The Effects of Calculator Usage on Post-Primary Mathematics Students at Junior Cycle Level

A Case Study Approach

Sabrina Marie O’Donnell

Master of Arts in Digital Media Development for Education

University of Limerick

Supervisor: Joe Collins
Declaration

“I hereby declare that this is entirely my own work and that it has not been submitted for the award of any degree at any other university”.

__________________
Sabrina O’Donnell

Student ID: 9951512
The Effects of Calculator Usage on Post-Primary Mathematics Students at Junior Cycle Level

A Case Study Approach

Abstract

The main purpose of this research paper was to explore the effects of calculator usage on post-primary mathematics students at junior cycle level. This research paper examines the effect of calculator usage on students’ mathematical performance and how student attitudes toward mathematics are influenced by calculator usage (“this Study”). Thirty-two junior cycle mathematics students and one post-primary school mathematics teacher, all residing in the County Donegal area, participated in this Study. The student participants and the post-primary mathematics teacher involved in this Study were selected through purposive sampling. The student participants were comprised of two mathematical ability levels with 12 students at higher level and 20 students at ordinary level. In this Study, all students were examined on three different tests, namely, (a) a pre-test without calculator access (b) a post-test with the optional use of the calculator and (c) a Likert questionnaire about students’ attitudes towards calculator usage and mathematics. This Study also examined a mathematics teacher’s perception towards calculator usage in mathematics. The results on students’ mathematical performance levels and attitudes towards calculator usage and the mathematics discipline are presented herein. The test for significance was set at .01 alpha level and Cohen’s d was the measure used to generate the effect sizes. Statistical analysis of the test results show that when students had access to a calculator their overall performance level improved significantly (large effect). The analysis of students’ attitudes toward the mathematics discipline was generally very positive. The overall analysis of students’ attitudes toward calculator usage in mathematics was very positive. The analysis of a teacher’s attitude towards calculator usage was very positive.
Acknowledgements

I would like to thank my supervisor Mr Joe Collins for his continuous support and encouragement during this study. At many stages during the course of this study I benefited from his advice. His positive outlook and confidence in my research inspired me and gave me confidence. His careful editing contributed enormously to the production of this study.

I would also like to thank Stephen Prendiville, the second reader of this study, who tirelessly read the various drafts and for all of his valuable suggestions. I could not have done this without you!

I would also like to thank my family for their endless encouragement and support. Most of all, I would like to thank my partner Paul Campbell, who has provided emotional and domestic support during the course of this study.
# Table of Contents

**Chapter One - Introduction**

1. Introduction .................................................................................................................. 1  
   1.1 Statement of the Problem ......................................................................................... 2  
   1.2 Goal of the Study .................................................................................................... 4  
   1.3 Significance of the Study ....................................................................................... 4  
   1.4 Methodology ........................................................................................................... 5  
   1.5 Limitations of the Study ......................................................................................... 5  
   1.6 Layout of the Study ................................................................................................ 6  

**Chapter Two - Literature Review**

2. Literature Review ........................................................................................................... 8  
   2.1 The Importance of Mathematics in Irish Society ..................................................... 8  
   2.2 Theories of and approaches to Mathematics Teaching & Learning ................. 10  
      2.2.1 Behaviourism .................................................................................................... 10  
      2.2.2 Constructivism ................................................................................................ 11  
   2.3 Mathematics Anxiety .............................................................................................. 12  
   2.4 Calculator Usage ..................................................................................................... 16  
   2.5 Calculators in the Irish Mathematics Curriculum .............................................. 20  
      2.5.1 Negative Effects of Calculator Use ................................................................. 23  
      2.5.2 Positive Effects of Calculator Use ................................................................. 26  
   2.6 Conclusion ............................................................................................................... 29  

**Chapter Three - Methodology**

3. Methodology ................................................................................................................ 30  
   3.1 Research Method ..................................................................................................... 30  
      3.1.1 The Action Research Strategy ....................................................................... 30  
      3.1.2 The Case Study Strategy ............................................................................... 31
Chapter Four - The Findings

4 The Findings .............................................................................................................. 43

4.1 Does an issue of mathematics phobia/anxiety exist in Irish post-primary school? .................................................................................................................. 43

4.2 How are students’ attitudes towards mathematics affected by the use of
the calculator? .............................................................................................................. 46

4.2.1 Anxiety towards calculator use in mathematics ........................................ 46

4.2.2 Negative thoughts towards calculator use in mathematics .................... 48

4.2.3 Enjoyment of calculator use in mathematics ............................................ 49

4.3 Is there a significant difference between students’ pre-test score and post-
test score? ................................................................................................................. 51

4.3.1 Overall student performance ..................................................................... 51

4.3.2 Performance by students according to ability level ................................ 52

4.3.3 Performance by students according to mathematics content area .......... 54
4.3.4 Calculator usage................................................................. 57
4.4 Teachers’ attitudes towards the use of the calculator ................ 57
  4.4.1 Positive effects.................................................................... 59
  4.4.2 Negative effects ................................................................. 59
4.5 Summary of major findings..................................................... 61

Chapter Five - Discussion
5  Discussion................................................................................... 63
  5.1 Does an issue of mathematics phobia exist in Irish post-primary schools? ................................................................. 63
  5.2 How are students’ attitudes towards mathematics affected by the use of the calculator? ....................................................... 64
    5.2.1 Anxiety towards calculator use in mathematics .................... 64
    5.2.2 Negative thoughts towards calculator use in mathematics .......... 65
    5.2.3 Enjoyment of calculator use in mathematics .......................... 66
  5.3 Is there a significant difference between students’ pre-test score and post-test score? ................................................................. 67
    5.3.1 Overall student performance .............................................. 67
    5.3.2 Performance by students according to ability level ............... 68
    5.3.3 Performance by students according to mathematics content area .. 69
    5.3.4 Calculator usage................................................................. 69
  5.4 What are teachers’ attitudes towards the use of the calculator in post-primary schools? ................................................................. 70

Chapter Six - Summary, Conclusions and Recommendations
6  Summary, Conclusions and Recommendations ............................. 75
  6.1 Summary................................................................................. 75
  6.2 Is there evidence of the existence of math phobia in Irish post-primary schools? ................................................................. 76
    6.2.1 Recommendations.............................................................. 76
6.3 Are students’ attitudes towards mathematics affected by the use of the calculator and if so, how? ................................................................. 77
   6.3.1 Recommendations .................................................................. 77

6.4 Is there a significant difference between students’ pre-test score and post-test score? ................................................................. 78
   6.4.1 Recommendations .................................................................. 78

6.5 What are teachers’ attitudes towards the use of the calculator in post-primary schools? ................................................................. 79
   6.5.1 Recommendations .................................................................. 80

6.6 Conclusion ..................................................................................... 81

6.7 Limitations and Recommendations for Future Research ............. 81

Bibliography

Bibliography ..................................................................................... 84
List of Appendices

Appendix A       Questionnaire administered to student participants
Appendix B       Pre-test administered to student participants
Appendix C       Post-test administered to student participants
Appendix D       Interview questions
Appendix E       Transcribed interview
Appendix F       Consent Form
Appendix G       Recorded Student Performance by content area
Appendix H       Student Performance Charts
Appendix I       Student Attitude Charts
## List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DES</td>
<td>Department of Education and Science</td>
</tr>
<tr>
<td>DETE</td>
<td>Department of Enterprise, Trade and Employment</td>
</tr>
<tr>
<td>EGFSN</td>
<td>Expert Group on Future Skills Needs</td>
</tr>
<tr>
<td>HLM</td>
<td>Hierarchical Linear Modelling</td>
</tr>
<tr>
<td>IBEC</td>
<td>Irish Business and Employers Confederation</td>
</tr>
<tr>
<td>IAEP</td>
<td>International Assessment of Educational Progress</td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communications Technology</td>
</tr>
<tr>
<td>IUA</td>
<td>Irish Universities Association</td>
</tr>
<tr>
<td>NCCA</td>
<td>National Council for Curriculum and Assessment</td>
</tr>
<tr>
<td>NCTM</td>
<td>National Council of Teachers of Mathematics</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>PISA</td>
<td>Programme for International Student Assessment</td>
</tr>
<tr>
<td>PSCM</td>
<td>Primary School Mathematics Curriculum</td>
</tr>
<tr>
<td>RIA</td>
<td>Royal Irish Academy</td>
</tr>
<tr>
<td>STI</td>
<td>Science, Technology and Innovation</td>
</tr>
<tr>
<td>TIMSS</td>
<td>Third International Mathematics and Science Study</td>
</tr>
</tbody>
</table>
List of Figures

Figure 3.1 The test administration procedure .................................................................40

List of Tables

Table 3.1 Quantifications used in the Likert questionnaire .................................................35
Table 3.2 Marking Scheme for Pre-test/Post-test ...............................................................38
Table 4.1 Frequency table of student attitudes towards the mathematics discipline ......44
Table 4.2 Frequency table of students responses to anxiety towards calculator usage...47
Table 4.3 Frequency table of negative thoughts towards the use of the calculator ........48
Table 4.4 Frequency table of students’ enjoyment of calculator use...............................50
Table 4.5 Overall student performance (pre-test vs post-test) .........................................52
Table 4.6 Student performance (pre-test vs. post-test) by ability level .........................53
Table 4.7 Student performance (pre-test vs. post-test) by content area .........................55
Table 4.8 Student performance (pre-test vs. post-test) by content area & ability level..56
Chapter One

1 Introduction

In 1986, the calculator made its first official appearance in the Irish mathematics classroom. Since then, the calculator has become a prevalent educational technology in the teaching of mathematics across Ireland and has evolved from a simple four-function calculator to a very complex, programmable, scientific machine. Kaput (1992) captured the role of educational technologies in the study of mathematics with his analogy:

*Anyone who presumes to describe the roles of technology in mathematics education faces challenges akin to describing a newly active volcano – the mathematical mountain is changing before our eyes, with myriad forces operating on it and within it simultaneously.*

(Kaput 1992, p.515)

The calculator is an educational technology that has been a catalyst for lively debate among mathematicians and mathematics educators. No consensus exists among these on the educational merits of using calculators in the teaching and learning of mathematics.

