Using an inquiry-based learning (IBL) approach to encourage higher order thinking among my students of mathematics?

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Abstract

This dissertation is my living theory of my learning about my educational influence as a post-primary school mathematics teacher. I engaged in an action research study of my teaching practice, as I answered my research question: How can I use inquiry-based learning to improve my practice and to encourage higher order thinking among my students of mathematics?

I set out my own context and I explored some of the extrinsic motivators that prompted me to initiate this research. In the literature review, I examined higher order thinking, inquiry-based learning and the role of the teacher in inquiry-based learning, as I sought to understand the processes underlying my research question.

I introduced inquiry-based learning to my classroom and I sought to help my students engage in higher order thinking. I did this through two cycles of research. My study was validated and critiqued at different stages during the research process.

In carrying out this enquiry I gained a deeper understanding of my embodied values that are implicit to my practice as a teacher. I used these values as my living standards of judgement for my research.

I have shown that the use of inquiry-based learning has resulted in an improvement in my practice. I successfully introduced inquiry-based learning to my teaching and used it as a means of encouraging higher order thinking. My own learning and that of my students has been transformed.
Chapter One - Introduction

1.1 Introduction to the Study

This study is an action research enquiry into how I can improve my practice as a teacher. I work in a post-primary school as a mathematics teacher. The study is an examination of how I can use inquiry-based learning (IBL) to enhance my students’ learning and to encourage higher order thinking among my students. In this chapter, I outline the context of the study and I explore some of the extrinsic motivators that prompted me to initiate this research. I look at Project Maths, the Pathway Project and CensusAtSchool, which are key elements in this enquiry.

1.2 The Context

I work in a multi-denominational, co-educational County Dublin VEC (Vocational Education Committee) post-primary school in North County Dublin. It is a newly established school. The school opened its doors to our first set of students at the end of August 2009. As I undertake this study the school is in its third academic year and has an enrolment of approximately 290 students. The student body consists of first, second and third year students. The male students outnumber the female students by more than three to one. The school employs a staff of eighteen teachers, a Principal, a Deputy Principal, a special needs assistant (SNA), a secretary and a caretaker.

I have worked as a teacher of mathematics and information and communications technology (ICT) for a total of seven years, three of which have been spent in the
school I am working in at present. I am currently trying to get to grips with a new curriculum that was introduced for post-primary maths students in September 2010, called Project Maths.

1.3 Reform of Mathematics Education in Ireland

After the Leaving Certificate results in Ireland in 2005, concerns about mathematics at post-primary level that were expressed in national newspapers reflected a general unrest about the subject at post-primary level. Among the headlines were the following:

“Poor maths results just don’t add up”
(The Irish Times, 12 August 2005)

“Overhaul of Leaving Cert Maths urged by key group”
(The Irish Times, 16 August 2005)

“High rates of failure in Leaving Certificate maths and science”
(The Irish Times, 17 August 2005)

(The National Council for Curriculum and Assessment 2005)

Furthermore, in the 2003 PISA tests Irish students ranked 20th out of 40 countries in mathematical literacy. This contrasts starkly with Irish students’ ranking in reading literacy, which is 5th of 39 countries (www.pisa.oecd.org).

As a result of these issues with post-primary mathematics education in Ireland the National Council for Curriculum and Assessment (NCCA) published the “Review of mathematics in post-primary education – report on the consultation” (2006). They consulted with teachers, post-primary and third-level students, parents, lecturers and
school principals in order to compile this report. A dominant theme in the consultation feedback was the need to make mathematics more related to the lives of students. Two main approaches were advocated for this:

- introducing mathematical concepts in real-life contexts so that it leads from the concrete to an appropriate level of abstraction;
- giving examples of ways in which mathematics is applied in the real world.

Project Maths is a curriculum and assessment project in post-primary mathematics that began in 2008, arising from the NCCA review of mathematics education (2005, 2006). The aim of Project Maths is to increase the numbers taking Higher Level mathematics at Leaving Certificate. In this new curriculum students will experience mathematics in a new way, using examples and applications that are meaningful for them. Project Maths allows students to appreciate how mathematics relates to daily life and to the world of work. Students can develop skills in analysing, interpreting and presenting mathematical information, in logical reasoning and argument, and in applying their mathematical knowledge and skills to solve familiar and unfamiliar problems (Project Maths Development Team 2008).

The introduction of Project Maths has inspired me to reconsider the way I teach mathematics. Along with every other mathematics teacher in the country, I was required to attend two full day workshops a year over three school years from 2009 to 2012 where I learned some of the teaching methodologies and teaching resources that are recommended for delivering this new mathematics curriculum. I discovered that in this new curriculum greater emphasis is placed on student understanding of mathematical concepts, with increased use of contexts and applications that will
enable students to relate mathematics to everyday experience (Project Maths Development Team 2008).

As I began to teach the Project Maths curriculum I realised that in order for my students to truly recognize the value of mathematics, they need to understand the role of mathematics in the real world, outside the classroom. I began investigating ways that I can make learning mathematics a more meaningful experience for my students. I drew on my experiences in the Project Maths workshops and my experiences from the Masters programme. I came to the conclusion that adopting an inquiry-based approach could help my students appreciate and understand mathematics because it enables students to discover knowledge for themselves and it draws on real life contexts. Inquiry-based learning (IBL) is where students are engaged in essentially open-ended, student-centered, hands-on activities based on real life problems (Colburn 2000).

1.4 The Pathway Project

The report "Science Education Now: A Renewed Pedagogy for the Future of Europe" report (Rocard 2007) recommended the reversal of school science and mathematics teaching pedagogy from mainly deductive to inquiry-based methods as a means to increase student interest in science and mathematics. Following the recommendations of this report, the Pathway Project is bringing together experts in the field of science and mathematics education research, teachers, policy makers and curriculum developers with the objective of promoting the effective and widespread use of inquiry and problem based teaching techniques in primary and secondary schools.
in Europe and around the world. The Pathway Project is a European funded project which supports the adoption of inquiry teaching in schools via professional development of teachers (The Pathway Project 2011a). The Pathway project is sometimes referred to as “The Pathway to Inquiry Based Science Teaching”.

It was very fortunate that I was able to participate in a Pathway workshop in the initial stages of carrying out this study. The two-day workshop was held in DCU on 13th and 14th February 2012 and the event was organised by Dr. Margaret Farren as part of the Pathway to Inquiry Based Science Education (IBSE) EU 7th Framework project. The workshop was entitled “Discovering and Promoting Inquiry in the Sciences through Computational Thinking” and it was led by Robert M. Panoff, Ph.D., President and Executive Director of Shodor and the National Computational Science Institute.

I found the workshops to be very beneficial in developing my understanding of inquiry-based learning. In these workshops I learned about the different types of inquiry, inquiry through computational thinking, online resources for use in IBL, inquiry through modelling and developing and assessing inquiry through small group projects. In addition to lecture-style sessions, these workshops afforded the participants the opportunity to experience being a student in an inquiry-based setting. Robert M. Panoff’s lectures, in particular, impacted my learning significantly. I learned that in order to facilitate IBL, I must change my role from teacher to mentor. I need to stop feeding the students information and support the students in their own discovery of facts and concepts. The students should be encouraged to persevere when they make mistakes or when they encounter setbacks. As Robert M. Panoff eloquently put it: the right answer = the wrong answer + corrections.
1.5 CensusAtSchool

The area of mathematics that I focus on in this study is statistics. Statistics is defined as the branch of mathematics that deals with the collection, organization, analysis, and interpretation of numerical data (The American Heritage Science Dictionary 2002). In cycle two of my research I realised that I needed a means of generating real and interesting data about the students. CensusAtSchool proved to be an extremely useful resource and it gave my students and me access to an enormous bank of interesting and relevant data.

CensusAtSchool is a website that facilitates students filling out questionnaires about themselves and accessing data from other students around the world. The Royal Statistical Society Centre for Statistical Education (RSCSE) started the CensusAtSchool project in 2000 in conjunction with the National Statistics Office in the United Kingdom. The project, originally a one-off, was linked to the UK population census of 2001 (Connor 2002). Since 2000 several other countries have embraced the project with necessary adjustments to reflect local culture and traditions. These countries are Australia, New Zealand, South Africa, Canada, the United States of America, Japan and Ireland. The worldwide database, which contains well over a million responses, can be sampled over the Internet for use in creating teaching and learning materials.
CensusAtSchool was launched in Ireland in 2009 for use in teaching statistics in the new Project Maths curriculum. The NCCA, the Central Statistics Office and the National Council for Technology in Education (NCTE) collaborated to set up the Irish website www.censusatschool.ie (Figure 1). The online questionnaires are non-invasive and anonymous (Appendix A). CensusAtSchool is free to all Irish schools.

CensusAtSchool allows students to collect relevant and interesting data about themselves and their peers. This helps to improve their understanding of the data gathering and data handling process and because the students are using real and meaningful data they are likely to have a genuine interest in the results (Townsend 2006, Marriott et al 2009). Students are enabled to construct their own understanding of data handling through the use of CensusAtSchool, which promotes inquiry originating from the students’ own personal questions and explorations (Townsend 2006).
1.6 Layout of the Dissertation

In Chapter Two I explore the literature pertaining to my research. In this chapter I consider the following three themes:

- The role of the teacher in inquiry-based learning;
- Inquiry-based learning and higher order thinking;
- Inquiry-based learning in mathematics.

In Chapter Three I provide the methodological framework for my research. I then explore action research, with particular focus on the living educational theory (Whitehead and McNiff 2006), my choice of research model. McNiff and Whitehead’s (2006) ten-step action plan is used to plan my action research.

In Chapter Four I describe the implementation and evaluation of two cycles of action research. I also consider the issues of validity and rigour in relation to my research.

In the final Chapter, Chapter Five, I present the overall conclusions drawn from my experiences in carrying out the research project and I summarise my learning.
Chapter Two – Literature Review

2.1 Introduction

The purpose of this literature review is to provide a theoretical framework for my research. I will examine three main themes in the literature to inform my understanding of my research question. How can I use inquiry-based learning to improve my practice and encourage higher order thinking among my students of mathematics? The key concepts in my research question form the basis for the three themes in my literature review:

- The role of the teacher in inquiry-based learning;
- Inquiry-based learning and higher order thinking;
- Inquiry-based learning in mathematics.

I hear and I forget. I see and I remember. I do and I understand.

This is wisdom of Confucius (551 BC - 479 BC), the Chinese Philosopher, on the nature of instruction and human learning. The meaning of this Chinese proverb is that the best way to learn something is through hands-on experience. Inquiry-based learning is an approach to learning that affords students hands-on experience and thus enables learners to better understand. I begin this literature review by exploring inquiry-based learning.
2.2 Inquiry-Based Learning

Hayes (2002) notes that defining inquiry-based learning precisely is quite difficult and that historically, definitions of IBL have ranged from traditional hands-on learning to student research. With this in mind, I have chosen two definitions of IBL to give a broader description of IBL.

Wilke and Straits (2001 cited in Coombs and Elden (2004)) emphasize the importance of the student’s existing knowledge in IBL. They define IBL as learning occurring when the learner constructs an understanding of new information by associating it with prior knowledge in an organized and systematic way. Within this context, IBL is a student-based exploration of real-life problems using the processes and the tools of inquiry.

Kahn and O’Rourke (2005) describe IBL as a broad umbrella term to describe approaches to learning that are driven by a process of inquiry. In their definition of IBL the tutor establishes the task and supports or facilitates the process, but the students pursue their own lines of inquiry, draw on their existing knowledge and take responsibility for analysing and presenting their ideas appropriately.

In both these definitions of inquiry-based learning the student is placed at the centre of the learning activity. John Dewey was an advocate of student centred teaching approaches. According to Dewey, the teacher should not stand at the front of the room passing out knowledge that is to be absorbed by passive students. Instead, the teacher should adopt the role of facilitator or guide. Dewey (1974 p.9) asserts that the
teacher’s role is “not to impose certain ideas or to form certain habits in the child”, but as “a member of the community to select the influences which shall affect the child and to assist him in properly responding to these influences.” The role of the teacher is an important feature of IBL, and I will examine it in more detail later in the chapter.

IBL draws on constructivist ideas of learning. According to Siemens (2005), constructivist approaches better prepare students for life-long learning because constructivism acknowledges that real life learning is messy and complex. Constructivism's central idea is that learning is an active process in which learners construct new ideas or concepts based upon their experiences and prior knowledge (Kanselaar 2002). Similarly, IBL is a student centred approach that encourages participants to draw on prior knowledge and experience in carrying out their inquiries (Kahn and O’Rourke 2005). In IBL the student is responsible for constructing their own meaning and understanding from the learning activities. Thus IBL can enable students to relate their learning to the demands of their own contexts and their future working lives (Kahn and O’Rourke 2005, Bell et al 2005, Abrams et al 2007).

2.2.1 Levels of Inquiry

The notion of different levels of inquiry was first introduced by Schwab (1962). Schwab (ibid) described two types of inquiry: stable inquiry and fluid inquiry. At the stable inquiry level, the teacher provides the questions and the materials for students to discover relationships for themselves. At the fluid inquiry level, the students must
generate their own questions, gather evidence, and propose explanations based on their work.

Based on Schwab’s work, Herron (1971) developed a scaled model with four levels of inquiry. Later, Rezba et al (1999) and Abrams et al (2007) proposed adapted versions of Herron’s model. The four-level model illustrates how inquiry-based learning can range from highly teacher directed to highly student directed. The levels of inquiry in all these models are confirmation inquiry, structured inquiry, guided inquiry and open inquiry, respectively. The following table offers a brief description of each level of inquiry:

Table 2.1

<table>
<thead>
<tr>
<th>Level of Inquiry</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confirmation Inquiry</td>
<td>This is the lowest level of inquiry. The teacher provides the students with the question to be investigated and the methods of gathering data and guides the students to an expected conclusion.</td>
</tr>
<tr>
<td>Structured Inquiry</td>
<td>At this level of inquiry students are provided with a question and a method but are responsible for the interpretation of the result.</td>
</tr>
<tr>
<td>Guided Inquiry</td>
<td>In guided inquiry students are provided with a question and are responsible for determining the method of investigation and how to interpret the results.</td>
</tr>
<tr>
<td>Open Inquiry</td>
<td>In the final level of inquiry students take responsibility for all major aspects of the investigation.</td>
</tr>
</tbody>
</table>

At the highest level of inquiry, ‘open inquiry’, students have the purest opportunities to act like scientists or mathematicians, deriving questions, designing and carrying out investigations, and communicating their results. This level requires the most reasoning skills and the greatest cognitive demand from students (Bell et al 2005). Banchi and Bell (2008) contend that it is only appropriate to facilitate students conducting open enquiries when they have demonstrated that they can successfully design and carry out investigations when provided with the question. This includes being able to record and analyse data, as well as draw conclusions from the evidence they have collected.

2.2.2 The Debate on Inquiry-Based Learning

Kirschner et al (2006) argue that there appears to be no body of research supporting inquiry-based learning. They report on several studies and meta-analyses of minimally guided instructional approaches including discovery learning, inquiry-based learning and constructivist learning. They claim that any evidence from controlled studies almost uniformly supports direct, strong instructional guidance rather constructivist-based minimal guidance. Furthermore, they claim that although constructivists often cite each other’s work, empirical evidence is not often cited. They also contend that for students with considerable prior knowledge, strong guidance while learning is most often found to be equally as effective as unguided approaches and that unguided instruction is normally less effective. Kirschner et al (ibid) write that there is also evidence that students acquire misconceptions or incomplete or disorganized knowledge in inquiry-based learning.
Hmelo-Silver et al (2007) refute these claims and cite several studies that demonstrate the success of the inquiry-based learning methods. For example, they describe a project called GenScope, an inquiry-based science software application designed to support high school students’ investigations of genetic phenomena. Hickey (1999) found that 381 students in 21 GenScope classrooms “showed significantly larger gains from pre-test to post-test than the 107 students in 6 comparison classrooms.”

Hmelo-Silver et al. (*ibid*) also cite a large study by Marx et al (2004) on the effectiveness of inquiry-based learning for urban middle school students. This large-scale, 3-year program engaged approximately 8,000 students in inquiry-based and technology-infused curriculum units. Again, results showed statistically significant gains from pretest to post-test, and the strengths of the effects grew over the 3 years of the study. In a follow-up to this study, Geier et al. (2008) examined the impact of these units on student performance on the high stakes state standardized test in science. Geier et al. (*ibid*) compared the performance of two cohorts of seventh and eighth graders that participated in the project with the remainder of the district population in this study. The improvement was 14% for the first cohort of students and 13% for the second cohort.

