Would you like to receive training and information on inquiry based learning?

- [ ] Yes
- [ ] No
- [ ] I don’t know

36. How well do you think your students would/are take/taking to learning through inquiry based learning?

- [ ] Very well
- [ ] Well
- [ ] Not so Well
- [ ] Not at all

Explain your answer.