Advocates for calculator use within the mathematics classroom see its potential as a valuable educational technology that reduces the time spent by students learning and performing tedious paper-and-pencil manipulations, allowing them to spend more time developing mathematical understanding, reasoning and number sense. The calculator can be viewed as an equaliser in mathematics education, allowing those students who lack confidence in their mathematical ability or frustrated by the tedious manipulations experience some measure of success.

Critics of calculator use fear that the calculator will serve as a crutch for many students. Students become over-reliant on the calculator to the point of being unable to do simple computations without the aid of the calculator.
This Study investigates if effective calculator use could lead to improved performance in mathematics. One of the reported benefits of calculator use is that it creates a more interesting and enjoyable mathematics experience for the student. This Study also reviews the research results for evidence to support this claim.

1.1 Statement of the Problem

Mathematical proficiency is essential for living and working in today’s modern society. The Director of Irish Pharmaceutical and Chemical Manufacturers’ Federation ("IPCMF"), (a sector within the Irish Business and Employers’ Confederation ("IBEC")) Matt Moran warned that “virtually no quality career will be available in high-tech sectors without a high knowledge of maths” (Independent, 2007).

Unfortunately, many Irish students are not confident about their mathematical ability. A negative attitude toward the discipline is thought to plague learners at every level of Irish post-primary schools (Irish Universities Association, 2008). The Royal Irish Academy ("RIA") (2006) has stated that there is a public perception amongst Irish students at post-primary level that mathematics is difficult. This fear of mathematics is known as mathematics anxiety or mathophobia.

In 2007, the Programme for International Student Assessment (“PISA”) ranked Ireland mid-table 16th out of 30 of the Organisation for Economic Co-operation and Development (“OECD”) nations for mathematical proficiency. More recently, a PISA study (released in 2010) ranked Ireland 26th place, a fall of 10 places in just three years. Ireland’s level of mathematical proficiency is critical to its development as a world-class research and innovation centre and its growth as a knowledge economy. The Expert Group on Future Skills Needs (“EGFSN”) (2008) and Engineers Ireland (2010) have highlighted that a national strategic approach is required to match Ireland’s national mathematical achievement with the standards set by the country’s leading the OECD-PISA table. Improvements to Ireland’s mathematical proficiency will provide them with a competitive advantage over other OECD countries competing for Science,
Technology and Innovation ("STI") investment, thus assisting the regeneration of Ireland’s struggling economy.

In order to improve Ireland’s level of mathematical proficiency the EGFSN (2008) has advised that there is a need:

- to build positive attitudes towards mathematics as a discipline; and
- to boost the number of students with a high level of mathematical proficiency.

The National Council of Teachers of Mathematics ("NCTM") a professional organisation of 94,000 mathematics teachers and university professors dedicated to the improvement of mathematics education recommends the use of the calculator in supporting students’ computational abilities in enhancing the learning of mathematics (NCTM, 2000). Hembree and Dessart (1986) reported that students who used a calculator for mathematics instruction possessed a better attitude toward mathematics than non-calculator users. A consistent body of research shows that calculators can effectively support mathematics learning and improve a student’s attitude toward mathematics.

Despite support for calculator use in mathematics there are many mathematics educators who worry that calculator use will impair students’ mathematical ability and result in mathematical illiteracy. Most recently, Engineers Ireland (2010) in recognising some of the educational benefits of calculator use, such as the calculator’s ability to improve students’ performance in assessment, proposed that the Minister should ban or withdraw calculators at both primary and post-primary levels up to and including the Junior Certificate. Engineers Ireland (2010) reported that the reliance on calculators in early school years interferes with a student’s ability to appreciate numbers and leads to a general decline in some aspects of numeracy.

These differing perspectives on the impact that the use of the calculator will have on mathematical ability coupled with the issue identified by IBEC and the EGFSN that mathematics ability will be central to the Irish economy’s future success, creates a dilemma for current educators. This Study will lend itself to bridging the information
deficit to further enable educators to plan effectively as regards the use of calculators in mathematics.

1.2 Goal of the Study

A large body of research has examined the effect of calculator usage on students’ attitudes and performance in the mathematical classroom. Extensive research exists reporting on a variety of issues regarding the use of graphic calculators, but there is comparatively little research on the use of the scientific calculator in the mathematics classroom. Much of the Irish research in relation to calculator usage has focused on the effect of calculator usage on students’ mathematical performance but limited research exists on Irish students’ attitudes toward calculator usage. Close et al (2008) claimed that few studies have been completed on teachers’ attitudes toward calculator usage in the Irish mathematics classroom (Close et al, 2008).

The main goal of this Study is to bridge the current gap in the research in the Irish context by conducting an investigation into the effects of calculator usage on post-primary mathematic students at junior cycle level. In particular, this Study aims to achieve the following objectives:

- To determine whether an issue of mathematics anxiety exists at post-primary junior cycle level;
- To examine the attitudes of students and teachers toward calculator usage at post-primary junior cycle level; and?
- To examine the effects of calculator access on students mathematical performance.

1.3 Significance of the Study

This Study is significant in informing Irish post-primary school teachers about the effects of calculators on students’ mathematical performance, and the implications of
calculator availability on students’ attitudes towards mathematics. This Study may also go some way to increasing the relevant research evidence in the Irish context.

1.4 Methodology

For the administration of the testing of participants and the questionnaire, this Study has utilised a laboratory experiment type approach. A laboratory experiment is an experiment that takes place in an ‘artificial’ setting rather than in the research participants’ ‘natural’ setting. A laboratory experiment was the most appropriate method of research with benefits such as the ability to control the environment, because the researcher was able to purposively chose participants (drawn from three local post-primary schools with different levels of mathematical ability), rather than use participants available in a field setting (i.e. the real classroom setting); and the ability to watch and measure the performance of participants without external interference (i.e. post-primary school principals/teachers). The results of the laboratory experiment form the case study from which the research questions are analysed.

1.5 Limitations of the Study

The Study results are restricted by a number of limitations. As a laboratory setting was used to administer the testing and the questionnaire, the research suffers from the inherent selection bias, context bias and scrutiny effect that characterises laboratory experiment based research. These limitations are further detailed in [Methodology section 1.2.2.]

The Study has limited itself to assessing post primary junior cycle student participants from three post-primary schools in the Donegal area. The schools who participated were not randomly selected, rather they were chosen due to their proximity to the researcher and the researcher’s rapport with the three institutes involved.

For these reasons, the generalisability of the results of this Study is limited. The findings therefore, cannot be applied to the whole population of junior cycle
mathematics students in Ireland. Nor can the findings be extended to the broad student grades outside of the junior cycle students. In addition, the number of teachers interviewed is not statistically significant and may not have been sufficient to identify all teacher attitudes towards calculator usage.

It should therefore be noted that the intent of the Study is not to draw a generalisation in this respect but rather provide a basis for further research of calculator use in the classroom setting and provide a degree of additional evidence regarding calculator usage and its effect on students’ attitudes and student performance in mathematics.

1.6 Layout of the Study

The Study is laid out herein as follows:

- Chapter one introduces the research question. It sets out the main aims and objectives of the Study;

- Chapter two contains a literature review of recent and previous research in the area of mathematics anxiety. The literature looks at the importance of mathematics for Irish society and the use of the calculator in the mathematics curriculum. The review of the literature explores the positive and negative effects of calculator usage on students’ mathematical performance and on students’ attitudes toward the mathematics discipline drawing from both Irish and International studies;

- Chapter three is devoted to a discussion of the methodology framework applied in collecting the research data needed to realise the objectives of this Study. Aspects discussed include the research strategy, the research design, the research instruments, the participants of the research paper, the test-administration procedure, the validation of the research instruments, data reliability and ethical considerations;

- Chapter four gives a detailed analysis of the relevant research data from the student testing instruments, the questionnaire and the teacher interview;
• Chapter five examines the link between the research findings and the research questions. The research findings are then compared, contrasted and analysed against the literature review as outlined in Chapter two; and

• Chapter six will comprise of three sections, the conclusions drawn from the Study, the recommendations for further research and the limitations of the Study.
Chapter Two

2 Literature Review

For many years paper-and-pencil manipulation has been the standard approach in the teaching and learning of mathematics. However, today’s technology has the potential to change that. The calculator can give students the opportunity to explore mathematical concepts that would be tedious and time consuming using paper-and-pencil methods. Nowadays, there is an increasing realisation that technologies such as the calculator may help students in the learning of mathematics.

The purpose of this chapter is to present a literature review on the influence of the calculator in the teaching and learning of mathematics. The focus will be on the use of the calculator as a learning tool. A review of studies related to its use and the influence thereof in the teaching and learning of mathematics will be reported.

2.1 The Importance of Mathematics in Irish Society

An ideal education in which students have democratic access to powerful mathematical ideas can result in students having the mathematical skills, knowledge and understanding to become educated citizens who use their political rights to shape government and their personal futures. They see the power of mathematics and understand that they can use mathematical power to address ills in our society.