A more recent study by Blanchard et al (2010) systematically compared the efficacy of guided inquiry-based laboratory instruction versus traditional laboratory instruction in the learning of concepts related to a forensics unit, as measured through standardised assessments. The sample included 1,700 students placed in the classrooms of 12 middle school and 12 high school science teachers. They found that overall, students who participated in a guided inquiry-based laboratory unit showed significantly stronger growth in test scores when compared to the students who
participated in a traditional laboratory-based unit.

Many researchers maintain that learning taking place may have errors, misconceptions or be confusing or frustrating to the learner, if the learner is left to self-discovery of topics (Mayer 2004, Kirschner et al 2006, Alfieri et al 2011). Mayer (2004) argues that open inquiry-based learning tasks do not help learners discover concepts or problem solving rules. He holds that while under some circumstances constructivist-based approaches may be beneficial, open inquiry-based learning lacks structure in nature and hence will not be beneficial for the learner. This conflicts with Bruner’s view that allowing students to discover information for themselves teaches them to acquire information in a way that makes that information more readily viable in problem solving (1961, 1985). Bruner (1961) also argued that students are more likely to remember concepts if they discover them on their own as opposed being taught them directly. Many researchers share Bruner’s views but they assert that the teacher’s role as a facilitator of learning and a guide is crucial to students’ learning in IBL (De Jong and Van Joolingen 1998, Bell et al 2005, Bain 2005, Champine et al 2009). In the next section of this literature review I examine the role of the teacher in inquiry-based learning.

2.3 The Role of the Teacher in Inquiry-Based Learning

Colburn (2000) holds that the teacher is the key element in a successful inquiry-based classroom. He writes that teachers should “possess certain attitudes and skills to encourage student success in the inquiry-based classroom.” To be really effective the teacher needs formal operational thinking abilities, knowledge of the subject students
are investigating, and some understanding of how students learn. (ibid) Scaffolding the learning for students is an important feature of IBL. (Hmelo-Silver 2004) In the next section I explore scaffolding in inquiry-based learning.

2.3.1 Scaffolding

Kirschner et al. (2006) maintain that in inquiry-based approaches novice learners need guidance, but later as they gain confidence and become competent then they may learn through inquiry. Sweller (1988) proposed the cognitive load theory to explain how novices react to constructivist-based approaches to learning during the early stages of learning. The cognitive load theory is that in the early stages of the learning process, learners may find it difficult to process a large amount of information in a short amount of time. Because of this, the rigours of inquiry-based learning may become an issue for novices. Sweller (ibid) conducted several studies with students studying algebra problems in the classroom. These studies have shown that active problem solving early in the learning process is a less effective teaching method than studying worked examples. However, as the learners become more competent, and better able to deal with their working memory limitations, Sweller (ibid) contends that inquiry-based learning approaches can be useful.

Scaffolding is one method of reducing the cognitive load of learners (Hmelo-Silver et al 2007). Scaffolding in relation to cognition, is attributed to Lev Vygotsky, a Russian psychologist. Scaffolding is described by Wood et al (1976) as an adult controlling those elements of the task that are essentially beyond the learner's capacity, so that the learner can concentrate upon and complete only those elements that are within his or
her range of competence.

Scaffolding methods are most useful to fade guidance during inquiry-based learning (Anderson 1989, Hmelo-Silver 2004, Hmelo-Silver et al 2007). Hmelo-Silver (2004) explains the process of fading as the teacher acting as a facilitator of learning and scaffolding student learning through modelling and coaching, and progressively fading their scaffolding as students become more experienced with IBL. The teacher or facilitator is responsible both for moving the students through the various stages of IBL and for monitoring the learning process. An example of fading guidance is when helping learners to slowly move from studying examples to solving problems. In inquiry-based learning fading guidance was found to be quite effective in helping to reduce the cognitive load of learners (Anderson 1989, Hmelo-Silver 2004, Hmelo-Silver et al 2007).

2.3.2 Teacher Professional Development

According to Pathway (2011b) it is a must for a successful inquiry-based learning teacher to have various teaching strategies available, to improve every teaching aspect with in-service education and to be able to reflect their own teaching methods. To use inquiry-based teaching approaches, Pathway (ibid) assert that teachers should have a distinct pedagogical content knowledge and that they have to have the competencies to match the inquiry focused lesson with the existing topics, methods and materials. “The cognitive level achieved by students is related to the competence of their teachers.” (ibid)
This is particularly true for teachers of mathematics. Stipek et al (2001) hold that inquiry-oriented mathematics teaching requires considerable knowledge of mathematics because teachers need to diagnose the concepts that underlie students’ responses or problem-solving strategies and respond with appropriate scaffolding. Later in the chapter I explore inquiry-based learning in relation to mathematics teaching.

2.4 Inquiry-Based Learning and Higher Order Thinking

Higher order thinking is defined as “a non-algorithmic, complex mode of thinking that often generates multiple solutions” and such thinking involves “uncertainty, application of multiple criteria, reflection, and self-regulation” (Resnick 1987). Problem solving, inferring, estimating, predicting, generalising and creative thinking are all considered to be higher order thinking skills (Miri et al 2007).

Bloom’s taxonomy categorised and ordered thinking skills and objectives according to six cognitive levels of complexity (Bloom 1956). The idea is that some types of learning require more cognitive processing than others. The lowest three levels of cognition in Bloom’s taxonomy are knowledge, comprehension, and application and are considered to be lower-order thinking skills. The highest three levels are analysis, synthesis, and evaluation and are thought to be of a higher order, and require different learning and teaching methods than the learning of facts and concepts (Krathwohl 2002). The following table outlines some of the thinking skills associated with the six categories within Bloom’s taxonomy:
Table 2.2

<table>
<thead>
<tr>
<th>Level in Bloom’s Taxonomy</th>
<th>Associated Thinking Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>define, describe, recall, recognize;</td>
</tr>
<tr>
<td>Comprehension</td>
<td>explain, extend, interpret, summarise;</td>
</tr>
<tr>
<td>Application</td>
<td>construct, demonstrate, modify, prepare, solve;</td>
</tr>
<tr>
<td>Analysis</td>
<td>compare, contrast, distinguish, identify, illustrate;</td>
</tr>
<tr>
<td>Synthesis</td>
<td>categorise, devise, design, generate, organise, reconstruct, relate;</td>
</tr>
<tr>
<td>Evaluation</td>
<td>appraise, compare, conclude, contrast, interprets, justifies, supports;</td>
</tr>
</tbody>
</table>

Adapted from Bloom (1956), Krathwohl (2002) and Lord and Baviskar (2007)

In 2001 Anderson and Krathwohl adapted and revised Bloom’s taxonomy. With the dramatic changes in society and education over the last five decades, the revised Bloom's taxonomy provides an even more powerful tool to fit today's teachers' needs. The structure of the revised taxonomy provides a clear, concise visual representation of the alignment between standards and educational goals, objectives, products, and activities (Forehand 2005). This is the amended taxonomy of thinking skills:

Table 2.3

<table>
<thead>
<tr>
<th>Level in Revised Taxonomy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remembering</td>
<td>Retrieving, recognizing, and recalling relevant knowledge from long-term memory;</td>
</tr>
<tr>
<td>Understanding</td>
<td>Constructing meaning from oral, written, and graphic messages through interpreting,</td>
</tr>
<tr>
<td>Category</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Exemplifying</td>
<td>Classifying, summarizing, inferring, comparing, and explaining;</td>
</tr>
<tr>
<td>Applying</td>
<td>Carrying out or using a procedure through executing, or implementing;</td>
</tr>
<tr>
<td>Analyzing</td>
<td>Breaking material into constituent parts, determining how the parts relate to one another and to an overall structure or purpose through differentiating, organizing, and attributing;</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Making judgments based on criteria and standards through checking and critiquing;</td>
</tr>
<tr>
<td>Creating</td>
<td>Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing.</td>
</tr>
</tbody>
</table>

(Anderson and Krathwohl 2001 p.67-68)

Many researchers believe that fostering higher order thinking among students of all ages is an important educational goal and that quality thinking is an important element of life success (Gough 1991, Marzano 1998, Zohar et al 2001, Sousa 2008, Lord and Baviskar 2007). Miri et al (2007) assert that our ever-changing and challenging world requires students, our future citizens, to go beyond the building of their knowledge capacity and need to develop higher order thinking skills.

The combination of motivated students, well informed teachers, relevant content and a useful scheme for assessment should ensure that higher order thinking is achieved.
for most if not all students by the end of secondary school (Watson 1997). Identifying how to encourage and teach higher order thinking skills is an important role of the teacher (Sousa 2008, Cullinane 2010).

A major factor in the facilitation of higher order thinking capability is an active, inquiry-based, student centred classroom (Crowl et al 1997, Zohar and Dori 2003, Sousa 2008). Lord and Baviskar (2007) argue that students want to be active, rather than passive, in the assimilation of information and that teachers must move from lecture-based to inquiry-based lessons in order to motivate students to apply higher levels of thinking. Most students, regardless of age, need to develop their inquiry abilities in order to move toward higher order thinking (Banchi and Bell 2008).

2.4.1 Higher Order Thinking in Mathematics

According to Schoenfeld (1994 cited in Henningsen and Stein 1997) students’ learning of mathematics is to be seen as the process of acquiring a ‘mathematical disposition’ as well as acquiring mathematical knowledge and tools for working with and constructing knowledge. Having a mathematical disposition is characterised by activities such as conjecturing, generalizing, justifying, using available resources effectively and appropriately to formulate and solve problems, communicating one's mathematical ideas and deciding on whether mathematical results are reasonable (Schoenfeld 1992). These activities have much in common with the active reasoning processes that Anderson and Krathwohl (2001) have proposed as characteristics of higher order thinking.
Henningsen and Stein (1997) maintain that without engaging in active processes during classroom instruction, students cannot be expected to develop the capacity to think, reason, and problem solve in mathematically appropriate and powerful ways. Connections with students’ prior knowledge and experience also play an important role in engaging students in high-level thought processes (Henningsen and Stein 1997, Abu-Febiri 2002). In a review of research on classroom instruction for high-level understanding of mathematics, Anderson (1989) emphasized the importance of active learning and prior knowledge in the learning of mathematics.

2.4.2 The SOLO Taxonomy

In order to assess students’ levels of higher order thinking in students’ work it is necessary to look at a framework of sorts. A useful model is the SOLO taxonomy. SOLO is an acronym for Structure of Observed Learning Outcomes. It was developed by Biggs and Collis (1982). The SOLO taxonomy is a hierarchy of learning evaluation based on both the learning quantity and quality and has been shown to effectively measure different kinds of cognitive learning outcomes within a wide range of subject areas (Kanuka 2005 and Atherton 2011). The five levels are as follows, in increasing order of structural complexity:
<table>
<thead>
<tr>
<th>Level in the SOLO Taxonomy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The Pre-Structural Level</td>
<td>The student does not have any kind of understanding but uses irrelevant information or misses the point altogether.</td>
</tr>
<tr>
<td>2. The Uni-Structural Level</td>
<td>The student can deal with one single aspect and make obvious connections.</td>
</tr>
<tr>
<td>3. The Multi-Structural Level</td>
<td>The student can deal with several aspects but these are considered independently and not in connection.</td>
</tr>
<tr>
<td>4. The Relational Level</td>
<td>The student understands relations between several aspects and how they might fit together to form a whole.</td>
</tr>
<tr>
<td>5. The Extended Abstract Level</td>
<td>The student shows profound understanding and can apply this understanding to wider contexts and new applications.</td>
</tr>
</tbody>
</table>

Adapted from Biggs and Collis (1982 p.17-31) and Kanuka (2005)

Assessments, such as tests or exercises that target higher order thinking skills could more than likely lead teachers to teach content at those levels, and students, to perform at those levels (Redfield and Rousseau 1981). Research indicates that if assessments are used that only require lower order thinking skills such as knowledge and comprehension, students will not develop and use their higher order thinking skills even if instructional methods that employ these skills are implemented (Redfield and Rousseau 1981, Newman and Archbald 1992, Atherton 2011).
2.5 Inquiry-Based Learning in Mathematics


An approach to mathematics focused on real-world problem solving has come to increasing prominence since the early 1990s in mathematics education at second level in many countries (Conway and Sloane 2006). Realistic mathematics education (RME) is an idea derived by Hans Freudenthal (1978), a Dutch-based mathematician turned mathematics educator, whose ideas have had a profound impact on mathematics education internationally. Gough and Hough (2007) describe RME as a teaching approach which uses real-world contexts to help students make sense of mathematics. The importance of real-world contexts is key to learning mathematical concepts and applying mathematical methods (Libman 2010, Gough and Hough 2007).
The current wave of globalisation presents challenges, such as the explosion of information, environmental sustainability, pandemics such as HIV/AIDS and SARS, terrorism, and national and global inequalities, that demand deep disciplinary knowledge, the capacity for interdisciplinary knowledge construction, and competence in dealing with non-routine problems (Gardner 2004). Future challenges that today’s students will have to address will demand competence in how they can manipulate and apply knowledge to unstructured problems and continue to do this throughout their lives (Eivers et al 2008, Gough and Hough 2007). Conway and Sloane (2006) note that a recurrent focus on the importance of learning to learn in the context of promoting lifelong learning is one of the most distinctive features of contemporary educational and economic policy-making at national and international levels. Self-directed learning, capacity for independent and collaborative problem solving, developing ownership of learning, and self-regulated learning are terms used interchangeably in terms of highlighting learning to learn as an educational aim. (ibid)

The promotion of skilled problem solving in mathematics has been a long-standing concern among mathematics educators (De Corte et al 1996). Early work by Polya (1945 cited in Conway and Sloane 2006) on problem solving heuristics promoted mathematical problem solving long before the more recent focus on learning to learn. The steps in Polya’s (ibid) problem solving heuristics are understand the problem, find the connection between the data and the unknown by possibly considering related problems, develop a plan, carry it out, and examine the solution. Later Schoenfeld (1992) also promoted a problem solving approach to mathematics learning. According to Schoenfeld (1992), students need to develop strategies and techniques for problem solving such as working backwards, or drawing figures, in order to be successful at
mathematics. Inquiry-based approaches help students to develop problem-solving skills because it engages students in investigating real-world questions (Henningsen and Stein 1997, Towers 2010).

2.5.1 Inquiry-Based Learning in Statistics

My study is focused on statistics. Statistics is defined as the branch of mathematics that deals with the collection, organization, analysis, and interpretation of numerical data (The American Heritage Science Dictionary 2002). Traditional methods of statistics teaching have come under serious criticism because of their failure to help students achieve sufficient in-depth understanding of statistical concepts and principles so as to be able to use them in new situations (Libman 2010). Gaining a deep understanding of statistics, which will enable the student to properly apply what he or she has learned requires an approach to learning that allows the learner to investigate freely, in realistic circumstances and meaningful contexts. This involves two requirements: personal investigation, and complex and meaningful context (Libman 2010, Singer and Willett 1990). Allowing students to learn in context dictates teaching approaches that require the learners to do their own investigating and cope by themselves in order to create meaning and statistical understanding (Prawat 1996, Marriott et al 2009).

A study carried out by Libman (2010) indicated that statistical investigations that are based on real-life data collected by the students meant that the students were more engaged and they were drawn more deeply into thinking critically about the information. Libman (ibid) remarked that a real data approach seems even more valid
when we are talking about applied academic studies such as statistics, whose very objective is to enable students to conduct inquiry through intelligent use of statistical methods.

2.5.2 Maths Education Worldwide

For the purposes of this study, I will look at two countries that employ inquiry-based learning approaches in post-primary mathematics teaching – Singapore and the United States of America. Singapore scored high in mathematics in international comparison tests and the USA do relatively poorly in the same tests. I will briefly examine some of the reasons for this achievement gap.

The OECD (Organisation for the Co-operation and Development) PISA (Programme for International Student Assessment) tests surveys 15-year-olds in the principal industrialised countries. Every three years, it assesses numeracy and mathematical ability. The Trends in International Mathematics and Science Study (TIMSS) is an international assessment of the mathematics and science knowledge of 13–14 year olds developed by the International Association for the Evaluation of Educational Achievement (IEA). TIMSS is administered every 4 years. The following table outlines the results of Singapore, the USA and Ireland in these international tests:
Singapore is a small state of four million, and is focused on nurturing every ounce of talent of every single citizen. That is why, although its eighth class students (roughly equivalent to second year students in Ireland) already score consistently high in international PISA and TIMSS mathematics tests, Singapore has been introducing more innovations into schools (Eivers et al 2008).