(C.E. Malloy, 2002)

Science, technology and innovation is seen as vital to the economic and social progress of the Irish economy (Department of Enterprise Trade and Employment, 2006). In an article “Few high flyers want science” in the Irish Independent Matt Moran, the director of IBEC’s Pharmaceutical Ireland warned that “virtually no quality career will be available in high-tech sectors without a high knowledge of maths” (Independent, 2007).
Mathematics education is seen as of primary importance for students pursuing careers in “engineering, experimental and numerative disciplines, and is of strategic importance to Ireland’s transformation to an innovation driven society” (Irish Universities Association, 2008, p.1).

In Ireland, mathematics has always formed a mandatory part of a student’s post primary experience. The Irish economy recognises the significance of mathematics as a component of general education, of employment, and for third level education (National Council for Curriculum and Assessment, 2005). However, despite its importance, a growing concern has been expressed regarding the mathematical skills of students emerging from post-primary education (Tickly and Wolf, 2000).

In 2008, 57,000 students sat the Leaving Certificate Mathematics paper. The results showed that more than 5,000 of these students failed the Mathematics paper at ordinary and foundation level, making many ineligible for entry into third level education (The Irish Times, 2008). These poor results highlight that many Irish students have difficulty in learning mathematics. A negative attitude towards mathematics or an issue of “mathophobia”, a fear of mathematics is apparent in Irish society today (Irish Universities Association, 2008). These negative attitudes towards mathematics need to change as the inadequate mathematical skills of a student will not only affect a student’s development and career opportunities but will also have economic implications in a society increasingly reliant on science and technology (National Council for Curriculum and Assessment, 2005; RIA, 2007).

Recent studies into Irish classrooms have shown that mathematics is taught and learned in a traditional manner, the teacher gives an explanation or demonstration of the procedural skill and then the students’ practice this skill (RIA, 2007). While traditional teaching is necessary to some degree, RIA (2007) proposes that it should not be the only teaching strategy employed. For example RIA (2007) highlights that the use of technology in the classroom could play a role in varying the methods used to teach mathematics.
2.2 Theories of and approaches to Mathematics Teaching & Learning

For many years mathematics has been taught in what is referred to as traditional teaching based on the framework of behaviourism.

2.2.1 Behaviourism

Behaviourism has been the dominant teaching theory throughout the twentieth century (Maddux et al, 2001). The behaviourist theory based on Thorndike’s stimulus-response principle views learning as a result of stimuli and responses through the use of rewards (von Glasersfeld, 1995). Chen (2003) stated that the behaviourist approach emphasises performance rather than the reasons that the learner performs a certain way. Educators who use the behaviourist framework break the content area into smaller components, sequence them and then transmit them (Chen, 2003). This approach assumes that once students have learned the parts, they can put them together as a whole and apply them when needed (Bredo, 1997; Fosnot, 1996). It is a teaching approach that is also referred to as directed instruction, where the teacher lectures and the students listen and take notes (Forrester and Jantzie, 2000).

In the behaviourist mathematics classroom the teacher transmits all the knowledge and the student passively accepts it without question (Ijeh, 2003). The teacher only shows how and what is to be done, there is little discussion; students are rarely given an opportunity to ask questions if they do not understand something (Ijeh, 2003). This environment does not allow for experiences where students are able to discover, invent or apply mathematics to problems that are significant to them (Cangelosi, 1996). Often students, who already have built up a phobia or anxiety towards mathematics, feel afraid of the teacher and the reaction of their class peers if they do not understand (Ijeh, 2003).

The behaviourist theory has served well in teaching the past generations, however, future generations may not respond as well to this method of teaching as they are growing up in an environment that differs fundamentally from that of their parents (Forrester & Jantzie, 2000). The past generations grew up with limited technology while the calculator and other technologies dominate the current generation.
2.2.2 Constructivism

Since 1980, the theory of constructivism has been advocated as an effective way of learning and teaching mathematics (Narainsamy, 1998). Constructivist learning has become a prominent theory in teaching during the last decade due to the introduction of new technologies into the classroom, such as computers and calculators. The constructivist approach is in direct contrast to the traditional behaviourist approach. Constructivism views learning as a process of knowledge construction, with concept development and comprehensive understanding as the goals (Fosnot, 1996). According to Anderson and Piazza (1996), constructivism is based on two main principles.

The first principle is:

*that knowledge is actively constructed by the learner, that is, knowledge is the result of learners’ activities rather than of the passive reception of information or instruction*

*(Anderson & Piazza, 1996, p.51)*

Learning in constructivism requires the building of conceptual structures through reflection and abstraction (Schuman, 1987; von Glaserfeld, 1995). Constructivists such as Bruner (1966) and Dewey (1938) state that for learning to occur, the learners must be involved in the construction and reorganisation of concepts.

The second principle is:

*that knowledge is an adaptive function, that is gaining knowledge is a process of adapting to the world that is experienced by the learner*

*(Anderson & Piazza, 1996, p.51)*

According to the constructivist theory, learners actively construct their own knowledge with the focus on a problem-centered approach. Constructivists believe learning is the discovery and transformation of complex information and that traditional teacher-centred instruction of predetermined plans, skills and content is inappropriate (Nicaise & Barnes, 1996). Nicaise and Barnes (1996) suggest that learning occurs within the world students experience and that when they deal with problems and situations simulating and representing authenticity, they learn more.
In the mathematics classroom the constructivist perspective of learning is particularly appealing because the student constructs his or her own understanding which is seen as being very conducive in building strong problem solving skills in mathematics (Tajuddin et al., 2009). Research has shown that teachers who use calculators frequently in the teaching and learning of mathematics hold a constructivist teaching philosophy (Becker 2000; Burke, 2001). Orton (1992) stated that the calculator can be used in an “exploratory and investigatory” way to help students construct their own understanding of arithmetic. Kissane (1999) defined exploratory data analysis as the checking, editing, transforming, augmenting, analysing and re-analysing of data which has been stored in a calculator. The calculator allows students to investigate different solutions of a mathematical problem (Kissane, 1999). In the constructivist classroom students are not seen as passive absorbers of information but active participants in their own learning as they acquire new knowledge through the use of the calculator (Tajuddin et al., 2009). Tsao (2006) showed that students who were exposed to a constructivist-based learning approach in a mathematics statistics class gained positive attitudes towards the topic. Research has shown that constructivist learning environments may offer alternative learning opportunities for those students who do not fully understand mathematical concepts presented in the traditional behaviourist format (Tsao, 2006).

2.3 Mathematics Anxiety

In 2008, 12% of Leaving Certificate students who sat the ordinary level leaving certificate mathematics paper, failed to achieve a level D grade or higher. Failure rates have remained high over the past number of years highlighting that many Irish students find mathematics difficult to learn. Recent reviews of the mathematics curriculum such as ‘The International Trends in Post–Primary Mathematics Education: Perspectives on Learning, Teaching and Assessment’ (Conway & Sloane, 2006), ‘Review of Mathematics in Post Primary Education – A discussion paper’ (NCCA, 2005), and ‘The Government of Ireland’s Strategy for Science, Technology and Innovation 2006-2013’, have all emphasised the importance of a student’s attitude to mathematics as a factor of their success in this subject. However, the Irish Universities Association (“IUA”)
found that a negative attitude towards mathematics or an issue of “mathophobia”, i.e. a fear of mathematics, is apparent in Irish society today. The RIA (2008) also stated that there is a public perception among Irish students at post-primary level that mathematics is difficult and that it is acceptable not to be good at it. The National Council for Curriculum and Assessment’s (“NCCA”) Review of Mathematics in Post Primary Education 2005 also found that students see mathematics as hard work and that a degree of natural ability is necessary to do well.

It has been stated that “mathophobia is not a disease but a handicap that can have a dramatic effect on a student’s life” (Clawson, 1991).

Mathophobia is more often referred to as mathematics anxiety. Mathematics anxiety has been defined as:

\[
\text{the panic, helplessness, paralysis and mental disorganisation that arises among some people when they are required to solve a mathematical problem}
\]

\[\text{(Tobias & Weissbrod, 1980)}\]

Tobias (1978) described mathematics anxiety as an anxious feeling that may stop a person from solving mathematical problems or manipulating numbers. Students who suffer from mathematics anxiety feel that they are incapable of classroom participation as they are afraid to ask questions when confused, in case they look stupid (Tobias, 1993; Mahony et al, 2008). The physiological symptoms of mathematics anxiety may include heart palpitations, sweaty palms, nervous stomach and experiences of paralysis of thought (Cemen, 1987; Krantz, 1999). The psychological symptoms may include a feeling of helplessness or inability to cope, panic or fear and a desire to flee the situation (Cemen, 1987; Haralson, 2003).

Research has shown that most mathematics anxiety has its roots in the teachers and the teaching of mathematics (Fiore, 1999; Williams, 1988). Fiore (1999) reported that many students have been abused by a teacher while performing mathematics. Mathematics abuse can be defined as “any negative experience acquired while doing mathematics” (Fiore, 1999).
Mathematics abuse could be verbal ("you're stupid if you can't solve this problem"), or physical (striking someone when given the wrong answer) (Fiore, 1999). Greenwood (1984) stated that mathematics anxiety usually results more from the way the subject is presented or taught rather than from the subject matter itself. Hembree (1990) carried out a meta-analysis of 151 students suffering from mathematics anxiety and concluded that the condition is related to poor performance in mathematics tests. Other researchers have suggested that mathematics anxiety is associated with a strong sense of failure, memories of low scores on mathematical tests and a fear of getting it wrong (Feldhusen et al, 1965; Perry, 2004).

Research has shown that students who suffer from high levels of mathematics anxiety have lower levels of mathematics achievement (Scarpello, 2007; Burns 1998). A student with low levels of mathematics achievement has limited opportunities to pursue rewarding careers in science, engineering, ICT and business as well as access to many third-level courses; limiting them in their immediate and future careers. The Irish government’s publication “Towards 2016 – Social Partnership Agreement 2006-2015” (2006), urged that the declining quality in mathematics needed to be addressed for the development of a knowledge economy. The EGFSN (2008) highlighted an urgent need to alleviate mathematics anxiety and build positive attitudes towards mathematics in order to boost the numbers of students with a high level of mathematical proficiency.

Educators should be prepared to provide students with a more positive mathematical experience in an effort to alleviate mathematics anxiety and allow students to become more confident in their ability to learn mathematics. Stuart (2000) stated that innovations in teaching methods and the use of teaching aids may help to improve a student’s feeling of success in mathematics; thereby increasing his/her confidence. Furner et al (2005) asserted that by utilising best practices in mathematics teaching and learning and addressing mathematics anxiety, educators can begin to see higher levels of mathematics achievement. Maccini and Gagnon (2000) put together a list of what are considered best practices for the teaching of mathematics. This listing included the use of calculators, computers and all technology. Yushau et al (2003) asserted that
technology has the ability to enhance a student’s learning experience by providing greater flexibility and giving students with a more self-reliant role in their own education. In 1974, the NCTM urged the use of calculators as an instructional aid and computational tool. The NCTM stated that “technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning” (NCTM, 2000, p.24)

Robertson and Claesgens (1983) proposed four methods that should be utilised when teaching sufferers of mathematics anxiety, one of which is that teachers encourage the use of calculators in the teaching and learning of mathematics. Hembree and Dessart’s (1986) meta-analysis on calculator use concluded that students using calculators have a better attitude towards mathematics and a much better understanding of mathematics than non-calculator students. A study conducted by Acelajado (2003), concluded that the use of graphing calculators improved achievement and attitude toward mathematics to a certain degree and also reduced mathematics anxiety. Several studies have shown that the use of a calculator improves a student’s mathematical achievement through discovery and exploration (Suydam, 1976; Hembree & Dessart, 1986). Through the usage of calculators in mathematics, improvements have been observed in a student’s number sense, problem solving skills, and understanding of arithmetic operations (Campbell & Stewart, 1993; Miller, 2003). Calculator usage can increase student confidence, enthusiasm and self-concept (Campbell & Stewart, 1993; Hembree & Dessart, 1986). According to Suydam (1987), through the scrutiny of over 100 studies reported that the use of calculators:

(a) promotes achievement;

(b) improves problem-solving skills; and

(c) increases understanding of mathematical ideas.

In the past some students held negative attitudes toward the usage of calculators in mathematics. These students found that calculator usage did not aid them in the learning of mathematics, the calculator was just something else to learn, and they lost
control of the mathematical problem (Ruthven, 1995). Ruthven (1995) stated that students who hold negative attitudes towards calculator usage lack confidence in the calculator mode of calculation. An Irish report titled “Pressing the Right Buttons - Calculator use in schools and in Junior Cycle Mathematics” (Surgenor et al., 2007) noted that students who were negatively disposed to the calculator and felt that calculator usage would make them lazy had lower performance levels on mathematical assignments in comparison to students who did not hold such views (Surgenor et al., 2007). On the other hand research carried out by Abdullah et al (2005) on the effects of scientific calculator use on students’ attitudes in mathematics classrooms concluded that students today have a broad exposure to calculators and have a positive acceptance of calculator usage in the mathematics classroom. Ellington (2004) conducted a study titled “The Calculators role in mathematics attitude” which concluded that students who use calculators, report more positive attitudes towards mathematics than their non-calculator counterparts. Ellington (2004) also reported that her results supported the fact that students enjoy having access to calculators while learning mathematics.

The research presented indicates that the introduction of technology into the mathematics classroom has shown positive results. The use of the calculator in the teaching and learning of mathematics has the ability to improve a student’s attitude towards mathematics.

### 2.4 Calculator Usage

In the United States, the NCTM (1974) urged that calculators should be integrated into schools. NCTM (1980) recommended that all schools “introduce calculators and computers into the classroom at the earliest grade practicable”. NCTM (1989) recommended that calculators should be used in grades K-4 ‘Pre-kindergarten’ when students are 4 to 5 years of age. NCTM (1986) recommended that all teachers and authors of mathematics curriculum integrate calculators into the mathematics program at all grade levels, including homework and assessment. The National Research Council (1990) urged the replacement of most paper-and-pencil drills with calculator-
based instruction. Calculators were noted to reduce computation time and provide for immediate feedback, allowing students to forget about the routine mathematical calculations and allow them to focus on discovery and exploration (National Research Council, 1990). NCTM (1991) stated that a mathematics teacher should help students learn to use calculators, computers, and other technological devices as mathematical tools.

In line with the NCTM’s ever-increasing support for the use of calculators to enhance the mathematics classroom, there has been an increase in the resources necessary to support their vision (Leatham, 2007). Since the 1990’s, the National Science Foundation in the United States has invested millions in the development of curriculum materials that promise to integrate calculators (Loveless, 2004).

There has been a limited amount of research undertaken on mathematics education in Ireland (Lyons et al, 2003; Close et al, 1978; Oldham, 1993, 1996). However, Ireland has participated in a number of major international studies of mathematics curriculum and achievement (Beaton et al, 1996). In 1991, the Second International Assessment of Educational Progress (“IAEP II”) reflected the low usage of calculators in Irish education, with just 25% of Irish 13 year old students reporting that they used a calculator in the mathematics classroom (Martin et al, 1992). A total of 20 countries participated in the IAEP II study. Twelve of these countries reported a higher usage of calculators than Ireland (Martin et al, 1992). Six countries, England, Scotland, France, Canada, Hungary, and Taiwan reported that over two thirds of their students used a calculator in the mathematics classroom (Martin et al, 1992).

In 1995, the Third International Mathematics and Science Study (“TIMSS”) reported that 62% of eighth grade teachers in the United States used calculators daily in their mathematics classroom (Beaton et al, 1996). This percentage was higher than the international average. At the same time, it was reported that 11% of grade eight teachers in Ireland used calculators daily in the mathematics classroom (Beaton et al, 1996). This low percentage contrasts sharply with other countries such as Austria,
Canada, England, Norway, the Netherlands and Singapore where at least 80% of grade eight teachers reported usage of calculators almost every day (Beaton et al, 1996).

In 1999, the TIMSS carried out a Repeat Study, a follow up of TIMSS 1995 in which Ireland did not participate. There were notable differences between the calculator usages of the various countries who participated in the TIMSS Repeat Study. Australia (13th place), Canada (10th place), Israel (28th place), New Zealand (20th place), South Africa (37th place), The Netherlands (7th place), and the United States (18th place) reported high levels of calculator usage while some of the high performing countries in mathematics achievement such as Korea (2nd place) and Japan (5th place) reported low calculator usage (TIMSS, 1999; Exhibit R3.12, Close et al, 2004). The TIMSS Repeat Study found that there was a decrease of 16% in the number of eighth grade students in England who reported high levels of calculator usage since the 1995 report (Close et al, 2004). The TIMSS Repeat Study also found that the Netherlands saw an increase of 13% in their levels of calculator usage (Close et al, 2004).

A report in 2000 titled, “A Comparison of Calculator Use in Eighth-Grade Mathematics Classrooms in the United States, Japan, and Portugal: Results from the Third International Mathematics and Science Study” (Tarr et al, 2000) reported the virtual absence of the calculator from the mathematics classroom in Japan which was particularly surprising given its technologically advanced society. The report found that only 0.37% of students in Japan used a calculator in the mathematics classroom, while 43.03% of US students used calculators (Tarr et al, 2000).

The Japanese educational system has had much success in producing students who excel in mathematics as pointed out in the TIMSS results. The TIMSS results created much interest internationally in the Japanese educational system. In 1999, a report known as “Japan: A Different Model of Mathematics Education” (Judson, 1999) looked at the Japanese educational system. This report found that the current Japanese mathematics curriculum encourages the use of the calculator beyond 5th grade, however, despite this the calculator remains absent from many Japanese classrooms (Judson, 1999). Judson (1999) reported that the reason for the absence of the calculator from
Japanese classrooms was due to the substantial emphasis on preparing junior high school students for high school and university entrance. Judson (1999) asserted that there is tremendous pressure upon Japanese students to perform well to get into the best high schools and universities. At present, the use of the calculator is prohibited in the entrance examination for Japanese high schools and university entrance; therefore teachers place great emphasis on Japanese students’ ability without the calculator.

In 2008, the TIMSS carried out an advanced study to provide information about the trends in student achievement in advanced mathematics in the final year of post-primary school (Mullis & Martin, 2009). The results of the TIMSS Advanced Study (released December, 2009) saw that the advanced students in the Netherlands (2nd place) placed high emphasis on calculator usage in the mathematics classroom (Mullis & Martin, 2009). While the top performing Russian Federation students used calculators to a far lesser degree (Mullis & Martin, 2009).