In Singapore numerical skills are considered to be very important and the country is concerned with how to encourage Singaporean students and teachers to be more innovative and creative in their mathematics lessons (Conway and Sloane 2006). The focus has changed from content alone to making use of the content (Sloane 2003 cited in Conway and Sloane 2006).

Conway and Sloane (2006) report that similarly to Singapore, the US mathematics education system for middle school fosters creativity and innovation in the learning of mathematics. However the USA does not enjoy the same success as Singapore in the PISA and TIMSS tests. The TIMSS 1999 video study (Stigler et al 2000) offers a
potential reason for this achievement gap between the two countries. The study found that American middle school teachers use teaching approaches similar to those of their counterparts in higher-achieving countries such as Singapore. However, American teachers omit one crucial ingredient: the underlying mathematical ideas that help students understand how the skills they are learning are part of a logical and coherent intellectual discipline (ibid).

Higher achieving countries focus on developing conceptual underpinnings of the problems. Stigler et al (2000) report that America mathematics teachers tend to teach students how to solve a particular type of problem and then ask them to solve examples on their own. Students are seldom given problems to work on by themselves before they have been taught by the teacher. Stigler et al (ibid) argue that this practice is so pervasive in the USA that many people would question the competence of a teacher who gave students a problem to solve that had not been covered in class. Stipek et al (2001) argues that a teacher’s ability to use IBL correlates with their real understanding of mathematics. The achievement of the student is reliant on the subject knowledge of the teacher in learning mathematical concepts and methods (Henningsen and Stein 1997, Boaler 2008).

2.6 Conclusion

The purpose of the literature review was to establish a theoretical framework for my research. I began by exploring the definition of inquiry-based learning. I then looked at the levels of inquiry-based learning and some of challenges of minimally guided or open inquiry-based approaches. This naturally led to considering the role of the
teacher in inquiry-based learning and the importance of scaffolding and teacher professional development. The average age of my research population is 13 years old and they are essentially novices in inquiry-based learning. My reading of the literature has helped to form my belief that, because of their age and lack of experience in inquiry-based learning, it is important that I scaffold the students’ learning. Furthermore, I believe that a guided approach to inquiry-based learning would be more appropriate for my first cycle of action research.

I examined higher order thinking and the role of an active learning environment in its provocation. My understanding from reading the literature is that it is important to draw on students’ prior knowledge and scaffold the learning in engaging students in higher order thinking in mathematics. I sought to find a framework to assess higher order thinking and found the SOLO taxonomy (Biggs and Collis 1982) to be particularly instructive for my context. My interest is in the use of inquiry-based learning in mathematics. I concluded by investigating the use of inquiry-based learning in mathematics around the world and its effectiveness.

My aim in carrying out this study is to improve my practice as a teacher of mathematics. My experiences at Project Maths workshops, Pathway workshops and as a MSc student have lead me to the realisation that in order for my students to truly understand mathematics and to engage in high-level thought processes, they need to understand the value of mathematics in the real world. From these experiences and my review of the literature I conclude that adopting an inquiry-based approach could potentially encourage higher order thinking skills among my students. IBL engages students in investigating real world questions and it enables students to discover
knowledge for themselves and thus construct their own understanding of mathematics.
Chapter Three - Methodological Approach

3.1 Introduction

In this chapter I provide the methodological framework for my research. I begin by investigating the different research paradigms and exploring my ontology and my epistemology. I then explore action research, with particular focus on living educational theory, the research approach I will adopt. I describe why I have chosen this approach for my inquiry. McNiff and Whitehead’s (2006) ten-step action plan is used to set out my plans for the action research process. I conclude the chapter by considering data collection methods, evidence, validity and ethics.

3.2 Research Paradigms

The concept of the research paradigm is defined by Usher (1996 p.15) as “an exemplar or exemplary way of working that functions as a model for what and how to do research, what problems to focus on and what to work on.” I considered the positivist, interpretivist and critical theory paradigms in order to determine which approach best represents my personal philosophy.

According to O’Donoghue (2007 p.6) positivism assumes that things can be studied as hard facts and the relationship between these facts can be established as scientific laws. For positivists, such laws have the status of truth and social objects can be studied in much the same way as natural objects. Conversely, an interpretivist approach assumes that people create and associate their own subjective and inter-
subjective meanings as they interact with the world around them. Interpretive researchers thus attempt to understand phenomena through accessing the meanings participants assign to them (Orlikowski and Baroudi 1991).

Critical theory emerged as a critique of positivist and Interpretivist forms of research, on the basis that research is never neutral, but used by the researcher for a specific purpose, which is often linked with desire to predict and control (McNiff and Whitehead 2006 p.41). The theory assumes that it is important to understand the human interests in a situation in order to change it. In critical theory “the contention is that it can never be value free, but always representing the interests of some group within society.” (O’Donoghue 2007 p.10) Critical theory draws on the work of Aristotle and his concept of ‘praxis’ as doing rather than making and the idea that personal theory and practice are inextricably linked, developing in unison (Carr and Kemmis 1986 p.132).

3.2.1 Ontology and Epistemology

My own ontological and epistemological positions impacted my choice of research paradigm. Ontology refers to a theory of being, which influences how we perceive ourselves to our environment, including others. Your epistemology or theory of knowledge is influenced by your ontological stance (Whitehead and McNiff 2006 p.22-23). Cohen and Manion (1994 p.6) write that ontology challenges our assumptions about the nature of the social phenomena being researched, while epistemology challenges us to view knowledge as hard and objective or personal and unique. In carrying out this research I examine my own learning and how I am
influencing the learning of my students. My research is practice-based, personal and value-laden. Therefore, the research paradigm that I feel best agrees with my ontological and epistemological positions is action research as understood in the context of living educational theory.

3.2.2 Action Research

Action research developed out of the critical theory research paradigm. Critical theory asked, ‘How can this situation be understood in order to change it?’ but aimed only for understanding, not for action. Action research went into action and asked, ‘How can it be changed?’ (McNiff and Whitehead 2006 p.41) Action research is a reflective, highly rigorous approach to research. Berg (2004 p.197) describes action research as an approach that endorses consensual, democratic, and participatory strategies to encourage people to examine reflectively their problems or particular issues affecting them or their community. Furthermore, he asserts, “It encourages people to formulate accounts and explanations of their situation and to develop plans that may resolve these problems.” (ibid p.197)

Kurt Lewin is generally credited as the person who coined the term ‘action research’ (Carr and Kemmis 1986, Smith 1996, McNiff and Whitehead 2006). Lewin (1948) outlined his conception of action research as “a comparative research on the conditions and effects of various forms of social action, and research leading to social action.” (Lewin 1948 p.202 cited in Smith 1996) It was intended to be a practical problem-solving research approach oriented towards social and organisational settings (Smith 2001). Carr and Kemmis (1986) offer the following definition of action
Action research is a form of self-reflective inquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices, their understanding of these practices, and the situations in which the practices are carried out. (p.162)

Kurt Lewin’s action research model involves a spiral of steps, “each of which is composed of a circle of planning, action and fact-finding about the result of the action.” (Carr and Kemmis 1986) Kemmis and McTaggart (1988) proposed a spiral model comprising of four steps: planning, acting, observing and reflecting. Stringer (1996 p.18) suggested a spiral model but with three steps: look, think and act. In all of these models action research is a continuous spiral or cycle, whereby the practitioner identifies a problem through observation and reflection, plans to make a change to their practice in order to solve the problem, evaluates the effectiveness of the solution, and adapts the solution should unexpected results or deficiencies emerge. Kemmis and McTaggart (1988) argue that in practice, things rarely go perfectly according to plan first time round. One cycle or spiral therefore usually leads to another, in which improvements suggested by the initial cycle can be incorporated.

3.2.3 Developing a living theory

I will employ an action research approach as outlined by Whitehead and McNiff (2006). What distinguishes this form of action research from other forms of action research is that it is grounded in the ontological ‘I’ of the researcher, and researchers organise their thinking in terms of what they are experiencing at the moment. (McNiff and Whitehead 2006 p.41-42).
I have chosen this form of action research because it is a self-critical, self-reflective form of inquiry that is based on democracy and aims for human betterment. This decision is influenced by my desire to improve my practice as a mathematics teacher and thus to enhance my students learning experience. In taking this approach, I will be engaging with my educational values that add meaning and direction to my practice. I am accountable for my learning and how I influence the learning of others.

Mc Niff and Whitehead (2002) believe that “studying our practice and its underpinning assumptions enables us to develop a creative understanding of ourselves and our own processes of learning and growth.” (p.59)

Whitehead (1989) asserts that individuals can create their own theory as descriptions and explanations of their own learning as they live their life of enquiry. In carrying out this research I am compelled to address the contradictions of my values in my own practice. In a living educational theory the action researchers present their claims to knowledge in this form:

• I experience a problem when some of my educational values are negated in my practice;

• I imagine a solution to my problem;

• I act in the direction of my solution;

• I evaluate the outcomes of my actions;

• I modify my problems, ideas and actions in the light of my evaluations.

(Whitehead 1989)
3.3 Developing an Action Plan

So how can I improve my practice as a mathematics teacher? I believe that the answer to my question is inquiry-based learning, which I describe and examine in the literature review chapter. I intend to adopt an inquiry-based learning approach in my own teaching and use action research to investigate if this learning approach encourages my students to think at a higher-level. I plan to research my own learning and how I am influencing learning of my students. I will use McNiff and Whitehead’s (2006 p.91) action plan to outline my intentions for my research.

3.3.1 What is my concern?

My concern is that when my students come across a problem that they find difficult or requires a higher order thinking they tend to give up. I believe that the reason why they are not motivated to apply higher order thinking skills to the problems they are confronted with is because they are learning mathematics in such a way that they cannot appreciate its real world applications.

3.3.2 Why am I concerned?

I appreciate the beauty of mathematics and I try to instil this appreciation for mathematics in my students. In my teaching I use lots of different resources and methodologies to make the learning experience more interesting and manageable for my students. However, I am not always successful in my efforts because I am often
asked “when are we ever going to use this?” and “when can we use this in real-life?” On reflection, I feel that I am not providing opportunities for my students to construct their own meaning from their experiences in the classroom. I am feeding the students the information and demonstrating skills that they have to then try to imitate. I assume that my students can understand methods and learn skills for which they can see no real life application. I realise that my educational values of student engagement, self-directed learning and responsibility and accountability are being denied in practice. I do not allow the students to take ownership of their knowledge by constructing their own understanding of mathematics.

I value higher order thinking and I would like my students to consider problems more rigorously and weigh up all the possible solutions rather than giving up after the first attempt. I want my students to enjoy the success of solving a challenging problem. I believe that students have to continuously practice their mathematical skills in order to achieve an understanding of mathematical methods and concepts. I would like my students to enjoy studying mathematics and to want to spend their time improving their mathematical skills.

3.3.3 What kinds of experiences can I describe to show why I am concerned?

I will record my experiences through my reflective journal, through video recordings of my lessons and through video recordings of my validation group.

3.3.4 What can I do about it?
In exploring the options I could pursue to encourage higher order thinking in my students I can identify the following:

- I could use higher order questioning in my teaching such as asking my students to justify their thinking, to explore all the options in a problem and to reveal their assumptions in reasoning.
- I could pose problems that do not have a clear starting point so that the students are encouraged to consider several options rather than applying routine techniques.
- I could adopt an inquiry-based approach.

3.3.5 What will I do about it?

My review of the literature has confounded my belief that inquiry-based learning can help students to develop higher order thinking skills because it engages students in investigating real world questions and it enables students to discover knowledge for themselves and construct their own understanding of mathematics. In my research I propose to investigate if I can encourage higher order thinking among my students of mathematics through the use of inquiry-based learning. I will evaluate the research process and consider any other outcomes that arise. I will reflect on my own learning and my students’ learning and I will consult with my supervisor, a validation group and my critical friend throughout.
3.3.6 What kind of data will I gather to show the situation as it unfolds?

I will videotape my lessons and record my observations after each lesson in my reflective journal. I will also analyse my students’ work for evidence of higher order thinking.

3.3.7 How will I explain my educational influences in learning?

While I aim initially to improve my understanding of my own practice, my ultimate aim is to improve my practice for the mutual benefit of my students and myself. I will explain my educational influences in learning by regularly challenging my own assumptions, by listening to others and by discussing my research with others.

3.3.8 How will I ensure that any conclusions I reach are reasonably fair and accurate?

I will seek advice from my fellow teachers, my fellow MSc students, my critical friend and my supervisor, Dr. Margaret Farren. I will also welcome feedback from my students that will hopefully give me an insight as to their experiences in and opinions of inquiry-based learning. I will ensure that analysis is systematic and rigorous so that my conclusions will be credible. I will share my findings with my colleagues and my critical friend.
3.3.9 How will I evaluate the validity of the evidence-based account of my learning?

In making a claim to knowledge I intend to show that I have learned something new, both about my practice and my own learning. These claims will then be tested for rigour and validity. I explain this process of establishing validity later in this chapter.

3.3.10 How will I modify my concerns, ideas and practice in the light of my evaluations?

I will continue with my practice as a mathematics teacher and continue with my efforts to grow and learn in my work. If the data reveals insights that I would rather not see I am prepared to modify my behaviour in light of the evidence.

3.4 Data Collection

I will use the triangulation method of data collection. According to Bogdan and Biklen (2006) triangulation is the use of two or more methods in a study with a view to double (or triple) checking results. The use of flexible and multiple methods is a means of studying a small sample in depth over time in order to establish warranted assertions (Berg 2004). I plan to keep a reflective journal, videotape my lessons and analyse the students’ work to gather data for my research.

I will use a reflective journal to record my reflections and observations after each lesson during the research period. In my reflective journal I aim to not only write
about what I did but also write about what I learned. McNiff and Whitehead (2002) assert that it is easy enough to describe what happened and that showing learning is more difficult but essential.

I plan to record the lessons during the research period on video, with a view to making further observations and reflections. McNiff and Whitehead (2006) write that video “can be especially powerful when you come to generate evidence in support of a claim to knowledge.” Video recordings can offer me a more effective medium to demonstrate my implicit educational values. Whitehead (2008) suggests that because the expression of energy in the meanings of these values cannot be communicated using only words on pages of text, video-data in a visual narrative can help with the public communication of these meanings. Also the video recordings will allow me to more rigorously examine the lessons and to observe events or situations that I may have missed or forgotten in real time. I intend to document these videotape observations and reflections in a journal.

I plan to photograph all the project work as evidence. I propose to assess if there is any evidence of higher order thinking in the students’ work. The Biggs and Collis’ SOLO taxonomy (1982) will offer me a means of measuring higher order thinking.

3.5 Making a Claim to Knowledge

In making a claim to have improved my practice, I am also making a claim to have a new theory of practice. This theory of practice is my claim to knowledge. The standards of judgement I set for that claim to knowledge relate to my own values. I
need to show that these values had an influence for good on my students’ learning.

Mc Niff and Whitehead (2006 p150) contend that the job of the practitioner-researcher is to set down your own standards of practice and judgement, and show how you are fulfilling them. As an action researcher I must ask myself if I am using my own core values as my standards. Furthermore, Mc Niff and Whitehead contend that you must articulate these standards, and communicate them to others, so that others can see how you judge your practice, and negotiate your judgement with you. I must share my judgements and reflections with others and be open to critique.

Making a claim to knowledge through action research is about showing that I understand my practice better than I did before. I need to offer descriptions of what I did and explanations for why I did it. These descriptions and explanations together will become my theory of practice. (McNiff and Whitehead 2006) However our theories remain so much speculation unless we support them with evidence that has been validated by others. (McNiff and Whitehead 2002)

3.6 Validating the Evidence

Habermas (1979 cited in McNiff and Whitehead 2006 p.104) states that the criteria to judge the legitimacy of knowledge claims are that:

- A statement is true;
- A speech act is comprehensible;
- The speaker is authentic;
- The situation is appropriate for these things being said.
My claims to knowledge will be critically evaluated formally at validation meetings with my MSc colleagues and my supervisor. I have employed a critical friend, who will also evaluate my claims to knowledge. McNiff and Whitehead define a critical friend as “a person who will listen to a researcher’s account of practice and critique the thinking behind the account” (2006 p.256). I have invited a fellow mathematics teacher from my school to be my critical friend. I also plan to further test the rigour of my claims to knowledge by applying Winter’s six criteria of rigour:

<table>
<thead>
<tr>
<th>Criteria of Rigour</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflexive critique</td>
<td>a transformational dialogue between writer and reader of the research;</td>
</tr>
<tr>
<td>Dialectic critique</td>
<td>constant questioning of relationships of unity and contradiction within the research process;</td>
</tr>
<tr>
<td>Collaborative resource</td>
<td>participants and practitioners are co-workers in the research process;</td>
</tr>
<tr>
<td>Risk</td>
<td>at every level of the research process there is the risk of transformation or refutation;</td>
</tr>
<tr>
<td>Plural structure</td>
<td>the research report will reflect a number of different accounts reflecting the various relationships during the research process;</td>
</tr>
<tr>
<td>Theory, practice, transformation</td>
<td>the interdependency between theory and practice is realised.</td>
</tr>
</tbody>
</table>

Adapted from Winter (1989)
Throughout the research process I will interrogate the assumptions underlying my own thinking and I will consider the opinions of those I invite to critique my work.