For this reason, Mullis and Martin (2009) reported that calculator use cannot be related to achievement across countries. Similarly, Roshelle and Gallagher (2005) also reported that there is no clear distinction between calculator use and mathematics achievement by country. Some researchers believe that differences in mathematical achievement between countries are related to differences in the testing environments and cultural norms (Roshelle & Gallagher, 2005). For example, the ‘high stakes’ university entrance examinations in Japan prohibits the use of the calculator, while in the US the use of the calculator may be required (Lennex et al, 2000). Roshellle and Gallagher (2005) assert that:

*the calculator is never a stand-alone, uniform intervention; rather, it interacts with curricular, pedagogical, and cultural factors to produce an effect.*

*(Roshelle & Gallagher, 2005, p.11)*

The body of research discussed above indicates that a large differential exists between the acceptances of calculator use within the mathematics classroom from one country to another. The evidence from the literature review suggests that there is no clear relationship between calculator use and mathematics achievement across countries.
2.5 Calculators in the Irish Mathematics Curriculum

The current mathematics curriculum in Irish post-primary schools has evolved significantly in the past forty years. In the mid-1960s, Ireland was greatly affected by the “modern mathematics” movement (Oldham, 2006). The “modern” Leaving Certificate for the post-primary curriculum was introduced in 1964; Intermediate Certificate courses (known as the Junior Certificate today) were introduced in 1966 with the introduction of Higher and Ordinary course levels. Revisions of the Intermediate Certificate curriculum took place in 1973 and to the Leaving Certificate curriculum in 1976 (Close et al., 2003). However, none of these subsequent revisions considered the usage of calculators in the mathematics curriculum (Close et al., 2003, Surgenor et al., 2007). During this period the subject of calculator usage within the mathematics classroom was being widely debated in other countries (Surgenor et al., 2007).

In 1980, the Irish Mathematics Teachers’ Association expressed its support for the use of calculators in state examinations (Surgenor et al., 2007). At this time, the arguments supporting the use of calculators within the mathematics classroom included; the calculator’s ability to enable students to concentrate on the mathematical idea rather than on routine computations, and to prepare students for life outside school (Surgenor et al., 2007). The arguments against the use of calculators within the mathematics classroom included the cost burden of supplying calculators to the students and what would happen if a calculator was to malfunction during a state examination (Surgenor et al., 2007). However, this debate did not take into consideration the potential of the calculator as a learning tool as well as its ability to act as a computational device (Surgenor et al., 2007).

In 1986, Ireland first permitted the usage of non-programmable calculators into the Leaving Certificate examination. However, no alteration of the mathematics curriculum took place for the inclusion of calculator usage (Surgenor et al., 2007). This was viewed as a significant omission that was politically unacceptable at the time (Close et al., 2004).
In 1990, a third level was introduced for the Leaving Certificate mathematics curriculum known as the Ordinary Alternative level, known today as Foundation level. The curriculum for this new level included the accurate and efficient use of the calculator as a specific assessment objective, with students given the option of completing a question designed to test computational skills with the use of a calculator (Leaving Certificate Curriculum, 1990; Close et al, 2003). In 1992, revisions of the Higher and Ordinary levels of the mathematics curriculum were introduced. These revisions referred to the use of the calculator during examinations but did not include the use of the calculator as a specific assessment objective (Surgenor et al, 2007; Close et al, 2003). By 1995, statistics from the Ordinary Alternative level examination reported that the majority of students opted for the optional calculator question (Surgenor et al, 2007; Close et al, 2003). Evidence also emerged from the Ordinary Alternative level examination that weakened arguments against the use of calculators in the mathematics curriculum when minimal difficulties were encountered through the use of the calculator in state examinations (Surgenor et al, 2007; Close et al, 2003).

In 1995, it was reported by TIMSS that 68% of eighth grade 13 year old mathematics students in Ireland were taught by teachers who reported that they ‘hardly ever or never’ used a calculator in the mathematics classroom (Beaton et al, 1996). In 2000, the NCCA identified that this absence of calculators was a negative aspect to the Junior Certificate program (Close et al, 2008). In 1999, a revision of the Primary School Mathematics Curriculum (“PSCM”) introduced the usage of calculators from fourth class on (Department of Education and Science/National Council for Curriculum and Assessment, 1999a, 1999b). The introduction of calculators at primary level provided the Department of Education and Science (“DES”) with grounds for seeking the introduction of calculators into the Junior Certificate program (Oldham et al, 2006). Arguments against the use of calculators, debated in the 1980s, had now become less prevalent since the cost of the calculator had since decreased and their reliability had increased (Close et al, 2003). In 2003, the calculator was first permitted to be used in the Junior Certificate mathematics examination.
The introduction of the calculator to the Junior Certificate mathematics curriculum promoted the integration of the calculator into post-primary school as shown from the results from an international survey, PISA. PISA, initiated by the OECD is a collaborative effort among OECD member countries to assess the skills of 15-year olds in three domains: reading, mathematics and the sciences. In 2000, PISA carried out an international survey of 15-year olds which found that 24.2% of 15-year old Irish post-primary students used a calculator frequently in mathematics (Cosgrove et al., 2005). Three years later, PISA repeated this survey and reported that 78% of 15-year old Irish post-primary students reported frequent calculator use in mathematics (Cosgrove et al., 2005), reflecting the introduction of calculators into the Junior Certificate. In 2008, 81.1% of Irish third year students surveyed for a report known as “The effects of calculator use on mathematics in schools and in certificate examinations” (Close et al., 2008), stated that they used a calculator ‘often’ in the mathematics classroom, when fewer than 1% reported using a calculator ‘often’ in 2000. With the introduction of the revised PSCM in 1999, Irish primary schools also witnessed an increased usage of calculators as stated in the report, “Counting on Success - Mathematics Achievement in Irish primary schools” (Surgenor et al., 2006). The report found that 5% of fourth class Irish students used a calculator in the mathematics classroom in 1999 compared to 67% in 2004 (Surgenor et al., 2008). However, despite this substantial increase in calculator usage, two-thirds who reported using a calculator in 2004 said that they did so no more than once or twice a month (Surgenor et al., 2008). The other one-third of the fourth class students reported having ‘never’ or ‘hardly ever’ used a calculator in the mathematics classroom (Surgenor et al., 2008).

This research indicates that the frequency of calculator use within the mathematics classroom has increased, due to the introduction of calculator use to the Junior Certificate mathematics curriculum. While the number of Irish primary school students using a calculator in the mathematics classroom has increased, the scale of the increase is still low.
The issue of calculator use in mathematics education has caused widespread controversy. Some professional mathematicians and parent groups advocate banning the use of calculators in the mathematics classroom, while others express great hopes for the potential positive effects of calculator use in the classroom.

2.5.1 Negative Effects of Calculator Use

Critics believe that calculator use within the mathematics classroom may impede learning. The main fear cited by critics is that calculator use within the mathematics classroom could affect a student’s mastery of basic computational skills acquired through the traditional paper-and-pencil methods (NCTM, 1974). The most frequently cited report on the effects of calculator use on mathematics achievement is that of Hembree and Dessart (1986, 1992). In a 1986 study in the Journal for Research in Mathematics Education, Hembree and Dessart’s meta-analysis (1986) of seventy-nine research reports concluded that sustained calculator use by fourth grade students hampered students’ basic paper-and-pencil skills. In 1992, Hembree and Dessart reminded educators that:

*calculators, though beneficial, may not be appropriate for use at all times, in all places, and for all subject matters

(Hembree and Dessart, 1992, p.25)

The most vocal critic against the use of calculators in the mathematics classroom was John Saxon, a mathematics textbook publisher and former college mathematics instructor from the U.S. state Georgia. Saxon (1986) stated that the use of the calculator will cripple students to the extent that they will not be able to “do simple computations in their heads, and worst of all they will not be able to estimate”.
In the article “New Teaching Method puts Maths in Real Life” (Celis, 1993) which appeared in the New York Times on June 16, 1993, Saxon stated

My contention is that calculators will cause short-term gains in a few students and long-term damage to many. It won’t become apparent for another 10 to 12 years, at which point it will be distressingly apparent.

(Saxon, 1993)

Other opponents against the use of calculators in the mathematics classroom have cited that students will become over-reliant or dependent on the calculating device; the risk being that the calculator will serve as a crutch for students. The crutch premise essentially means that if students use the calculator for simple mathematical computations that can be done by hand, the students will be unable to do these simple computations when the calculator is taken away (Usiskin, 1978). A debate article on “Advanced calculators” written by two Swedish mathematics professors Thunberg and Lingefjärd in 2006 questioned the use of calculators within the mathematics classroom (Persson, 2008). They argued that the routine use of calculators at both primary and secondary school level, leads to decreased manual and mental skills for all students (Persson, 2008). Mc Cauliff (2004) stated that if students become reliant on the use of the calculator, if only for the checking of answers, they will suffer when the calculator is absent. The report “Pressing the right buttons: calculator use in schools and Junior Cycle mathematics” (Surgenor et al, 2007) reported that the main perceived disadvantage of calculator use in the mathematics classroom was the
greater potential for making mistakes, difficulty in using the calculator, and a fear that calculators ‘do not engage the brain’.

(Surgenor et al, 2007, p.24)

In the same study it was reported that 41% of Irish students at Junior Cycle believed that the use of a calculator would make them lazy (Surgenor et al, 2007).

Another prominent concern surrounding calculator use is that the calculator can give a student a false sense of confidence about their true mathematical ability (Burke, 2001;
Mc Cauliff, 2004). Linn (2000) found that too much of mathematics instruction is spent teaching students how to use a calculator instead of teaching mathematics computation and problem solving skills. Hunsaker (1997) found that calculator use will result in students having a lack of “constructive methods” and will prevent students from seeing the “inherent structure and beauty” in mathematics. Hunsaker (1997) believes that students who learn to manipulate numbers mentally are better equipped to solve mathematical computations and problems. These students will also have a better idea as to what the answer to a problem should be, as experience has taught them a degree of number sense. Moreover, Hunsaker (1997) stated that students, who erroneously enter a problem into the calculator without noticing, do not question the “obviously incorrect” answer as students believe that the calculator is always right. Most importantly, Hunsaker (1997) argues that the sole purpose of teaching mathematics is for thinking and discipline, all of which she feels the calculator prohibits.

Reynolds and Farrell (1996) suggested in their review of international surveys of educational achievement that the early introduction of calculators into the mathematics classroom, and their too frequent use, is one of the reasons for a relatively poor mathematical performance of students in England (Keys, 1999). In 1999, the TIMSS report observed that three of the five top scoring countries (Belgium, Korea, and Japan) ‘never’ or ‘rarely used’ a calculator in the mathematics classroom (Beaton et al., 1996). In contrast, ten of the eleven countries (including the United States) who scored lower than the international average reported using a calculator ‘almost every day’ or ‘several times a week’ in the mathematics classroom (Beaton et al., 1996). These results from the TIMSS 1999 report suggest that students who have limited or virtually no access to a calculator in the mathematics classroom can achieve better test scores than a group of students who routinely use a calculator in the mathematics classroom. Antonijević (2005) stated that students with no calculator access in the mathematics classroom must master all the abilities and skills required in the area of calculating and consequently these students attain better mathematics test scores.
Papanastasiou and Paparistodemou (2002) examined the interrelationships that exist between calculator usage and mathematics achievement using the 2003 TIMSS dataset. The sample of this study included eighth grade students from the United States, Cyprus, the Russian Federation, and South Africa. Papanastasiou and Paparistodemou (2002) concluded that calculator usage did not have any practically significant effect in the Russian Federation and in South Africa whereas calculator usage was negatively associated with mathematics achievement in Cyprus and positively associated with mathematics achievement in the United States. Again these results further suggest that calculator usage in the mathematics classroom may not increase students’ mathematics achievement.

2.5.2 Positive Effects of Calculator Use

Research has shown that there can be many positive effects from calculator usage in the mathematics classroom. The definitive study on the effects of calculator usage on mathematics achievement by Hembree and Dessart (1986) concluded that from kindergarten through to twelfth grade (“K-12”) (except grade four) calculator usage in conjunction with traditional mathematics can improve average students’ paper-and-pencil skills, both in basic computations and problem solving. Hembree and Dessart’s (1986) analysis found that high and low ability students who participated displayed no significant difference in skill acquisition through the usage of the calculator. Hembree and Dessart (1986) stated that:

*Students using calculators possess a better attitude toward mathematics and an especially better self-concept in mathematics than non-calculator students. This statement applies across all grades and ability levels.*

*(Hembree & Dessart, 1986, p.83)*

In the 1992 NCTM Yearbook edited by James T. Fey and Christian R. Hirsch, Hembree and Dessart extended their meta-analysis of 1986 with a further nine additional studies of calculator usage and student achievement. Hembree and Dessart’s research analysis of 1992 enhanced their previous study of 1986 in concluding that the appropriate use of
the calculator in the mathematics classroom improves paper-and-pencil skills for low, average, and high ability students (Dunham, 2000). In another meta-analysis of twenty-four research studies conducted from 1984 to 1995, Smith (1997) as part of a Doctoral dissertation for Texas A&M University-Commerce extended the results found by Hembree and Dessart. Smith (1997) reported significantly higher achievement for students who used the calculator; and stated that calculator usage had a significant positive effect on students in problem solving, computation, and conceptual understanding. Smith (1997) also reported that calculator usage did not hinder the development of paper-and-pencil skills.

Another meta-analysis of fifty-four research studies used to determine the effects of calculators on student achievement and attitude levels carried out by Ellington (2003) supported many of Hembree and Dessart’s results. Ellington (2003) found that calculator usage during instruction and testing in grades K-12 students maintained paper-and-pencil skills, experienced an improvement in operational skills and the skills necessary for understanding mathematical concepts. As in Hembree and Dessart’s study, test results showed that calculator use in the mathematics classroom resulted in better attitudes towards mathematics (Ellington, 2003). Ellington (2003) stated that to get the greatest benefit from calculator usage within the classroom, calculator use should not be confined to the mere checking of work; it should have a pedagogical role in the mathematics classroom. Ellington (2003, 2006) reported more positive results in a student’s mathematical achievement and attitude towards mathematics when a student used the calculator for longer periods of time (nine weeks or more).

Researchers have shown that students display high enthusiasm and value towards the use of the calculator in the mathematics classroom (Pennington, 1998; Wheatley, 1980; Hembree & Dessart, 1986). Students believe that the calculator will improve their ability to solve problems (Dunham & Dick, 1994). Countryman and Wilson (1991) presented a case for the use of the calculator within the classroom which reported that students who used a calculator within the mathematics classroom were engaged and enthusiastic about the basic fundamentals of mathematics. Kaiser (1994) reported that
after a few weeks of calculator usage within the mathematics classroom, students displayed enthusiasm for calculators and a greater ability in the mathematics classroom. Gilchrist (1993) reported that when calculators are permitted in the mathematics classroom students are more eager to attend mathematics class. Pomerantz and Waits (1997) stated that students who would usually be bored with mathematical computation no longer feel threatened when confronted with tedious computations when the calculator is present. Other researchers have asserted that calculators can be used to lessen mathematics anxiety and to counter students dislike and phobia for mathematics (Libov, 1985; Hembree & Dessart, 1986; Pomerantz, & Waits, 1997; Acelajado, 2003; Abador, 2008). Allowing students to use the calculator encourages the learning of complex mathematics skills, thereby helping to alleviate issues of mathematics anxiety (Libov, 1985).

Many critics of calculator use are of the belief that calculators function as a crutch for many students. The crutch premise is manifested from the opinion that students will become over-reliant on the use of the calculator to the detriment of their mathematical understanding (Carter et al, 2008). In 1976, Suydam questioned this crutch premise. Suydam (1976) stated that the crutch premise rests on the principle that a crutch is a bad thing. However, Suydam (1976) asserts that to an injured person a crutch is often a necessity in some cases. Suydam (1986) identified that 40% of seventeen-year-olds entering college were not sufficiently proficient at arithmetic. Suydam (1976) stated that for these students the non-use of the calculator would condemn these students to a life without arithmetic. Suydam (1976) concluded that for such students the calculator is not a crutch but their only way of accessing the correct answer. Suydam (1976) advised that once the basic computational skills had been learnt first, the use of the calculator in the mathematics classroom did not harm a student’s calculation skills. Suydam (1982) reported that there was no evidence that elementary students become calculator dependent.

Proponents of calculator use within the mathematics classroom believe that through calculator use students will become more comfortable with using new technologies in
today’s technologically driven world (Linn et al., 2000). In a survey conducted to identify commonly used mathematical skills used in occupations, it was identified that 98% of respondents used the calculator in their job (Saunders, 1998). Therefore, it could be argued that if the calculator is so readily required in the real world then it seems prudent that students have the opportunity to use this learning tool in the classroom. Other researchers look at the technological advantage presented by the calculator; its ability to reduce the time spent on mathematical computations leading to an increased amount of time spent on understanding mathematical concepts, discovery and observing patterns (Pomerantz & Waits, 1997). Pomerantz and Waits (1997) claim that there is little mathematical reasoning involved in performing mathematical computation in the first place, therefore students do not miss out on anything in using the calculator to do the computations for them.

### 2.6 Conclusion

There is a myriad of research available supporting the use of the calculator within the mathematics classroom. However, an under-utilisation of the calculator still exists within the mathematics classroom with many teachers still apprehensive about the implementation of the calculator and reluctance to change their traditional teaching methods (Groves et al., 2004). Based upon the literature previously cited it would seem that most proponents of calculator use support it only in certain situations, while critics fear the possibility that the calculator will be improperly used within the mathematics classroom. Therefore the question does not appear to be ‘should’ calculators be used within the mathematics classroom but rather ‘how’ can calculators be integrated into the mathematics classroom. Hembree & Dessart (1992) reaffirmed these ideas when they concluded that additional research should investigate the best ways to implement and integrate the calculator into the mathematics curriculum.
Chapter Three

3 Methodology

This chapter discusses the methodology framework applied in collecting, assimilating, analysing and interpreting the research data needed to achieve the aims and objectives of this Study. Aspects discussed include the research strategy, the research design, the research instruments, the participants of the research paper, the test-administration procedure, the validation of the research instruments, data reliability and ethical considerations.

3.1 Research Method

A research method is a strategy of inquiry which moves from the underlying philosophical assumptions to research design and data collection

(Myers, 1997, p.5)

3.1.1 The Action Research Strategy

The Action Research strategy of inquiry is fundamentally an interventionist approach that can be defined as:

an iterative process involving researchers and practitioners acting together on a particular cycle of activities, including problem diagnosis, action intervention, and reflective learning

(Avison et al, 1999, p. 94)

Action Research is a well established strategy of inquiry introduced by Kurt Lewin in his 1946 paper “Action Research and Minority Problems” to address social system change through action. According to Hitchcock and Hughes (1995), the principle features of this research strategy are “change (action) or collaboration” and that the researchers’ main concern is to “improve a situation through active intervention and in collaboration with the parties involved”. Due to its focus on intervention, Action
Research was deemed to be an inappropriate research strategy for this Study since the researcher has no control over the research environment.

### 3.1.2 The Case Study Strategy

A Case Study based research strategy of inquiry was employed for this Study. A case study can be defined as:

> a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence

*(Robson, 2002, p.178)*.