### 3.7 Ethical Considerations

According to Alderson (2005) researchers need to think very seriously about two key questions:

- Is the research worth doing?
- Is the research explained clearly enough so that anyone asked to take part can make an informed decision about whether they want to consent or refuse? (p.31)

I feel that my research is worth doing. It should benefit my learning and my practice as a teacher. In turn the student participants could gain in terms of my influence on their learning. Also I have ensured that the research participants are fully informed about my research in order to make an informed decision about whether or not they wish to participate.

I have secured written permission to conduct research in the school from my Principal and the board of management of my school. I have received written permission for each of the students taking part in my research from both the students and their parents. I will endeavour to ensure that all of the students participating in my study are kept anonymous. I have not identified the name of the school in the research. The names of students participating in the study have been changed in order to insure their anonymity. The recordings of my lessons will be made available to my dissertation supervisor and any reader she chooses to make it available to, for the purposes of examination only.
In undertaking my research I am mindful that I have a duty of care to my students. My role as a teacher supersedes my role as a researcher. I understand that observation and videotape recordings are all potentially intrusive and may provoke anxiety in some of my participants. I will ensure that I am honest and respectful in my treatment of research participants.

3.9 Conclusion

I began this chapter by discussing the different research paradigms. I then explained how my ontological and epistemological positions led me to adopt the living educational theory approach to action research as an appropriate methodological framework for my study. I described my action plan and my chosen methods of data collection. Finally, the issues of validating my claims to knowledge and ethics were discussed.
Chapter Four - Implementation and Evaluation

4.1 Introduction

In this chapter I examine the use of inquiry-based learning in my mathematics lessons with a first year group in a post-primary school in order to encourage higher order thinking among my students. The main focus of this chapter is to show how I tried to improve my practice in the use of an inquiry-based approach in the teaching of mathematics.

I invited my first year Junior Certificate mathematics class to join me in this research. The class comprises of twenty-three students, five girls and eighteen boys. The average age of the students at the time of the research was thirteen. The students come from a wide range of different primary schools in the locality so the students met most or all of their classmates for the first time at the beginning of the school year. The class consists of a vast array of abilities, ranging from students who have difficulty adding fractions to those who can grasp abstract concepts in algebra. They are currently studying the Project Maths common level first year introductory course. I teach this class every day for a single class period, which is 35 or 40 minutes long depending on the time of day.

The chapter includes two cycles of research. I present my account of these cycles in a chronological fashion. The branch of mathematics we explored in these cycles was statistics, in particular data handling (Figure 4.1). The new statistics curriculum for Project Maths, which is outlined in the “Teacher Handbook for Junior Certificate
Strand 1: Probability and Statistics” (Project Maths Development Team 2010) requires the students to understand the data handling cycle.

![Data Handling Cycle Diagram]

*Figure 4.1 – The Data Handling Cycle*

Cycle one of the research took place over eleven consecutive class periods in March 2012 and the focus was on introducing inquiry-based learning. I adopted a guided inquiry approach in cycle one. The students carried out their inquiries in groups during this cycle. In cycle one I intended to implement an inquiry-based approach and hopefully to elicit higher order thinking.

The second cycle took place over fourteen consecutive class periods in April and May 2012. In this cycle I used an open inquiry approach. I allowed the students to work on their own individual inquiries and to take responsibility for all the aspects of the inquiry. We used CensusAtSchool as a means of generating data about the students in this cycle.

Throughout the research process I continually examined my own learning and my influence in the learning of others. During the research period I video recorded each lesson. Each evening during the research period, before I sat down to write my
reflective journal, I looked at the recording and this allowed me to relive the lesson and to observe student activities that I would otherwise have missed. The video recordings proved to be hugely beneficial to my learning. I separated my journal into two sections – what I did, and what I learned in accordance with McNiff and Whitehead’s (2002) recommendations. In carrying out this research I came to recognise and to better understand my own core values that motivate my practice as a teacher, which I discuss in more detail later in the chapter.

I begin by expressing my rationale for introducing inquiry-based learning to my practice as a mathematics teacher. I articulate the educational values that underpin my research and I explain how I hope to overcome the ‘living contradiction’ (Whitehead 2008) between these values and my practice.

4.1.1 Rationale

Mathematical skills are essential for students’ everyday lives and their future working lives (NCCA 2005, 2006, 2007). One of my fundamental objectives as a mathematics teacher is to foster a more positive attitude to the subject and to make learning mathematics a less daunting experience for my students. I would like my students to enjoy studying mathematics and to want to spend time improving their mathematical skills.

I value perseverance in problem solving and I encourage a positive attitude to mistakes and difficulties in my students. I also value my students taking responsibility and accountability for their own learning of mathematics. As I embarked on the
research process, I was concerned that my students were not persevering with problem solving and were not taking ownership of their own understanding of mathematical methods and concepts. I observed that when my students came across a problem that they found difficult or required higher order thinking they tended to give up and wait for me to explain it on the board. I want my students to consider problems more rigorously and weigh up all the possible solutions rather than giving up after the first attempt. To put it simply, I want my students to apply higher order thinking to their work.

After much reflection I came to recognize that my teaching methods negated my educational values. In my teaching I was feeding the students information and demonstrating skills that they had to then try to imitate. I assumed that my students could understand methods and learn skills for which they could see no real life application. I was not affording the students the opportunity to take ownership of their learning by constructing their own meaning from their experiences in the classroom.

I saw the need to make my lessons more activity orientated and engage my students more by relating to their experiences and interests. The literature of Prawat (1996), Henningsen and Stein (1997), Jarworski (2006) and Libman (2010) indicates that classroom activities should be based on real life situations so that the students can appreciate the applications of mathematics in everyday life and in their future working lives. My experiences at Project Maths workshops, Pathway workshops and as a MSc student and my review of the literature have informed my belief that adopting an inquiry-based approach could help my students appreciate mathematics and apply a higher level of thinking to their work because it engages students in
investigating real world questions and it enables students to discover knowledge for themselves. Inquiry-based learning is learning through doing. IBL is a student-centred, teacher-guided instructional approach that engages students in investigating real world questions (Colburn 2000, Kahn and O’Rourke 2005).

4.2 Cycle One

Cycle one of the research took place over eleven consecutive class periods in March 2012 (Table 4.1). I structured the narrative of cycle one using headings that describe the different stages in preparing the students for and guiding the students in their data handling inquiries – scaffolding for cycle one, planning a survey, collecting the data and interpreting the data.

<table>
<thead>
<tr>
<th>Date</th>
<th>Brief Description of Lesson</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thursday 15th March</td>
<td>Introduction to data collection, different data types;</td>
<td>Scaffolding for the Inquiry Phase</td>
</tr>
<tr>
<td>Friday 16th March</td>
<td>Identifying different data types;</td>
<td></td>
</tr>
<tr>
<td>Monday 19th March</td>
<td>School Holiday;</td>
<td></td>
</tr>
<tr>
<td>Tuesday 20th March</td>
<td>Drawing tables to record data, tallying;</td>
<td></td>
</tr>
<tr>
<td>Wednesday 21st March</td>
<td>Drawing tables to record data, tallying;</td>
<td></td>
</tr>
<tr>
<td>Thursday 22nd March</td>
<td>Sampling Techniques;</td>
<td></td>
</tr>
<tr>
<td>Friday 23rd March</td>
<td>Sampling Techniques and Biased Data;</td>
<td></td>
</tr>
<tr>
<td>Monday 26th March</td>
<td>Designing clear and unbiased questionnaires;</td>
<td></td>
</tr>
<tr>
<td>Tuesday 27th March</td>
<td>Planning the surveys;</td>
<td>Inquiry</td>
</tr>
</tbody>
</table>
Wednesday 28th March | Class discussion about questions posed by students; | Phase
--- | --- | ---
Thursday 29th March | Collection the data for the group work surveys; | ---
Friday 30th March | Class discussion on findings of the surveys; | ---

As both the students and I, the teacher, are novices to inquiry-based learning I decided to employ a guided inquiry approach in this cycle and adapt this approach to suit my needs as a mathematics teacher. My review of the literature informed this choice. Sweller (1988) and Kirscher et al (2006) contend that novices to inquiry-based learning need a lot of teacher guidance and support. In guided inquiry the teacher provides the question and the students are responsible for determining the method of investigation and interpretation of the results. I offered the students a choice of measuring tools. The students were responsible for deciding what they wanted to measure, how they carried out these measurements and interpreting the results.

### 4.2.1 Scaffolding for Cycle One

In an effort to guide my students through the inquiry-based learning experience I used the fading method of scaffolding. Education researchers support this method of scaffolding in inquiry-based learning (Anderson 1989, Hmelo-Silver 2004, Hmelo-Silver et al 2007). In the initial lesson I gave more support and direction to the students and I gradually faded my guidance as the students become more accustomed to inquiry-based learning.
The section of the syllabus we explored in cycle one was statistics and the topic was data handling. From my review of the literature, I learned the importance of prior knowledge in inquiry-based learning (Sweller 1988, Kansalaar 2002, Kahn and O’Rourke 2005). With this in mind, I tried to teach my students all they needed to know about data handling in order to participate in the inquiry-based learning lessons.

In preparation for the students’ inquiries, I spent seven lessons teaching the students about the different types of data, data collection and designing questionnaires. I started these seven lessons by explaining the different types of data on the board – numerical, categorical, discrete and continuous. I followed this explanation with a quiz to challenge the students’ ability to identify the different types of data. In the next lesson the students worked on exercises from their textbooks (Morris et al 2011) to consolidate what they had learned about the different types of data. In the following two lessons the students learned how to put the data into tables. I introduced tables by surveying the class on their favourite TV programmes and recording the data in a table on the whiteboard. In these two lessons they practiced drawing and reading tables using exercises from their textbooks and I checked their work to make sure that they were doing it correctly. I spent two lessons teaching the students about sampling techniques and biased data. I showed a fourteen minute long YouTube video clip that illustrates the importance of an unbiased sample (EncoreVisions 2010). In the seventh lesson the students learned about designing a questionnaire and how to ensure that they pose questions that are clear and unbiased. Their class work was to identify problems with different questionnaires and to come up with better questions.
4.2.2 Planning the Survey

I dedicated one lesson on the 27th March 2012 to teaching the students about planning a survey and facilitating the students working in groups to plan their group surveys. I tried to structure the lesson so that the students were very clear on what I wanted them to do. I delivered a PowerPoint presentation (Appendix B) to teach the students about data handling with specific emphasis on the planning stage of data handling (Video 1).

I then split the class into groups of three and four and handed out worksheets that I had designed to help the students to plan their group inquiries (Appendix C). I offered each group a variety of tools of measurement to choose from in an effort to help them to decide what they would like to investigate. I offered them a choice of a timer, a measuring tape, a ruler, a protractor, weighing scales or a thermometer. At the end of the lesson each group shared the questions that they wanted to pose with the rest of the class. Their homework was to plan their own individual surveys and to plan what data to collect and how they would collect that data (Appendix D). My thinking in instructing the students to carry out the group work surveys was to help the students practice before they carried out their own individual inquiries.

There were some early indications of higher order thinking in the students’ activities. In my journal entry on the 27th March 2012 I described my observations:

*I feel that there were some signs of higher order thinking in the group work activity.*

*Some of the questions posed by the groups were creative and original such as*
questioning how long it would take students to write their name backwards and how far students can blow a malteaser with a straw. (Appendix E)

However the completed group worksheets (Appendix F) that the students were required to fill out do not reveal much analytical thinking and evaluation. Most of the questions were answered with one-line responses.

In the proceeding lesson the students shared their individual questions with each other and offered constructive criticism to each other. Peer interactions are beneficial to assist students to clarify and focus their statistical questions (Lowrie 2002). There were several problems with their questions. I described the difficulties we encountered in my journal entry on the 28th March 2012:

I didn’t anticipate that there would be so many problems with their research questions. I hoped that the students would learn from the group activity and would have little difficulty coming up with questions. However, they ran into several difficulties. Firstly, some students didn’t seem to know the difference between categorical and discrete data, even though we’ve been through it in several lessons, including in yesterday’s lesson. Secondly, some of the questions would be impossible to research such as “how big is your hair?” or “how long does it take to change a light bulb?” or “how many clouds are in the sky between 8.15 and 3.15” because they were ambiguous and it would be impossible to measure. (Appendix G)

Overall the quality of research questions that the students came up with was poor and there was very little evidence of higher order thinking (Appendix H). Also the students seemed to have difficulty in finding the flaws in each other’s questions.
At this point I decided to abandon the individual inquiries. This is mostly due to time constraints. I only had two lessons remaining with the class before the Easter holidays started. Also this would allow us to focus all our attention on the group work inquiries. In hindsight, I feel that I was too ambitious in asking the students to carry out two surveys simultaneously in such a short space of time.

An on-going issue for me was that my lessons remained teacher-dominated. The work of several authors previously discussed in the literature review, such as Dewey (1987), Colburn (2000), Hmelo-Silver (2004) and Lord and Baviskar (2007), emphasize the importance of a student-centred classroom. I wrote in my reflective journal on 28th March 2012:

*I still have to work on playing a less active role in the class and allow my students to do all the talking. When I looked at the recording I noticed that I had to stop myself from prompting the students or giving the students too much direction.* (Appendix G)

### 4.2.3 Collecting the Data

The objective of the lesson on the 29th March 2012 was to allow the students to carry out the data collection phase of their group investigations. The only way I could describe this lesson was organised chaos, or unorganised chaos at times. However, overall I was happy with the lesson and I was satisfied that I achieved my aim of making the lesson more student-centred.
It was evident to me that the students really enjoyed this lesson. At one stage Jack said to me “Ours is really fun, Miss” referring to his survey (Video 2). When I looked at the recording all of the students were engaged, active, interested and in some cases a little over-excited (Video 2).

I believe that a key factor in the success of this lesson was the time we spent on the planning stage. This meant that the students knew exactly what they were doing and how they were going to carry it out. This helped to structure the inquiry for the students. The writings of Sweller (1988) and Kirschner et al (2006) on the need for teacher support and guidance for novices to inquiry-based learning influenced my decision to dedicate significant time to planning the inquiry.

I observed further indications of higher order thinking as the student’s generated data for their inquiries, which I described in my journal entry on the 29th March 2012:

*I feel that there were many examples of higher order thinking in the students’ activities today. One group who were measuring height asked students to take off their shoes before they measured them to get more accurate data. Another group set up their experiment in an intelligent way. They wanted to see how long it took students to pack away their books and equipment into their bags. They had the desk set up as it would be at the end of a lesson, with the Maths book open, pencil case open, copy open etc. They were modelling the real-life situation. Also the teams organised themselves in terms of collecting and recording the data with little or no help from me.* (Appendix I)

These activities fit into the higher levels of Anderson and Krathwohl’s amended version of Blooms taxonomy of thinking skills (2001), specifically evaluating and
creating (table 4.2).

Table 4.2

<table>
<thead>
<tr>
<th>Level in Revised Taxonomy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remembering</td>
<td>Retrieving, recognizing, and recalling relevant knowledge from long-term memory;</td>
</tr>
<tr>
<td>Understanding</td>
<td>Constructing meaning from oral, written, and graphic messages through interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining;</td>
</tr>
<tr>
<td>Applying</td>
<td>Carrying out or using a procedure through executing, or implementing;</td>
</tr>
<tr>
<td>Analyzing</td>
<td>Breaking material into constituent parts, determining how the parts relate to one another and to an overall structure or purpose through differentiating, organizing, and attributing;</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Making judgments based on criteria and standards through checking and critiquing;</td>
</tr>
<tr>
<td>Creating</td>
<td>Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing.</td>
</tr>
</tbody>
</table>

(Anderson and Krathwohl 2001 p.67-68)
4.2.4 Interpreting the Data

A key objective of the new mathematics curriculum, Project Maths, is to enable students to develop their skills in communication (NCCA 2007 p.5). The purpose of the lesson on the 30th March 2012 was to discuss how the investigations went in the previous lesson. I asked each group to tell the class and I about their inquiry. I recorded the students on video as they spoke about the data they collected and explained their conclusions (Video 3).