It is accepted that a case study based research design is useful when questions of ‘how’ and ‘why’ are being asked about events over which the investigator has little or no control *(Yin, 1994)*. This Study utilised a laboratory experiment setting for the collection of data and then employed a case study based data analysis strategy to explore the effects of calculator usage on mathematics students from three post-primary schools in County Donegal at junior cycle level. For the purpose of this Study it was not possible to undertake the research in a pure case study fashion (i.e. using a real classroom setting); rather the laboratory experiment type setting forms the ‘case’ that has been analysed. This adopted case study approach design is a good fit for the aims and requirements of this Study, as it requires an in-depth investigation of a contemporary phenomenon (the effects of calculator usage on mathematics students) within a specific real life context (three post-primary schools). It is also an appropriate design for this research as it relies on multiple data sources.

A laboratory experiment is an experiment conducted in a highly controlled setting expressly prepared for this Study. The main advantages of a laboratory experiment for the researcher are:

- the tight control over the setting which is important for high internal validity; and
• the replication of data by other researchers leading to greater confidence in the research findings.

The main disadvantage of a laboratory experiment is the lack of realism and the effect that this experimental environment has on the participants’ behaviour, as they are aware that their behaviour is being monitored, recorded, and subsequently scrutinized i.e. the scrutiny effect (Levitt & List, 2006). Therefore, the behaviour of participants in a laboratory experiment may not provide guidance for their behaviour in a natural occurring setting.

The Hawthorne Effect is another example of an instance where experimental participants changed their behaviour because they were being watched (Orne, 1962).

Despite this potential bias in the approach, the case study strategy is the most appropriate method assessed to achieve the research aims and objectives given that the researcher was not in a position to directly administer the study on a full classroom of junior cycle post-primary students.

3.2 Research Questions

A number of research questions arise out of the Literature Review which provides the focus for this Study:

1. Is there evidence of the existence of mathematics phobia/anxiety in Irish post-primary schools?

2. Are students’ attitudes towards mathematics affected by the use of the calculator and if so, how?

3. Is there a significant difference between students’ pre-test score (without the aid of a calculator) and post-test score (optional use of the calculator)? and

4. What are teachers’ attitudes towards the use of the calculator in post-primary schools?
3.3 Research Design

This Study aims to investigate the effects of calculator usage on mathematics students in Irish post-primary schools at junior cycle level and to answer the research questions posed above.

According to Yin (1994), the empirical evidence for case studies should use multiple sources of evidence in the data collection process, such as interviews, archival sources, and direct or participatory observation to ‘construct validity’. Therefore, to answer the research questions raised and to ensure the ‘construct validity’ of a case study, an eclectic research design has been utilized, according to the elements of triangulation. Cohen and Manion (1995) defined triangulation as the use of more than one method of data collection such as tasks, questionnaires, interviews and observations. According to De Vos et al (2002) triangulation combines both qualitative and quantitative styles of research data enabling the researcher to view the research data from several different angles. With no exclusive reliance on one method of data collection, triangulation will help the researcher to reduce bias or distortion of the data collected (Cohen & Manion, 1980).

The triangulation approach poses many challenges for the researcher such as the need to become familiar with both quantitative and qualitative styles of researching data, the need to undertake extensive data collection and the time demands required to analyse both textual and numerical data.

3.3.1 Quantitative research design

A quantitative research approach is “explaining phenomena by collecting numerical data that are analysed using mathematically based methods” (Creswell, 1994).

Although this type of research is initially harder to design, the results are structured and highly detailed and can be easily gathered and statistically presented (Neville, 2005). This Study generated quantitative data through the use of a questionnaire and administering a pre-test and post-test to participants.
3.3.2 Qualitative research design

Denzin and Lincoln (1994) stated that a qualitative research approach aims to interpret or make sense of phenomena in terms of the meanings people bring to them. Qualitative research comprises of first-hand accounts of subjects’ experiences and aims to describe events in detail (Terr & Kelly, 1999). This Study generated qualitative data through an interview with a teacher of post-primary school mathematics who has direct experience and knowledge of the various aspects of calculator usage at junior cycle level.

The use of both quantitative and qualitative methods provides a rich source of data through the drawing of both measurable and non-measurable data covering all aspects of this Study.

3.4 Research Instruments

A number of research instruments were employed to aid in the data collection: a questionnaire, a pre-test, a post-test and an interview. The research instruments are discussed in more detail below.

3.4.1 Questionnaires

Questionnaires have the power to obtain data from a large sample relatively inexpensively and are the most efficient way of collecting research data without placing pressure on its participants (Thietart, 1999). This Study used a researcher designed Likert questionnaire to measure students’ attitudes toward the subject of mathematics and calculator use.

3.4.1.1 Design of Questionnaire

The questionnaire (see Appendix [A]) uses a simple structure which is subdivided into two sections. The first section of the questionnaire measures students’ cognitive attitudes towards the subject of mathematics (items 1 to 10). The second section of the questionnaire measures students’:

1. Anxiety towards calculator use in mathematics (items 11 to 15);
2. Negative thoughts towards calculator use in mathematics (items 16 to 23); and
3. Enjoyment of calculator use in mathematics (items 24 to 31).

All items are closed-ended statements that ask each student to rate as either:

- Strongly Agree (SA);
- Agree (A);
- Disagree (D); or
- Strongly Disagree (SD).

Closed-ended statements were chosen as participants will be able to rate them with minimal effort and answers are easy to analyse. Furthermore, given the age profile of the intended questionnaire recipients the use of open-ended questions was deemed to be inappropriate.

### 3.4.1.2 Analysis of Questionnaire

The participants of the questionnaire were given four response options. These options serve as the quantification of the participants’ agreement or disagreement to each statement. The designated quantifications used in the questionnaire are shown in Table 3.1.

<table>
<thead>
<tr>
<th>Quantification</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>2</td>
<td>Agree</td>
</tr>
<tr>
<td>3</td>
<td>Disagree</td>
</tr>
<tr>
<td>4</td>
<td>Strongly Disagree</td>
</tr>
</tbody>
</table>

**Table 3.1 Quantifications used in the Likert questionnaire**

### 3.4.2 Testing

The pre-test/post-test assessment is widely used, and is accepted as a reliable measure of outcome assessment across many disciplines (Adams, 1995; Gee, 1994). A pre-
test/post-test instrument was utilized to assess the calculator’s role in the mathematical performance of students. The instrument while time-consuming to construct, generated rich and valuable data to assess the calculator’s role in students’ mathematical performance. The pre-test/post-test data can reveal a variance in scores that can be measured for significance.

3.4.2.1 Design of Pre-test

The Guidelines for Teachers of Mathematics at Junior Certificate stated that students should be able to perform the basic skills and carry out the routine algorithms that are involved in doing mathematics without dependence on the calculator (NCCA, 2002). This Study uses a researcher designed pre-test (see Appendix [B]) to measure a student’s ability to carry out a mental mathematics assignment without the aid of a calculator. The pre-test comprises of five sections that test a student’s basic numeracy skills and mental arithmetic skills:

- Section one of the pre-test concentrates on mental computation and the order of operations (questions 1 to 3);
- Section two of the pre-test concentrates on mental computation and the properties of integers (questions 4 to 11);
- Section three of the pre-test focuses on mental computation and the addition, subtraction, multiplication and division of fractions (questions 12 to 17);
- Section four of the pre-test investigates mental computation and the addition, subtraction, multiplication and division of decimal numbers (questions 18 to 22); and
- Section five of the pre-test examines mental computation and recognition of familiar percentages (questions 23 to 27).

3.4.2.2 Design of Post-test

This Study uses a researcher designed post-test (see Appendix [C]) to measure a student’s ability to carry out a mental mathematics assignment with the optional use of the calculator. The structure of the post-test is identical to that of the pre-test however;
the figures contained in each question of the post-test differ from those contained in the pre-test. For example: question 1 of the pre-test asked $3 + 12 \div 6$ compared to question 1 in the post-test which asked $5 + 18 \div 3$. It must be stressed that the difficulty rating is equal for both the pre-test and post-test. After each question in the pre-test the students were asked to indicate by ticking appropriately whether they used a calculator for the question. The literature review revealed that in 2008, 81.1% of Irish third year students surveyed for a report known as “The effects of calculator use on mathematics in schools and in certificate examinations” (Close et al, 2008), stated that they used a calculator ‘often’. With this in mind, the purpose of allowing the optional use of the calculator was to examine the extent to which students with access to calculators chose to use their pencil and paper skills, either in preference to the calculator or in conjunction with it.

3.4.2.3 Analysis of the pre-test/post-test

The designated quantifications used in both the pre-test/post-test are shown in Table 3.2 below. An indicator of the impact of the calculators use on students’ mathematical performance can be obtained through a standardised measure of difference between the means of the students pre-test (without the aid of the calculator) and post-test (with calculator access) scores. The researcher used Cohen’s $d$ a widely used and recommended effect size (Ledesma et al, 2009) for expressing the difference between the two means. Cohen’s $d$ will lend strength to the analysis since the effect size will describe the significance of the findings and will present the findings in a readily understood format (Trusty et al, 2004).
<table>
<thead>
<tr>
<th>Quantification</th>
<th>Observed characteristics of student’s work</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No attempt of question</td>
</tr>
<tr>
<td>1</td>
<td>Attempt shown but incorrect strategy used</td>
</tr>
<tr>
<td>2</td>
<td>Correct strategy but problem not completed</td>
</tr>
<tr>
<td>3</td>
<td>Correct strategy used but incorrect answer due to computational error</td>
</tr>
<tr>
<td>4</td>
<td>Correct answer</td>
</tr>
</tbody>
</table>

Table 3.2 Marking Scheme for Pre-test/Post-test

3.4.3 Interview

An interview is a very versatile way of gathering research data, where the interviewer can probe for responses from the interviewee and examine their attitudes and motives toward the subject (Bell, 2005). An interview is one of the best methods of obtaining personal, detailed, or in-depth information and aligns with the qualitative method applied in this research paper (Walonick, 1996).