I observed that the students were engaged and eager to share their results and conclusions. I wrote in my reflective journal on the 30th March 2012:

*I found the students to be very forthcoming with their thoughts about the data. They all seemed very interested in the results. The problem I had in previous lessons with the students not listening to each other did not arise today. I feel that because they were participants in each other’s investigations they were genuinely interested in the results. We had quite the lively discussion. (Appendix J)*

There were signs of higher order thinking in the class discussions, which I described in my reflective journal on the 30th March 2012:

*Some students carried out deeper analysis of the data and gave reasons for the results. One group were measuring the weight of students’ bags and they found that the students that carried all their books for the day had heavier bags. One group found that students who wrote in joined writing wrote faster than those who didn’t. ....John argued that some of the experiments could be improved because they didn’t*
properly model what happens in real life. In fact, all the students had opinions about how to improve the investigations.

They seemed to understand the importance of collecting valid and unbiased data. In terms of carrying out the investigations, the students did seem to understand the importance of setting clear guidelines and being rigorous. The group weighing bags found that when they got slightly different values for the same bag each time they weighed it, so they took the middle value. I have not discussed averages or means with the students yet so this was impressive to me. (Appendix J)

However, when I collected the students’ copies to read what they had written for their conclusions, I was very disappointed. Although the students were able to speak eloquently and at length about their investigations, they wrote very little in their written conclusions. This is evident in the following samples of the students’ written conclusions:

“Were the results unexpected? Yes as nearly everyone is nearly equal height. This shows the finger of piggyness length. The average is 8cm. I find it unusual because Patrick’s is really long”

“The data was not what I expected because I taught it would be slower. It took longer for the people who had shorter names. The data shows that people write their name fast.”

“I expected that the time would be shorter. The usual data is that some people took too long. The data shows how long it takes people to write their name backwards”
“The data was not as I suspected. Someone took 56 seconds to pack the bag. The data shows that everyone is different when under pressure. Sandra took 50.49 seconds just to pack a bag when in class she is usually very fast. Our average to pack a bag is 19.59 seconds.”

In order to get the students’ first impressions of IBL, I asked three of the participating students that I have for a Resource class, Brendan, Jamie and Amy to talk to me about their experiences. The feedback was very positive. Jamie said, “It was class” (Video 4). They all concurred that when they do it themselves they actually get it, “We understand.” “We want to do it well.” (Video 4, Appendix K) The feedback from the students and the evidence from the video recordings illustrates that the students enjoyed directing their own investigations.

The initial lessons in the “scaffolding for cycle one” and “planning the survey” stages were teacher dominated as I tried to prepare my students for inquiry. The later lessons in cycle one, the “collecting the data” and “interpreting the data” phases, were more student centred. This faded approach to scaffolding worked well. The feedback from the focus group students supported this. Jamie and Amy agreed that they wanted me to teach them the skills and knowledge first before they start their inquiries (Video 5, Appendix K).

In terms of the students’ understanding of statistics, the use of real data meant that the students were able to draw meaningful conclusions about the data. Because they were working with real data that concerned themselves, the students were more interested
and thus were able to make insightful interpretations and apply a higher level of thinking to the analysis of the data. My reading of the literature supports this finding. According to Singer and Willett (1990) and Libman (2010) students find real data intrinsically interesting.

4.2.5 Reflection on Cycle One

The commencement of the Easter holidays drew cycle one to a close, which allowed me two weeks off school to reflect on the issues and successes in cycle one and to consider what I would do differently before I began cycle two. I could see that I had successfully implemented an inquiry-based approach. Also I was starting to see more congruence between my educational values and my practice as a mathematics teacher. I identified at the beginning of the research process that I value student engagement, self-directed learning, students taking responsibility and accountability for their own work and a positive attitude towards the learning of mathematics in my students. The key improvement to my practice I could identify at the end of cycle one was increased student interest and engagement as illustrated in the students’ feedback (Video 4), the students’ enthusiasm in their classroom activities (Video 2) and their eagerness to share the results of their inquiries (Video 3). The students were self-directed in negotiating with their group members to plan and orchestrate their inquiries (Video 2). I also succeeded in allowing the students to take ownership of their own learning in the classroom by facilitating a student centred classroom (Appendix I). However, because they were sharing responsibility for the inquiries with their group members, I did not encourage the students to take responsibility and accountability for their own work.
One of the main stimuli behind the research was my desire to encourage higher order thinking among my students. Although there was some evidence of higher order thinking in the class discussions (Video 3) and the students’ activities (Video 2), I had yet to ascertain any concrete evidence of higher order thinking in their written work. Similarly, I encountered problems in asking the students to pose their own questions. Unfortunately, due to time constraints with the fast approaching Easter holidays, this meant that the students could not carry out their individual inquiries. Research acknowledges that writing good statistical questions is problematic for students (Arnold 2008, Wild and Pfannkuch 1999). It is important to ensure that students have sufficient interest, knowledge or experience in a topic to pose meaningful questions (Arnold 2008, Chin and Kayalvizhi 2002). It was at this point that I considered CensusAtSchool. CensusAtSchool is an online questionnaire for students and the questions are based on teenage interests and experiences (Townsend 2006, Marriott et al 2009). I examine CensusAtSchool in more detail in Chapter One. I have used CensusAtSchool with another class in the previous school year and I found it to be a valuable resource for generating data about the students. I believed that I could employ CensusAtSchool as a means of helping the students to come up with interesting and sensible questions for their individual inquiries.

At the end of my first cycle of action research I reflected that inquiry-based learning is very time consuming. I underestimated the time it would take to carry out the planned activities, which led to my decision to abandon the students’ individual inquiries. I now recognised that inquiry-based learning takes time and that I needed to be more flexible with the time I allocated to activities. It was clear to me, going in to
cycle two, that inquiry-based learning requires rigorous planning and preparation by the teacher. I had dedicated considerable time to planning and preparation in cycle one but I could see that if I had been better prepared at certain stages, such as helping the students with their questions, things could have run more smoothly.

4.3 Cycle Two

Cycle two is structured, similarly to cycle one, using headings that describe the different phases in preparing the students for and guiding the students in their data handling inquiries – scaffolding for cycle two, CensusAtSchool, project work and oral presentations. Cycle two took place in the three-week period from Tuesday 17th April to Friday 4th May 2012 (Table 4.3).

<table>
<thead>
<tr>
<th>Date</th>
<th>Brief Description of Lesson</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuesday 17th April</td>
<td>Introduction to data representation, drawing line plots;</td>
<td>Scaffolding</td>
</tr>
<tr>
<td>Wednesday 18th April</td>
<td>Drawing and reading line plots;</td>
<td>for the</td>
</tr>
<tr>
<td>Thursday 19th April</td>
<td>Drawing bar charts;</td>
<td>Inquiry</td>
</tr>
<tr>
<td>Friday 20th April</td>
<td>Drawing and reading bar charts;</td>
<td>Phase</td>
</tr>
<tr>
<td>Monday 23rd April</td>
<td>Drawing stem and leaf plots;</td>
<td></td>
</tr>
<tr>
<td>Tuesday 24th April</td>
<td>Drawing and reading stem and leaf plots;</td>
<td></td>
</tr>
<tr>
<td>Wednesday 25th April</td>
<td>Test on data representation;</td>
<td></td>
</tr>
<tr>
<td>Thursday 26th April</td>
<td>Filling out hard copy of CensusAtSchool questionnaire;</td>
<td>Inquiry</td>
</tr>
<tr>
<td>Friday 27th April</td>
<td>Filling out online CensusAtSchool questionnaire;</td>
<td>Phase</td>
</tr>
</tbody>
</table>
It was at this stage of the research process that I returned to the literature review. In cycle two I intended that the students would work individually, rather than in groups, on their own inquiries. Conway and Sloane (2006) emphasize the importance of self-directed and self-regulated learning in learning mathematics and learning to learn as an educational aim. Furthermore, I felt that it would be more practical to gauge the students’ levels of thinking skills based on individual work as opposed to their contributions to a group work assignment.

As I re-engaged with the literature, I recognised that assignments that target higher level thinking skills could lead students to perform at these levels (Redfield and Rousseau 1981, Newmann and Archbald 1992, Cumming and Maxwell 1999, McTighe and O’Connor 2005). Also I began to see a connection between higher order thinking and motivation. Biggs (1999) asserts that increased student motivation can lead to a deeper level of learning and understanding.

My focus in cycle two was on the students’ written work. I planned to use two methods in order to encourage the students to put more effort into their written conclusions. Firstly, I would try to motivate the students by offering prizes for the top

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday 30th April</td>
<td>Filling out online CensusAtSchool questionnaire;</td>
</tr>
<tr>
<td>Tuesday 1st May</td>
<td>Project Work;</td>
</tr>
<tr>
<td>Wednesday 2nd May</td>
<td>Project Work;</td>
</tr>
<tr>
<td>Thursday 3rd May</td>
<td>Oral Presentations;</td>
</tr>
<tr>
<td>Friday 4th May</td>
<td>Oral Presentations;</td>
</tr>
</tbody>
</table>
projects and weighting the marks for their projects in favour of the written parts.

Secondly, I would try to ensure that the students were clear on what I expected from them, by preparing a sample project and setting clear criteria for their projects. Students are more likely to put forth the required effort when they clearly understand the task and the learning goal and know how teachers will evaluate their learning (Marzano 1992 cited in McTighe and O’Connor 2005).

As the students had experienced a guided inquiry approach in cycle one and were no longer novices to inquiry-based learning, I decided to adopt a more open inquiry approach in this cycle. Banchi and Bell (2008) contend that it is appropriate to allow students to conduct open inquiries only when they have demonstrated that they can successfully carry out inquiries at the lower levels. At this level the student is responsible for all aspects of the inquiry. The student comes up with a question to investigate, generates and represents the data and interprets the results (Bell et al 2005).

4.3.1 Scaffolding for Cycle Two

At this high level of inquiry I continued to recognise the need for prior knowledge and scaffolding, as I learned from my experiences in cycle one and the literature of Sweller (1988), Kanselaar (2002) and Kahn and O’Rourke (2005). The section of statistics we explored in cycle two was data handling, with emphasis on data representation. I spent six lessons teaching the students about representing data graphically at the start of cycle two. They learned how to draw three different types of graphs - bar charts, line plots and stem and leaf plots. I introduced these charts and plots by surveying the class on their favourite subject, their shoe sizes, and the
number of pairs of shoes they own. I represented this information on the whiteboard using an appropriate chart or plot. I instructed the class to copy my chart or plot exactly. Then the students practised drawing and reading charts and plots using exercises from the textbook (Morris et al 2011) as I circulated the classroom and gave help and guidance where it was needed. My aim was to ensure that they drew their graphs neatly and accurately. A common issue for several students was that they forgot to label their graphs.

4.3.2 CensusAtSchool

In cycle one the students had great difficulties with posing a question to investigate. To address this I decided to use the CensusAtSchool online questionnaires in cycle two to help the students to come up with better questions. CensusAtSchool is a survey developed for teenagers and the questions are based on teenage interests and experiences.

There are a number of measurements required by the CensusAtSchool questionnaire (Appendix A) so I dedicated one lesson to filling out a hard copy of the questionnaire. My hope was that this would help to speed up the process of filling it in online. This activity took longer than I predicted – we spent one and a half lessons completing the hard copies of the questionnaire, 26th and 27th April. I wrote in my reflective diary on 26th April 2012:

The questionnaire itself was quite complicated. There were so many measurements to carry out for the questionnaire (height, foot size, hand span, arm span, vertical reach and pulse) that it was not possible to complete them within one class period. When I
used CensusAtSchool with another class last year I found the survey was much easier to complete. The previous year’s questionnaire, phase 10, did not require half as many measurements and the questions did not seem to cause as much confusion. (Appendix L)

Once the hard copies of the questionnaires were completed we moved to the computer room so that the students could begin filling out the online questionnaires. This activity also took longer than anticipated (Video 6). I had predicted that we would finish the questionnaires on the 27th April but we had to return to the computer room for the following lesson on the 30th April 2012 to complete the task.

In the CensusAtSchool lessons some classroom management issues arose, which I articulated in my journal entry on 27th April:

When we moved to the computer room it took a few minutes to get the Internet working and to make sure that every student could log on. This caused the class to become chatty and unsettled..... I believe that busy students will not have the opportunity to become disruptive. In the last two lessons there were periods of inactivity which caused the students to become restless. (Appendix M)

I realised that I needed to anticipate this inactivity and ensure that the students are kept on task so that they are not afforded the opportunity to become unsettled.

4.3.3 Project Work

Once the online questionnaires were completed I brought the students back to the classroom. The students worked on their projects on Tuesday 1st May and Wednesday
2\textsuperscript{nd} May. Before these lessons began I spent some time setting up the room. I organised the desks so that the students could sit in groups of four. I put white paper, graph paper, scissors, glue and a set of coloured markers on the desks for each group to share. Research shows that this set-up can provide pupils with opportunities to explain and evaluate their own work in a peer group setting (Carr 2010).

I felt that it was important, based on my experiences in cycle one, to explain to the students exactly what I expected from them. I wrote in my reflective journal on the 1\textsuperscript{st} May 2012:

\textit{Today I made sure that I was well prepared. I realise now that it takes a lot of preparation to run a class like this. I tried to pre-empt any difficulties that the students might run into.} (Appendix N)

I went through the project instructions on a PowerPoint presentation (Video 7, Appendix M) and I showed the students a sample project that I had prepared. (Appendix O) Then I handed out instructions (Appendix P), coloured card and a class dataset (Appendix Q) from the completed CensusAtSchool questionnaires to each student. I also handed out CensusAtSchool questionnaires so that the students could understand the class dataset. I set the students to work on their own projects and I circulated the classroom and offered guidance and encouragement where it was needed.

I found that the grouped seating worked very well for these lessons. I wrote in my reflective journal that the students were self-directed (Appendix N). They negotiated with each other and shared the equipment. Overall, I believe that the class was focused on the task. The students seemed to enjoy the project work and several
students stayed back after the bell had gone to continue with their projects. In fact, when I looked at the recording (Video 8), I was astonished to see that when the bell sounded nobody moved, even though it was the last class of the day. They seemed to be in no rush to leave, which is certainly not the norm. The students spent two lessons (1st and 2nd May 2012) completing their projects in class time and several students came back at lunchtime and after school to work on their projects.

I tried to encourage the students to give more consideration to their written conclusions, as this was an issue in cycle one. I put up a marking scheme that weighted the marks so that the conclusion would be considered an important part of the project:

- Tables: 10 marks
- Charts: 10 marks
- Design: 10 marks
- Conclusion: 20 marks
- Presentation: 20 marks

Bennett and Desforges (1988) and Sousa (2008) assert that if students are given challenging tasks that encourage the students to think at a higher level, then students’ cognitive processing during task implementation stands a better chance of remaining at a high level.

### 4.3.4 Oral Presentations

The objective of the final two lessons of cycle two was to allow all the students to present their projects. According to the National Research Council in the US (1996)
one of the fundamental abilities of inquiry is to communicate and defend a scientific argument. Barrow (2006) argues that students should refine their communication skills by giving oral presentations that involve responding appropriately to critical comments from peers.

Figure 4.2 – Video stills of the students presenting their projects
I gave the students one minute each and I timed them on a stopwatch. I questioned the students and I tried to encourage them when they were giving their presentations. The students listening seemed interested and also asked questions about each other’s work. I recorded my observations in my reflective journal (2\textsuperscript{nd} May 2012):

*The students spoke quite well about their projects, although some students did require prompting. All the students put a lot of work into their projects and they followed the criteria that I set. They put a lot of effort into the design of their posters. Some students endeavoured to draw meaningful conclusions about the data and to come up with reasons to explain their results. Some students dismissed the outliers or data that did not seem accurate. Luke said that he excluded some data because “some students were messers”. He didn’t think that a student would predict that Ireland would win 99 gold medals in the Olympics. In fact, this project particularly engaged the class and the students were all very interested in how many medals the class predicted Ireland would win.*

*Students comparing girls and boys data had access to data from only four girls and fifteen boys. Neil realised that he needed a better sample group with more girls to get a better picture of the correlation between height and gender. In his project he compared the heights or girls and boys. He recognised that a bigger sample group was needed to give more accurate results. I could have used the random data sampling feature on CensusAtSchool to generate better data from the enormous bank of student data available. However, I was influenced by my experiences in cycle one, when I noted that students were really interested in data that concerned themselves. So in spite of the high ratio of boys to girls I decided to allow the students to work with data about themselves.* (Appendix R)
I was impressed with the work the students put into their projects (Presentation 1). Although all the students put a lot of effort into their project work, two students, Patrick and Brendan demonstrated a lack of understanding of statistics in their work. Brendan, who has dyslexia and dyspraxia, did not show a good understanding of the data he collected. His table and bar chart did not correspond to his conclusion. He created a table and a bar chart about the hands students use to write with but in his conclusion he wrote about the feet people kick with. On the other hand, Patrick invented data. He wrote about students getting up early to cook eggs, which was not part of the CensusAtSchool dataset.

At the end of the presentations, I gave prizes to the best five projects, according to the marking scheme I set out. I gave the prize-winners Olympics mugs filled with sweets because I felt it was in keeping with the theme of the CensusAtSchool survey.

At the end of the class I had hoped to have a discussion with the students about their experiences of inquiry-based learning. Unfortunately, as I learned seems to be the way with inquiry-based lessons, I ran out of time and the bell rang before I could glean any meaningful feedback. I managed to ask only one question. I asked the class if they enjoyed doing the projects and I got a resounding “yes” in response.

In an effort to get more feedback I asked three students, Brendan, Jamie and Neil, that I teach Resource mathematics to, if I could talk to them about their experiences in carrying out the projects (Appendix S, Video 9). The feedback was very positive. They said they really enjoyed doing the projects. Neil said he preferred subjects that
allowed him to be creative and make things. All three students agreed that they would like if they could do project work in all their subjects.

I asked them if they preferred the individual projects in cycle two or the group work projects in cycle one. Jamie and Neil said that they preferred doing the projects on their own because they were responsible for all aspects of the projects and they did not have to negotiate with teammates (Appendix S, Video 9).

I was also interested in finding out if they felt that they had learned anything in doing the projects. All three students asserted that carrying out the projects helped their understanding of data handling. Jamie said that it helped him to learn about the different types of data and how to draw tables and charts properly (Appendix S, Video 9).

4.3.5 Evaluating Higher Order Thinking Skills in the Students’ Project Work

It was at this point in the research that I saw the need for a more rigorous method of assessing the students’ project work for higher order thinking. I had some difficulty in finding a model to assess higher order thinking that would suit my particular needs. My supervisor, Dr. Margaret Farren pointed me towards Biggs’ SOLO taxonomy (Biggs 1999, Biggs and Collis 1982). The SOLO taxonomy offered me a framework for classifying the students’ project work in terms of higher order thinking. As I discussed in the literature review in more detail, the SOLO taxonomy describes the levels of increasing complexity in the student’s understanding of a subject. At the highest two levels of the SOLO taxonomy, level four and five, the student
demonstrates a deep understanding of data handling and data representation in his or her project work. At level five of the SOLO taxonomy the student is making connections not only within the area of statistics, but also beyond it and is able to generalise and make hypotheses. When the students are operating at the two highest levels of understanding they are creating new knowledge. This is classified as a higher order thinking skill in Anderson and Krathwohl’s amended version of Blooms taxonomy of thinking skills (2001).

I examined the students’ written conclusions to see if they could explain the data they had collected and if they had come up with good reasons for their results and shown a deep understanding of statistics (Presentation 1). I also looked at their graphs and tables to see that they were accurate and correctly labelled and that they corresponded with their written conclusions. For each project I assessed the level of understanding of statistics demonstrated by the student using Biggs’ SOLO taxonomy (ibid). I consulted with my critical friend in making these assessments and I justified my assessments at my final validation meeting on the 28\textsuperscript{th} May 2012 (Video 10).

<table>
<thead>
<tr>
<th>Level of SOLO Taxonomy</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prestructural</td>
<td>1</td>
</tr>
<tr>
<td>Unstructured</td>
<td>1</td>
</tr>
<tr>
<td>Multi-structural</td>
<td>3</td>
</tr>
<tr>
<td>Relational</td>
<td>7</td>
</tr>
<tr>
<td>Extended Abstract</td>
<td>8</td>
</tr>
</tbody>
</table>
4.3.6 Reflection on Cycle Two

In carrying out their individual inquiries, the students have gained a deeper understanding of the data-handling process. At the beginning of cycle two when I was teaching the students how to draw charts and graphs I found myself constantly reminding students to put labels and titles on their graphs and charts. Conversely, when the students were representing the data graphically for their CensusAtSchool projects there were no problems with labelling and titling their graphs and charts. It seems that using real data enables students to understand the value in providing all the information on their graphs and charts. Some students used statistical language in their projects such as “population” and “representative”. Also they all correctly named the type of data used in their projects: categorical, discrete or continuous.

Using CensusAtSchool to generate data, although problematical at the initial stages, proved very successful. The students did not experience the same difficulties in coming up with reasonable questions as they did in cycle one. Also the quality of written work was much improved, when compared with their efforts in cycle one. This could be down to the students’ interest in the data or the motivation of winning a prize or a combination of both.

The students enjoyed carrying out their inquiries and were thoroughly absorbed by their work. They were self-directed and self-regulated. During this cycle the students were challenged to engage at a higher level of inquiry (open inquiry). The students responded to this challenge and impressed me greatly with the level of effort that they
put into their projects and the levels of understanding that they demonstrated in their work.

At the end of cycle one I felt that there remained some disagreement between my educational values and my practice. I had failed to facilitate the students taking responsibility and accountability for their own work, as they shared responsibility for the inquiries with their group members. In cycle two this was resolved as the students were responsible for all aspects of their individual inquiries and they could not rely on fellow group members. A further issue that emerged in cycle one was the poor quality of the students’ written work and the lack of evidence of higher order thinking skills in their written work. My analysis of the students’ work in cycle two using the SOLO taxonomy indicates clear evidence of higher order thinking. As I concluded my second cycle of action research, I could now see that I was now living more in the direction of my educational values.

4.4 My Core Values

Early in the research process I quickly identified that I value higher order thinking, student engagement, self-directed learning, and students taking responsibility and accountability for their own work and a positive attitude to the learning of mathematics in my students. However these are not my core values that drive and motivate me as a human being and a teacher. In an effort to identify my core values, I read back through all my journal entries and I looked at my video recordings. The three core values that emerged glaringly to me from my writing and my interactions with the students in the video recordings were responsibility and accountability,
inclusion and love.

**Responsibility and Accountability:** I recognize that as a teacher, I am in a position of influence and I can negatively or positively impact on my students’ learning experiences in mathematics. One of my key objectives is to foster a positive attitude to mathematics in my students and to make learning mathematics a less daunting experience for my students. In my teaching, I endeavour to make learning mathematics an enjoyable and engaging experience. I hold myself responsible and accountable for my students learning and enjoyment of my subject. In the final validation meeting on 28th May 2012 I explain why this is one of my core values (Video 11). Throughout this study I dedicated significant time to preparing the lessons and scaffolding the learning for my students (Video 1, Video 7). I also tried out the classroom activities in an effort to pre-empt any difficulties that the students may encounter (Appendix N).

**Inclusion:** Inclusion is about ensuring that all the students feel respected and valued. I understand that some students have difficulties with mathematics and I try to ensure that all the students can engage and participate actively in my lessons. I articulated this value in my final validation meeting on the 28th May 2012 (Video 12). In cycle two I tried to ensure that every student had a completed project. Unfortunately there was one student who did not seem to enjoy the project work. Brendan has several learning difficulties – he has been diagnosed with dyspraxia and dyslexia and he was recently diagnosed with autism spectrum disorder. He had great difficulties with this project and did not seem engaged with the task. I wrote in my reflective journal on 2nd May 2012:
I gave him as much help as I could. I realise that it takes him much longer than the average student to complete written assignments and I worried that he would be the only student that would not have a completed project. In the group activity in cycle one this was not a problem because his team helped him along. I worried that it would be demoralising for him to be the only student without a completed project. I discussed this with a fellow maths teacher in the school whom I have recruited as a critical friend. We decided that the best course of action was to allow him time to complete his project during the presentations the following day and to ask another student to help him. (Appendix T)

In the next lesson (Thursday 3rd April) I asked Cian, who had been absent for the previous two lessons and thus did not have a project of his own to work on, to help this student to finish his project. Thankfully this seemed to work well and by the end of the first presentations lesson Brendan had completed his project.

**Love:** I love the work that I do as a mathematics teacher and I care about my students. I appreciate the beauty of mathematics and I try to ignite a passion for mathematics in my students. A conversation with Dr. Jack Whitehead prompted me to acknowledge the ‘life-affirming loving energy’ that I feel in my practice as a teacher. I see it clearly in my video recordings. In cycle one when we were discussing the results of the group activities I could hear in my voice the fondness I have for my students (Video 3). In the feedback sessions with my focus group the students were relaxed and open with me, which is indicative of the good relationship I have built with my students (Video 4, Video 9). In the final validation meeting on 28th May 2012 I articulated this value and I spoke passionately about my work as a teacher and my students (Video 13).
My embodied values of responsibility and accountability, inclusion and love became my living standards of judgement (Whitehead and McNiff 2006 p.150). I defined these standards of judgement by clarifying the meanings of my embodied values as these meanings emerged through the course of practice. The importance of such standards is that their meanings can be publicly shared and hence used to test the validity of claims to knowledge (ibid).

4.5 Validation

During the research process, I informally presented my work on two occasions, 2nd and 23rd April 2012, to a small group of fellow MSc students and my dissertation supervisor, Dr. Margaret Farren, as I clarified, in particular, my educational values. I also had one-on-one meetings with my dissertation supervisor, Dr. Margaret Farren on the 9th February and the 14th May 2012. I regularly consulted with my critical friend and an English teacher at my school very kindly proofread my work. I also was fortunate to have a brief conversation with Dr. Jack Whitehead about my research on the 19th May 2012.

I had one formal meeting on the 28th May 2012 with a small group of fellow MSc students, my supervisor, Dr. Margaret Farren and Yvonne Crotty, a coordinator of the eLearning strand of the MSc in Education and Training Management at DCU. The purpose of this meeting was to validate my research. In preparation for this meeting I asked myself the following questions based on Habermas’ criteria of social validity (1979 cited in McNiff and Whitehead 2006 p.104):

• Is the account of my learning comprehensible?
• Is there sufficient evidence to justify the claims being made?
• Are the values that constitute the enquiry as educational clearly revealed and justified?
• Is there evidence of my educational influence on the learning of others?

I could confidently answer ‘yes’ to all these questions and I assert that I have provided sufficient evidence to support this response.

In making a claim to have improved my practice, I am also making a claim to have a new theory of practice. This theory of practice is my claim to knowledge. The standards of judgement I set for that claim to knowledge relate to my own values (Mc Niff and Whitehead 2006 p.150). In presenting my claims to knowledge to be validated I used my core values that emerged in the course of the enquiry as my living standards of judgement. These values are responsibility and accountability, inclusion and love and I used video clips, students’ work and journal excerpts to demonstrate how I am fulfilling them. I also demonstrated how these values had an influence for good on my students’ learning. (Video 10, 11, 12, 13)

I have tested the rigour of my claims to knowledge by applying Winter’s six criteria of rigour (1989). I believe that I have fulfilled the six criteria of rigour as set out by Winter (ibid). I have engaged with the contradictions in my teaching. I recognised that although I wanted my students to apply higher order thinking to their work, my teaching methods did not provide the students with many opportunities to do so. I have shared my reflections and observations with the reader. The enquiry became reflexive through the questions and suggestions that have emerged as I endeavoured to improve my practice. I have acknowledged and acted on advice from my
supervisor, my fellow MSc participants, my lecturers and my work colleagues and
feedback from my students, throughout the research process. I also engaged with the
theory set down by others in attempting to improve my practice as a mathematics
teacher. In terms of risk, I found it challenging to change the learning environment
from a teacher centred one to a student centred one. I am accustomed to taking
responsibility for the learning that takes place in my classroom so it was quite a
challenge for me to allow my students to take ownership of their own learning.

4.6 Conclusion

In carrying out this research my initial aim was to improve my understanding of my
own practice. My ultimate aim was to improve my practice for the mutual benefit of
my students and myself. I explained my educational influences in learning by
regularly challenging my own assumptions, by listening to others and by discussing
my research with others. I successfully introduced inquiry-based learning to my
teaching and used it as a means of encouraging higher order thinking. I helped my
students to learn in a new way and thus discover new possibilities for themselves.
I understood the processes involved and my own learning progressed. I gave careful
adherence to the issues of rigour and validity to help to ensure that my claims to
knowledge are legitimate.
Chapter Five - Conclusion

In this enquiry I asked, How can I use inquiry-based learning to improve my practice and to encourage higher order thinking among my students of mathematics? I have shown that the use of inquiry-based learning has resulted in an improvement in my practice. I have used IBL to encourage higher order thinking among my students. In this chapter I present the overall conclusions drawn from my experiences in carrying out the research project and I summarise my learning.

5.1 My Learning

This study has greatly improved my understanding of how to integrate inquiry-based learning into my teaching. I have not only gained a working knowledge of the difficulties that may be encountered along the way but also first-hand experience of the benefits that may accrue. The conclusions I have drawn and my key learning points are as follows:

- Inquiry-based learning requires rigorous preparation;
- Inquiry-based learning takes time;
- Motivation is key to encouraging higher order thinking;
- Inquiry-based learning helps to encourage higher order thinking;
- The students enjoyed inquiry-based learning more than traditional didactic approaches.

A significant learning point for me was that inquiry-based learning requires rigorous preparation. A key factor in the success of the inquiry-based lessons was the time we
spent on the planning stage. I also needed to dedicate time to setting up and preparing materials for the lessons. The teacher’s role in an IBL environment is that of a guide or mentor to the students (Pathway 2011b, Colburn 2000). Scaffolding is essential for a successful inquiry-based learning environment (Sweller 1988, Kansalaar 2002, Kahn and O’Rourke 2005). I learned that IBL requires readiness to deal with uncertainty and unexpected circumstances. I found it useful to test out the classroom activities to try to pre-empt difficulties the students might encounter.

I learned that inquiry-based learning takes time. In order to take part in IBL, the students need to have the prior knowledge necessary (Bruner 1961, Kahn and O’Rourke 2005). In this study I spent several lessons teaching the students about data handling to enable the students to take on their inquiries. Furthermore, during the inquiry phase many of the activities I had planned took longer than anticipated, such as completing the CensusAtSchool questionnaires. I discovered that I needed to be more flexible in the time I dedicated to inquiry-based activities. However, it is important to note that I found the time I spent on IBL was very worthwhile, in terms of enhancing the students understanding of data handling.

One of the objectives of this research was to encourage higher order thinking among my students. I learned that motivation is key to encouraging higher order thinking (Biggs 1993 and McTighe and O’Connor 2005). In cycle one the students’ written work did not demonstrate higher order thinking. In cycle two I gave consideration to motivation and incentives in an effort to elicit a better standard of written work from the students. Firstly, I tried to motivate the students by offering prizes for the top projects and weighting the marks for their projects in favour of the written parts.
Secondly, I tried to ensure that the students were clear on what I expected from them, by preparing a sample project and setting clear criteria for their projects. I was very impressed with the standard of written work and the quality of the project work by the students in cycle two. I now recognize the correlation between motivation and higher order thinking.

A key motivating factor for my students was their enjoyment of taking part in IBL. My students enjoyed inquiry-based learning more than the teacher-dominated approaches. The feedback from the focus group illustrated this. Also the video footage showed that the students were engaged and self-directed in the IBL lessons. This enjoyment had a positive impact on their learning. Inquiry-based learning encouraged my students to apply deeper analysis to the data and exhibit higher order thinking in their work.

5.2 The Importance of My Values

Early in the research process I identified that I value higher order thinking, student engagement, self-directed learning, and students taking responsibility and accountability for their own work and positivity towards the learning of mathematics in my students. I realised that these values were being denied in my practice. I was concerned that when my students encountered a difficult problem that required a higher level of thinking they tended to give up. I felt that my students were learning mathematics in such a way that they could not appreciate the value of mathematics or take responsibility for their understanding of the subject and as a result they were not motivated to apply higher order thinking skills to the problems they were confronted
with. Inquiry-based learning changed the way that my students learn mathematics. There was clear evidence of higher order thinking in their project work. They were engaged, self-directed and took responsibility and accountability for their own work. The video evidence clearly shows that my students enjoyed IBL and demonstrated a positive attitude to the learning of mathematics in their activities.

During the research process I also came to acknowledge the core values that are implicit to my practice as a teacher. These core values are responsibility and accountability, inclusion and love. I gained a deeper understanding of my practice and I can now see that I am living more in the direction of these embodied values. In presenting my claims to knowledge to be validated I used my core values that emerged in the course of the enquiry as my living standards of judgement.

5.3  Final Thoughts

I have validated evidence to show that I have elicited higher order thinking from my students through the use of inquiry-based learning. In that sense, I could say that my research was successful. However, I feel that the real success was in the journey and not the destination. In carrying out the research I was compelled to look at myself and my practice as a teacher with honesty. I acknowledge the love and passion I hold for my job as a teacher, my subject and my students. I now have a much deeper understanding of my implicit values and how they influence and motivate my practice as a mathematics teacher. My own learning and that of my students has been transformed and this gives me enormous satisfaction.
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Appendices

Appendix A – CensusAtSchool Questionnaire

Phase 11 CensusAtSchool Questionnaire

About You

1. Please state the XY coordinates of your school, eg 716020, 734837.

2. Are you?
   - Female
   - Male

3. Please state your age in completed years and the month you were born.
   - Year
   - Month

4. a) Which hand do you write with?
   - Left
   - Right
   - Either

   b) When going up stairs which foot would you place on the first step?
   - Left
   - Right
   - Either

5. Which one of the following would you rather have?
   - Agility (Nimbleness)
   - Endurance (Stamina)
   - Speed
   - Skill
   - Strength

6. What is your:
   - Height: __________cm
   - Length of right foot: __________cm
   - Vertical reach: __________cm
   - Open arm span: __________cm
   - Open hand span of the hand you write with: __________cm

7. What is your resting pulse rate? __________ per minute

At School

8. a) What time did you go to bed last night?
   - __________

   b) Where did you keep your mobile phone last night when you were asleep?
   - Under your pillow
   - In your bedroom
   - In another room
   - Other (please state) __________

9. What time did you get out of bed this morning?
   - __________

10. a) On a school day do you eat breakfast?
    - Before I leave for school
    - On the way to school
    - At school
    - Yes
    - No

   b) Please state what you had for breakfast this morning.
    - Fruit
    - Cereal
    - Cooked breakfast
    - Toast
    - Sweets/chocolate
    - Cake
    - Other (please specify) __________

    - Portions

   b) Were you at school yesterday?
    - Yes
    - No

12. Will you compete in your school’s sports day?
    - Yes
    - No
    - My school does not have sports day

Sport and Exercise

13. a) How much sport or exercise did you do in school last week (or the last week you were at school)?
    - __________ hours

   b) How much sport or exercise did you do out of school last week (or the last week you were at school)?
    - __________ hours

14. What sporting activities have you taken part in during the last year? This can be a club activity.

15. a) Have you been involved in competitive sport in the last year?
    - In school
    - Out of school
    - Yes
    - No

16. Can you?
    - Swim 25m?
    - Ride a bike?
    - Yes
    - No

17. Name a famous Olympian and state the event he/she competed in.

18. Are you going to an event at the:
    - 2012 Olympics
    - 2012 Paralympics
    - Yes
    - No

19. a) What month in 2012 does the torch relay start?

   b) Will you go to see the Torch Relay?
    - Yes
    - No
    - I don’t know

20. In the last week approximately how much time did you spend, to the nearest hour, playing motion-controlled games? (Wii, Xbox, PS3)
    - __________ hours

21. How many gold, silver and bronze medals do you think Ireland will win at London 2012?
    - Gold: __________
    - Silver: __________
    - Bronze: __________

22. There is a reaction time game to complete.
Teacher Information for Using CensusAtSchool

In order to facilitate Irish students filling out the online questionnaire and receiving the class dataset, the teacher must follow these procedures:

1. The teacher has to register with CensusAtSchool using his or her teaching council number (the identity number given to each teacher on the official teacher register in Ireland). The teacher is then emailed a password and username.

2. The students use this password and username to fill out online surveys about themselves.

3. Class results are provided in spreadsheet form and can be easily downloaded. Each class dataset can be analysed separately or compared to a variety of other datasets. (different countries, years etc.)
Appendix B - PowerPoint Presentation on Planning a Survey

**Introduction**
- April is the wettest month
- Whenever I buy a lottery ticket my numbers never come up – I’m sure some numbers come up more than others
- First years watch more television than third year students.
- How can you decide that these statements are true?
- Can you convince someone else?

**The Project – the Data Handling Cycle**

**Part One – Pose a Question**
- “I will try to find out if girls’ hands are smaller than boys. I want to investigate if being tall means that you’ll have bigger hands”
- “I will try to find out what is the most popular football team in the school”
- “I will try to find out what is students’ favourite subject in the school?”
- “I will try to find out what is the most popular brand of car in the teacher’s car park”

**Types of data**
- Pose three questions to collect these types of data:

1. Discrete data
   - Number of pets, family size, marks in a test
2. Continuous data – to be done in groups
   - Height, weight, time, length
3. Categorical data
   - Colours, subjects, TV programmes, friends stars

**Plan**
- What data do you need?
- Who will you get it from?
- Questions can be researched using the internet
  - “I will need to find out the heights, hand spans and shoe size of people in my class. I might need to get more data from another class to get a bigger sample...”

**Collecting Data**
- How will you collect it?
  - “I will carry out my survey in the canteen area at lunchtime”
- How will you record it?
  - “I will record the results in a tally chart”

**Reliability**
- How will you make sure the data is reliable?
  - “I will double check the data I collect.”
- Why? Give reasons for the choices you made.
  - “We made everyone take their shoes off when we measured the height because...”
What sampling technique will you use to ensure that there is no bias and your sample represents the population?

**Groupwork – Continuous Data**
- You will plan a survey to carry out in the classroom tomorrow.
- Decide what continuous data you want to collect.
- What question do you want to investigate? Make it something interesting!
- Decide what you need to carry out your measurements.
- Design a tally chart to record your results.

**Measuring Implements Available**
- Timer
- Measuring tape
- Ruler
- Protractor
- Weighing scales
- Thermometer

**Individual Work – Planning your survey**
- Your homework tonight is to come up with two questions that you want to investigate.
- One question must involve discrete data.
- The other question must involve categorical data.
- Fill out the worksheet to plan your survey.
Appendix C – Group Work Worksheet

GROUPWORK

NAMES :

CONTINUOUS DATA

What do you want to find out?

Predict an answer to your question

What data do you need?

How will you collect the data?

Design a tally chart to record your data.
Appendix D – Individual Surveys Worksheet

MY STATISTICS PROJECT

NAME: ____________________

QUESTION 1 – DISCRETE DATA

What do you want to find out?

Predict an answer to your question

What data do you need?

What is the population of your survey?

What sampling technique will you use?

What question will you ask if you are designing a questionnaire and what options will you provide?

Design a tally chart to record your data.
QUESTION 2 – CATEGORICAL DATA

What do you want to find out?

Predict an answer to your question

What data do you need?

What is the population of your survey?

What sampling technique will you use?

What question will you ask if you are designing a questionnaire and what options will you provide?

Design a tally chart to record your data.
Appendix E – My journal entry on planning the inquiries - Cycle One 27th

March 2012

What I Did

The aim of today’s class was to teach the students about planning a survey. I also planned to facilitate the students working in groups to pose questions that would require the collection of continuous data. Their homework was then to try to pose their own questions that they will investigate individually. In preparation for carrying out these surveys the students have learned about data collection in previous lessons.

I prepared a powerpoint presentation to teach the students about data handling with specific emphasis on the planning stage of data handling. I delivered this presentation and I tried to engage the students by questioning them throughout.

I then split the class into groups and handed out a worksheet that required each group to answer questions about what they want to investigate and what information they need to collect in order to carry out this investigation. They will carry out the data collection phase tomorrow.

At the end of the lesson each group shared the questions they wanted to pose with the rest of the class. Their homework was to plan their own individual surveys and to plan what data they need to collect and how they would collect that data.
What I Learned

I was trying to scaffold the learning for my students as they are new to inquiry-based learning. This is because I felt I needed to prepare my students for carrying out the assignment. However, this meant that when I looked at the recording of the lesson I discovered that I did most of the talking.

Unfortunately I accidentally turned the video off when I moved the camera to get a better shot of the students working at the beginning of the group-work part of the lesson. I realised this towards the end of the lesson. So I missed the 10 minutes of the lesson when the students were engaged in inquiry. I find this very frustrating since this was the part of the lesson I was most interested in analysing on the recording.

I feel that the students enjoyed the lesson. I asked one student on the way out of the class what he thought of the lesson and he said it was fun to do something in real-life in Maths. When I looked at the video the students all seem to be engaged and were actively involved in the lesson, even at the teacher-dominated stage of the lesson, which represents most of the recording since I accidentally didn’t record most of the group work.

When watching the video recording I noticed that I project my voice a lot in class. My voice is a lot louder than the students voices. Also I have a tendency to repeat what students say which I wasn’t aware of. It seems to be a good technique for allowing the students to hear each other’s answers and questions. However, it means that I am
doing most of the talking in the lesson, which goes against the principles of inquiry-based learning.

I feel that there were some signs of higher order thinking in the group work activity. Some of the questions posed by the groups were creative and original such as questioning how long it would take students to write their name backwards and how far students can blow a malteaser with a straw. However the group worksheets that they were required to fill out do not reveal much analytical thinking and evaluation. Most of the questions were answered with one-line responses. I hope that tomorrow’s lesson will encourage the students to think at a higher-level. They will be critiquing each other’s questions and carrying out the data collection phase of their group-work survey.
Appendix F – Completed Group Work Worksheets

Group 1
What do you want to find out?
How long it takes to write your name
Predict an answer to your question
5 seconds
What data do you need?

How will you collect the data?
timer

Group 2
What do you want to find out?
The weight of an average 1st year school bag
Predict an answer to your question
5 kilos
What data do you need?
To weigh all the school bags in the class
How will you collect the data?
Using a weighing scales

Group 3
What do you want to find out?
How tall are boys in the class
Predict an answer to your question
1 meter 60 cm

What data do you need?
Measuring tape

How will you collect the data?
Tell the students to take off their shoes

Group 4

What do you want to find out?
How long does it take to write your name backwards

Predict an answer to your question
8 – 9 seconds

What data do you need?
How long does it take?

How will you collect the data?
Stopwatch
Piece of paper

Group 5

What do you want to find out?
The length of your piggy finger

Predict an answer to your question
5 cm

What data do you need?
The distance
How will you collect the data?
We will measure the distance of their piggy finger with a ruler

Group 6
What do you want to find out?
How long it takes for someone to pack away all their maths equipment

Predict an answer to your question
Around 14 seconds

What data do you need?
Everyone in the classroom and maths equipment and a timer

How will you collect the data?
We will use a timer
Appendix G – My journal entry on my efforts to make my lessons more student-centred - Cycle One 28\textsuperscript{th} March 2012

What I Did

There were two aims for today’s lesson:

1. To allow the students to critique each other’s questions
2. To ask the students to carry out their group work surveys to collect continuous data

In reality, we only managed to cover the first aim because it took so long to critique all the student’s research questions. My own personal aim was to talk less and to allow the students to do all of the critiquing. However, the bell rang before we got to every student so I critiqued the questions for the last four students.

What I Learned

I don’t think the lesson went particularly well. We didn’t have time to allow for any enquiry-based learning. Also the students didn’t seem to enjoy the lesson. They didn’t seem to be engaged in the activity.

I think the camera made the students feel self-conscious. I was directing the camera at the students today because I planned that they would do most of the talking. However, they didn’t seem to be comfortable with a camera aimed at them and students were slow to put up their hands to offer advice. This is unusual for this class, who are normally very responsive. As the class wore on the students did seem to forget about
the camera and were more responsive. However, some students didn’t offer any
critique and seemed bored and uninterested in the lesson. To bring these students back
into the activity, I began asking them for input.

It was a very slow-moving lesson. I feel that I could have structured it better. I went
around the classroom student by student asking them to call out their research
questions. It seems that a lot of students didn’t listen to each other so I found myself
repeating the question in order to draw out a critique. This slowed down the whole
process.

I didn’t anticipate that there would be so many problems with their research
questions. I hoped that the students would learn from the group activity and would
have little difficulty coming up with questions. However, they ran into several
difficulties. Firstly, some students didn’t seem to know the difference between
categorical and discrete data, even though we’ve been through it in several lessons,
including in yesterday’s lesson. Secondly, some of the questions would be impossible
to research such as “how big is your hair?” or “how long does it take to change a light
bulb?” or “ how many clouds are in the sky between 8.15 and 3.15” because they
were ambiguous and it would be impossible to measure.

Overall the quality of research questions that the students came up with was poor and
there was very little evidence of higher order thinking. Also they seemed to have
difficulty in finding the flaws in each other’s questions.
The one positive I can draw from today’s lesson is that I can dedicate the whole of tomorrow’s lesson to the student’s investigations because the students still have to complete their group work assignments. I am considering leaving the individual assignments at the planning stage. I will look over the re-worded questions tomorrow and make my decision. I think it would be useful to try using CensusAtSchool in another cycle because there is set data to draw their questions from so it might help the students come up with more reasonable questions.

I still have to work on playing a less active role in the class and allow my students to do all the talking. When I looked at the recording I noticed that I had to stop myself from prompting the students or giving the students too much direction.

Hopefully tomorrow’s lesson will allow the students to play a more central role in the learning.
Appendix H – Sample Questions Students Posed from Cycle One

Discrete Data Questions:

(Data that can be counted such as the number of pets per household)

How many people purchase Nike wear as their main clothing company?
How many cars pass on Monday by my school in the morning?
How many Internet sources do you have in your house?
How long it takes to get up the school stair from the bottom to the top floor?
Average age of people in 3rd year.
How many clouds in the sky between 8.25 and 3.15
How hot is the sun?

Categorical Data Questions

(Data that is represented by words such as colours or car brands)

1st years favourite subject.
Colours of cards that passed your house.
How big is your hair?
How many different colour types of buildings are there in Balbriggan?
How many teachers have red cars?
Colours of people eyes in your class.
What type of movies people like.
Who is your favourite celebrity.
Appendix I – My journal entry on my observations of the students orchestrating their inquiries - Cycle One 29th March 2012

What I Did

The objective of today’s lesson was to allow the students to carry out data collection for investigating their group questions. I helped the students when they needed it and tried to act as a guide and an observer. I allowed the students to negotiate between themselves and had little or no involvement in the activities of the class.

All the members of the group had to have a record of the data collected. At the end of the class I set the students a homework assignment. For their homework the students had to look at the data and draw conclusions. They have to say what the data shows them and if their predictions were accurate.

What I Learned

The only way I could describe today’s class was organised chaos, or unorganised chaos at times. However overall I was happy with the lesson and I was happy that I achieved my aim of making the lesson more student-centred.

It was a very noisy class which I was very conscious of but I let the students make as much noise as they wanted in negotiating with their groups and their survey participants. Because I am accustomed to very organised, teacher-dominated classrooms (it was my only experience of classrooms in school) it is a challenge for me to hand over all the control to my students.
When I look at the recording I realised that at times the students were quite aggressive with each other and at one stage I had to instruct one student to stop pushing another student. My experiences today showed me that inquiry-based learning definitely challenges your classroom management skills. For the most part, the students worked well in their teams and showed teamwork skills.

I think part of the reason why today’s class worked so well is because we spent a whole lesson on the planning stage. So the students knew exactly what they were doing and how they were going to carry it out. This helped to structure the inquiry for the students.

I think the students really enjoyed today’s lesson. At one stage Jack said to me “Ours is really fun, Miss” referring to their survey (can be seen on the recording). When I look at the recording all of the students are engaged, active, interested and in some cases a little over-excited.

In terms of higher order thinking, I saw a lot of evidence of the students thinking on their feet. The students were making judgements about what to do through negotiation with their groups. Also they were generating data for their own experiments, which they created. Both of these activities fit into the higher level of Anderson and Krathwohl’s amended version of Blooms taxonomy of thinking skills, specifically evaluating and creating.

I feel that there were many examples of higher order thinking in the students’ activities today. One group who were measuring height asked students to take off
their shoes before they measured them to get more accurate data. Another group set up their experiment in an intelligent way. They wanted to see how long it took students to pack away their books and equipment into their bags. They had the desk set up as it would be at the end of a lesson, with the Maths book open, pencil case open, copy open etc. They were modelling the real-life situation. Also the teams organised themselves in terms of collecting and recording the data with little or no help from me.

In tomorrow’s lesson we will discuss the conclusions drawn by the students from the data.
Appendix J – My journal entry on student interest in data concerning themselves

- Cycle One 30th March 2012

What I Did

The purpose of today’s lesson was to discuss how the investigations went in yesterday’s lesson. I talked to each group in the class and asked them for feedback. I recorded the students on video as the spoke about the data they collected and they explained their conclusions. I had no idea how long this activity would take so I had also planned a group-work quiz for the end of class, but we never got to it.

What I Learned

I found the students to be very forthcoming with their thoughts about the data. They all seemed very interested in the results. The problem I had in previous lessons with the students not listening to each other did not arise today. I feel that because they were participants in each other’s investigations they were genuinely interested in the results. We had quite the lively discussion.

A lot of students noted the biggest and smallest numbers and referred back to their predictions. They all seemed to comment on surprising data. One group were timing how long it takes students to pack away their bag and they found it surprising that the student who is normally fastest out of the class was the slowest at packing up. Some students carried out deeper analysis of the data and gave reasons for the results. One group were measuring the weight of students’ bags and they found that the students that carried all their books for the day had heavier bags. One group found that students who wrote in joined writing wrote faster than those who didn’t. I believe that
because they were working with real data that concerned themselves, the students were more interested and thus were able to draw insightful conclusions and apply more higher level thinking to the analysis of the data.

John argued that some of the experiments could be improved because they didn’t properly model what happens in real life. In fact, all the students had opinions about how to improve the investigations. They seemed to understand the importance of collect valid and unbiased data.

In terms of carrying out the investigations, the students did seem to understand the importance of setting clear guidelines and being rigorous. The group weighing bags found that when they got slightly different values for the same bag each time they weighed it so they took the middle value. I have not discussed averages or means with the students yet so this was impressive to me.

All the groups seemed to collect lots of data, apart from one group. I feel that this is because they weren’t interested in the data. It was not their own question that they were investigating. This group was measuring height but it was not their original plan. They wanted to find out how far a student could blow a malteaser with a straw. However, one student brought in straws but nobody brought in the malteasers so they couldn’t carry out the experiment. I told them to measure students’ heights. In hindsight, I should have brought the supplies in for them. In my experience first year students are very forgetful and if you ask them to bring anything additional into class about half of them forget. I think this is because they are only getting used to the routine of secondary school, where they have their own locker and timetable and
many different teachers and subjects. They are expected to be more organised and independent than they were in primary school and I find it takes some students a while to adjust.

Although this group collected little data (they only measured three students) one student in that group showed some higher-level thinking in carrying out the experiment. He wouldn’t allow his group to measure the tallest student in the class because his dataset was so small and he realised that it would skew the data. This is what we call an outlier in Maths and it is not something that we have covered. I was very impressed that the students were using statistical procedures in collecting and analysing their data, although I haven’t mentioned any statistical operations in my lessons.

Overall, I think there was much evidence of higher-level thinking in today’s discussion. However, I am interested to see if they can apply the same thinking to their own individual investigations.
Appendix K – Focus Group Meeting Reflections – 30th March 2012

I have a few of the students from my research population for a Resource class, Brendan, Jamie and Amy, and I asked three of them if I could discuss how they found the lessons where we tried out inquiry-based learning. The feedback was very positive. Jamie said it was ‘deadly’.

They all agreed that they preferred inquiry-based learning to using the book because they got to move and actually try it out. Jamie and Amy said that they are kinesthetic learners so that’s how they should learn. They said that when they do it themselves they actually get it. “We understand.” “We want to do it well.”

I asked them what they learned and they said that they learned how to carry out a survey properly and how to come up with good questions to investigate.

I asked if there would be anything they would do differently and Jamie said that they would like to carry out an investigation outside – like timing students running a 100 meters. Brendan and Amy agreed. I think this would be challenging for me in terms of supervising the students.

Interestingly, the students did not feel that a pure inquiry approach was a good idea and they wanted me to teach them the skills first before they start their inquiries. So, it seems that the students want to mix inquiry and traditional approaches. Also, they wanted clear instructions about what I wanted them to do. This is a very structured
inquiry approach, which I feel is most suited to these students who are new to inquiry-based learning. My reading of the literature informed this belief.
Appendix L – My journal entry on the difficulties in filling out the
CensusAtSchool questionnaire – Cycle Two 26th April 2012

What I Did

The plan for today’s lesson was to fill out the hard copy of the CensusAtSchool
questionnaire so that it would speed up the process of filling it in online. This required
gathering a wide variety of data from the school’s xy map coordinates to pulse rate to
height. In preparation for this lesson I borrowed a timer from the science teacher and I
brought in some longer rulers for measuring foot length and hand span. I also looked
up the schools xy coordinates online from http://www.gridreference.ie/ and I found a
page that defined one portion of fruit or vegetable for a variety of different fruits and
vegetables.
(http://www.ethsa.co.uk/food%20five%20a%20day%20english%2008.pdf)

I have one measuring tape in my classroom and I asked a science teacher for more but
unfortunately he said he did not have any.

In my meeting with a small group of fellow MSc students and my supervisor, Dr.
Margaret Farren on Monday 23rd April a fellow student suggested that I structure the
seating in my classroom in groups to aid student learning and collaboration. I decided
to try this out so I rearranged the tables and chairs so that the students were seating
facing each other in groups of four.

I used the projector to put up the school’s xy map coordinates and the fruit and
vegetable portions. I helped the students to find their pulses, for some students I had
to find their pulse for them, which was time consuming. Then I timed them for a
minute measuring their pulses. Some students lost their pulses so I had to repeat. In
the interest of saving time, the second time I timed them for only 30 seconds and told
the students to double their results. I instructed the students to continue with the
questionnaires while I helped each group to measure their height and arm span. I
demonstrated how to do it and then supervised each group as they carried out the
measurements. By the time the bell went, I had only got through two groups. A
further delay to the lesson was interruption by the principal at the start of the lesson
for five minutes when he came in to speak to the class. I instructed the students to fill
out the questionnaire for homework.

What I Learned
I found today’s lesson quite stressful for several reasons. First of all I found that time
was against me. There were so many measurements to carry out for the survey that it
was not possible to complete them within the class time. Also because I only had one
measuring tape, it was virtually impossible, in hindsight, to measure every student’s
height and arm span.

I found that having the students sitting facing each other did not work well for this
lesson. While I was working with the individual groups carrying out the
measurements, the other groups were talking and unsettled. I had to constantly remind
the students to stay on task. I find it best to remain calm in situations where the class
are unsettled because from experience I find that becoming agitated only ignites the
situation and unsettles the class further. If I act like I’m still in control, I believe that
the students will still respect me and honour my authority as a teacher in the
classroom.
The questionnaire itself was quite complicated. There were so many measurements to carry out for the questionnaire (height, foot size, hand span, arm span, vertical reach and pulse) that it was not possible to complete them within one class period. When I used CensusAtSchool with another class last year I found the survey was much easier to complete. The previous year’s questionnaire, phase 10, did not require half as many measurements and the questions did not seem to cause as much confusion.

Another issue I found with the questionnaire is that the Irish CensusAtSchool site use the same survey as the UK CensusAtSchool so many of the questions are more appropriate to British students than Irish students. Many of the questions were focused on the Olympics as England is hosting the upcoming Olympics. Most of my students couldn’t name an Olympic athlete and they didn’t know what an Olympic torch was.

Although I felt I had prepared well for this lesson and I had tried to plan for issues with different questions I think that the lesson was quite disorganised and the students were not clear as to what they were supposed to be doing. When I looked at the recording of the lesson I noticed that the students were inclined to mess and talk to each other unless I gave them specific instructions of a task to complete. The students showed very little evidence of self-directed learning today and very little initiative.

Filling out the survey proved to be quite a labourious task, for me at least. The class were engaged at different points in the lesson. It is hard to say if the rearranged
seating or lack of interest in the questionnaire itself caused the students to become disengaged in the lesson.

For tomorrow’s lesson I plan to complete all the measurements. I will try and find some more measuring tapes in the school.
Appendix M – My journal entry on classroom management issues in IBL - Cycle Two 27th April 2012

What I Did

The plan for the lesson was to complete the measurements for the questionnaire (height, arm span and vertical reach) and to start to fill in the online survey. I knew from trying out the questionnaire myself at home that every question needs to be filled in for the online survey. I found out that the PE teacher had several measuring tapes and the woodwork teacher had some too. I managed to accumulate eight measuring tapes and I gave one to each group. Each group worked together to record each of the measurements required for each student in their group. They worked independently with little help from me.

Once the measurements were acquired I brought the students to the computer room. The Internet wasn’t working when we first arrived so it took me a couple of minutes to fix it. I used the interactive whiteboard to show the students how to access the questionnaire online. I circulated the classroom to ensure that students knew what they were doing. The bell went before the students had completed the online questionnaire. For homework I instructed the students to come up with a question that they want to investigate based on the CensusAtSchool questionnaire.

What I Learned

I realised that having more measuring tapes for the previous lesson would have made a big difference. All the students managed to complete the measurements in about
fifteen minutes and they had little difficulty in carrying them out properly. I supervised the activity but I found the students didn’t need as much direction as they did in yesterday’s lesson. The students showed initiative and were self-directed. Without any instruction from me the students stood on chairs to measure each other’s vertical reach. They were well organised and focused on the task.

When we moved to the computer room it took a few minutes to get the Internet working and to make sure that every student could log on. This caused the class to become chatty and unsettled. On the video recording I saw Ethan throw a balled up piece of paper at John. Normally my lessons are very structured and the students always know what they are supposed to be doing. In the computer room there were several moments where the students didn’t know what they were supposed to be doing and they naturally fall into messing and chatting with each other. These last two lessons have made me question my classroom management skills. I try to foster a positive environment in my Maths lessons and I rarely raise my voice. I believe that busy students will not have the opportunity to become disruptive. In the last two lessons there are periods of inactivity which caused the students to become restless. I will try and anticipate this inactivity and ensure that the students are kept on task and that they are not given the opportunity to become unsettled. Personally, I found the data collection and filling in the questionnaires online quite tedious and I wonder if the students felt the same. If they did this could also explain their unsettled behaviour. One other factor that may have affected how the lessons went was my own energy levels. Today’s lesson was last class on a Friday afternoon and it had been a particularly long week. Maybe if I was feeling fresher I would have been more on the ball in terms of my classroom management.
In Monday’s lesson I plan to get the students to complete the online questionnaire and to have a look at the questions posed by the students for their homework. In order to motivate my students to do their best with these data-handling projects, I think that it is important to offer a small reward for the best projects. I will have to print off the data for each student so that they can carry out their projects. For their homework on Monday, I will ask the students to identify the different types of data being collected for each question on the questionnaire. I aim to start the projects on Tuesday.
Appendix N – My journal entry on the importance of preparation in IBL - Cycle Two 1\textsuperscript{st} May 2012

\textbf{What I Did}

The aim of today’s lesson was to allow the students to make a start on their individual projects or investigations based on the completed CensusAtSchool questionnaires. I planned to go through the project instructions with the students at the start of the lesson and then allow the students to work independently on their projects for the remainder of the lesson and give guidance where it was needed.

Before the class began I spent some time organising the desks so that the students could sit in groups of four. I put scissors, glue and a set of coloured markers on the desks for each group to share.

When the students were seated in their groups I asked the students to look up at the board and I ran through the project. I offered a prize for the best projects as a motivation for the students to try their best. In order to give the students an idea of what I expected of them I showed the students a sample project that I made myself last night. Then I set the students to work on their own projects.

I handed out a class dataset to each student. I explained how to read the data using the CensusAtSchool questionnaire and I gave a copy of the CensusAtSchool questionnaire to each group. I handed out graph paper and blank paper. Then I gave each student some coloured card on which to do their projects. I allowed the students
to choose red or blue. Then I handed out instructions to each student outlining what they were required to do for their projects.

I circulated the class and gave help to students who asked for it and I gave advice to students where I felt they needed it. The class ended before we had a chance to finish so I decided to give the students one more lesson to work on their projects. The students pointed out that I had them again first class tomorrow so they could leave everything as it was and pick it up tomorrow.

For the homework, I instructed the students to draw the tables and charts required for their projects. My hope is that in doing that, it will mean that the students will finish their projects tomorrow.

**What I Learned**

Time was against me again today. I had no idea how long it would take the students to complete their projects but I provisionally assigned one lesson and I hoped that the students would present their projects tomorrow. In reality the students only managed to get started when the bell went. This is because it took so long to set up and explain everything that was to be done. Luckily the students got to leave everything as it was so this will save some time in setting up tomorrow’s lesson.

The students were very interested in the results of the questionnaire. I could hear the students discussing the data on the video recording. The students seemed surprised at how big the class dataset was.
There was some confusion at the start of the lesson. At the start the students weren’t clear on what I wanted them to do. Today I made sure that I was well prepared. I realise now that it takes a lot of preparation to run a class like this. I tried to pre-empt any difficulties that the students might run into. I had the sample project up on the projector to give the students an idea of what to do. After I went through the project using the projector I handed out instructions to each students and I had spare CensusAtSchool questionnaires so that the students could read the class dataset. Once the instructions were handed out the confusion seemed to dissipate.

Although I thought that working in grouped seating didn’t work well in the lesson on the 26th April I thought it worked very well for today’s lesson. I felt that the students were self-directed and they negotiated with each other and shared the equipment. Overall, I believe that the class were focused on the task.

I let the students choose their groups. This might not have been such a good idea. Although most of the groups seemed to work well, when I looked back at the recording I noticed that three of the students who have regular difficulties with maths had ended up together. They took longer to get started than the other students. I think it would have been a better idea for me to assign groups but again, this would have taken time, which I consider very precious in these lessons.

The students seemed to enjoy the task and several students stayed back after the bell had gone to continue with their projects. In fact, when I looked at the recording I was astonished to see that when the bell went nobody moved, even though it was the last class of the day. They seemed to be in no rush to leave, which is not the norm.
Appendix O – Powerpoint on Project Guidelines

Statistics Project - CensusAtSchool

The Project – the Data Handling Cycle

Part One – Pose a Question

- "I will try to find out if girls’ hands are smaller than boys."
- "I want to investigate if being tall means that you’ll have bigger hands."
- "I will try to find out when students eat their breakfast and what students eat for breakfast."
- "I will try to find out how many portions of fruit and veg students in my class eat."

Types of data

- What type of data will you collect?
- Discrete data
  Number of pets, family size, marks in a test
- Continuous data – to be done in groups
  Height, weight, time, length
- Categorical data
  Colours, subjects, TV programmes, Friends stars

Reliability

- How will you make sure the data is reliable?
- "I will double check the data to make sure that there is no unusual or impossible data."

Analyse the Data

- Create a Table
- Make sure your table is neat and accurate

| Score | Table | Program
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<td>10</td>
<td>1</td>
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</table>

Analyse the Data

- Create an appropriate chart or plot:
  - Line plot
  - Bar chart
  - Stem and leaf plot
- Make sure you label your chart or plot correctly
- Charts and plots must be neat and accurate

Interpret the Results

- Draw a conclusion based on the data:
  - Was the data as predicted?
  - Were there any surprising data?
  - What does the data show?
Appendix P – Sample project I prepared to show the students the standard of work I expected from them

**Type of Data:** Continuous

**How Much Exercise Did I Do Last Week?**

**In School**

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<th>3</th>
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<td>2</td>
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**Out of School**

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<th>2</th>
<th>3</th>
<th>4</th>
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</thead>
<tbody>
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<td>4</td>
<td>2</td>
<td>2</td>
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**Conclusion**

From the Charts we can see that the students in 3L spend more time exercising in school than they do at home. Most students spend between 0-2 hours exercising in school. Every student in the class does PE so that could be one reason. Students who do 3 or more hours of exercise in school are probably part of a team like the football team or the soccer team.

Most students don’t seem to exercise at home. 16 of the 25 students surveyed do no exercise outside of school. One reason for this could be that we get a lot of homework and many students like to spend their time watching TV or playing Wii, PlayStation or Xbox. I think students should try to exercise more because obesity is a growing problem in Ireland and doing exercise helps to burn calories.
Appendix Q – Project Instructions

DATA HANDLING PROJECT – CensusAtSchool

Representing Data

• **Pose a question** based on the data collected in the CensusAtSchool questionnaire

• **Predict an answer** to your question

• What **type of data** are you looking at – continuous, discrete or categorical?

• Draw a **table** to record your results

• Draw an appropriate **chart or plot** to record your results – stem and leaf plot, bar chart, line plot

• Draw a conclusion based on the data:
  - Was the data as predicted?
  - Were there any surprising data?
  - What does the data show?