The interview instrument was utilized to obtain accounts from those who are directly involved in the subject matter of the Study, the teachers of mathematics at junior cycle level.

3.4.3.1 Design of Interview

The interview was conducted using a one-on-one semi-structured framework. A semi-structured framework was chosen as this provides the researcher with a certain degree of structure as it involves a number of pre-determined questions to cover the subject as well as permitting the interviewer to probe deeper to extract a more rich explanation of answers. The interview was face-to-face with the advantage that the interviewer was able to adapt and clarify the questions when necessary and also to ensure that the interviewee understood each question through repetition and rephrasing.
The content of the questions (see Appendix [D]) for the interview was influenced by the Literature Review (Section [2.7]). The researcher used a mix of both open-ended and closed questions.

The one-on-one semi-structured interview provides the researcher with information about:

- teachers’ attitudes towards the use of the calculator in mathematics;
- which areas of the mathematics curriculum influence the teacher to integrate calculators into the curriculum;
- time spent during mathematics instruction training students to effectively use a calculator; and
- whether school policies exist for the use of the calculator in mathematics.

3.4.3.2 Analysis of Interview

The interview was recorded, transcribed and supplemented with interviewer notes (see Appendix [E] for analysis). The data and observations from the interview analysis were categorised into themes arising in response to the research questions posed.

3.5 Participants of the Study

The participants of this Study comprised of a teacher of mathematics at junior cycle level and thirty-two students of mathematics at junior cycle level.

3.5.1 Student Participants

The thirty-two student participants were selected through purposive sampling. Purposive sampling was used to allow individual judgments to be used when selecting the student participants. This was to facilitate the fact that the Study demanded a combination of both higher and ordinary level students of mathematics at junior cycle level. The student participants were selected from three post-primary schools in the Donegal area.
3.5.2 Teacher Participants

The teacher involved in this Study was also selected purposively as the teacher was known to the researcher.

3.6 Test- administration procedure

There were a number of steps involved in the test-administration procedure as shown in Figure 3.1 below.

![Figure 3.1 The test administration procedure](image)

3.7 Validity of the Instruments

The issue of validity is usually posed in terms of what is a credible claim to fact or truth (Silverman, 2000). One common response to improve validity is the use of data triangulation. Triangulation is the use of multiple sources of research data and multiple methods to enhance the probability that the researchers’ interpretations are credible (Miles & Huberman, 1994). In order to promote validity in this Study the researcher has employed triangulation.
In order to test the validity of the questionnaire and the interview, both were examined by two sample respondents. These respondents were two school teachers known to the researcher; they were not part of the Study and were consulted for the purpose of testing validity. Based on the comments and suggestions made by these respondents, the researcher modified the content of the questionnaire and interview questions. The modifications included the exclusion of irrelevant questions and the revision of certain questions.

Prior to the testing of the students, versions of the pre-test and post-test were verified and examined by a post-primary mathematics teacher. The teacher was consulted on the content of the items in the pre-test and post-test and the estimated time required for a student to answer all items. Based on the comments made by the teacher minor modifications were then made to correct items.

3.8 Reliability of the Instruments

Bell (1993) defined reliability as “the extent to which a test or procedure produces similar results under constant conditions on all occasions” (Bell, 1993, p.64).

Robson (2002) stated that there are four threats to reliability that should be avoided:

- Participant error;
- Participant bias;
- Observer error; and
- Observer bias.

In order to mitigate these threats, the researcher:

- Has not shown personal bias by avoiding certain gestures or comments during the interview so as not to influence the interviewee;
- Has analysed and transcribed the interview results without bias; and
- Explained the aims and objectives of the Study and gave participants constant reassurance regarding their anonymity. This will assist in reducing participant error and bias (Zikmund, 2000).
3.9 Ethical Considerations

All participants were informed about the content and purpose of this Study prior to all data collection techniques being initiated. Permission was required from the participants to use the data collected to aid in the fulfilment of the research goals. Participants had the right to withdraw from the Study without providing reason throughout the research exercise. The interview was recorded with the permission of the interviewee.
Chapter Four

4 The Findings

The goal of this Study was to address the following research questions:

1. Does an issue of mathematics phobia/anxiety exist in Irish post-primary schools?
2. How are students’ attitudes towards mathematics affected by the use of the calculator?
3. Is there a significant difference between students’ pre-test score (without the aid of a calculator) and post-test score (optional use of the calculator)? and
4. What are teachers’ attitudes towards the use of the calculator in post-primary schools?

4.1 Does an issue of mathematics phobia/anxiety exist in Irish post-primary school?

A Likert questionnaire was administered to the student participants to measure their attitudes toward the subject of mathematics. The questionnaire contained a series of statements about student attitudes towards the mathematics discipline and students were asked to indicate their level of agreement with each statement (Strongly Agree, Agree, Disagree, and Strongly Disagree).
The results of the questionnaire are reflected in table 4.1 below:\(^1\):

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maths is fun</td>
<td>5</td>
<td>12</td>
<td>8</td>
<td>7</td>
<td>2.53</td>
</tr>
<tr>
<td></td>
<td>15.63%</td>
<td>37.5%</td>
<td>25%</td>
<td>21.87%</td>
<td>(Disagree)</td>
</tr>
<tr>
<td>Maths if one of my favourite classes in school</td>
<td>2</td>
<td>14</td>
<td>9</td>
<td>7</td>
<td>2.66</td>
</tr>
<tr>
<td></td>
<td>6.25%</td>
<td>43.75%</td>
<td>28.13%</td>
<td>21.87%</td>
<td>(Disagree)</td>
</tr>
<tr>
<td>Maths is boring</td>
<td>6</td>
<td>7</td>
<td>13</td>
<td>6</td>
<td>2.59</td>
</tr>
<tr>
<td></td>
<td>18.75%</td>
<td>21.87%</td>
<td>40.63%</td>
<td>18.75%</td>
<td>(Disagree)</td>
</tr>
<tr>
<td>Doing maths makes me nervous</td>
<td>5</td>
<td>12</td>
<td>10</td>
<td>5</td>
<td>2.47</td>
</tr>
<tr>
<td></td>
<td>15.63%</td>
<td>37.5%</td>
<td>31.25%</td>
<td>15.63%</td>
<td>(Agree)</td>
</tr>
<tr>
<td>I cringe when I go to maths class</td>
<td>5</td>
<td>4</td>
<td>14</td>
<td>9</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>15.63%</td>
<td>12.5%</td>
<td>43.75%</td>
<td>28.12%</td>
<td>(Disagree)</td>
</tr>
<tr>
<td>I am afraid to ask questions in a maths class</td>
<td>6</td>
<td>6</td>
<td>16</td>
<td>4</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>18.75%</td>
<td>18.75%</td>
<td>50%</td>
<td>12.5%</td>
<td>(Disagree)</td>
</tr>
<tr>
<td>I tend to zone out in maths class</td>
<td>4</td>
<td>9</td>
<td>13</td>
<td>6</td>
<td>2.66</td>
</tr>
<tr>
<td></td>
<td>12.5%</td>
<td>28.13%</td>
<td>40.62%</td>
<td>18.75%</td>
<td>(Disagree)</td>
</tr>
<tr>
<td>I fear maths more than any other subject</td>
<td>3</td>
<td>5</td>
<td>18</td>
<td>6</td>
<td>2.84</td>
</tr>
<tr>
<td></td>
<td>9.38%</td>
<td>15.63%</td>
<td>56.25%</td>
<td>18.75%</td>
<td>(Disagree)</td>
</tr>
<tr>
<td>I’m afraid I won’t be able to keep up with the rest of the class</td>
<td>2</td>
<td>14</td>
<td>9</td>
<td>7</td>
<td>2.66</td>
</tr>
<tr>
<td></td>
<td>6.25%</td>
<td>43.75%</td>
<td>28.13%</td>
<td>21.87%</td>
<td>(Disagree)</td>
</tr>
<tr>
<td>Most people who are at work use maths in their jobs</td>
<td>4</td>
<td>19</td>
<td>9</td>
<td>0</td>
<td>2.16</td>
</tr>
<tr>
<td></td>
<td>12.5%</td>
<td>59.37%</td>
<td>28.13%</td>
<td>0%</td>
<td>(Agree)</td>
</tr>
</tbody>
</table>

**Table 4.1 Frequency table of student attitudes towards the mathematics discipline**

Strongly Agree (1.00 – 1.49), Agree, (1.50 – 2.49), Disagree (2.5 – 3.49), Strongly Disagree (3.50 – 4)

---

\(^1\) For further breakdown see Appendix [I], Chart no.1

44
An analysis of the results reveals some interesting insights. Students were in agreement that ‘most people who are at work use maths in their jobs’ with 72% students indicating either ‘strong agreement’ or ‘agreement’.

Student participants ‘disagreed’ with the statement that ‘maths is fun’, with a strong conviction against this statement (22% of students ‘strongly disagreeing’). Furthermore, student participants ‘disagreed’ with the statement ‘that maths was one of their favourite subjects’. Couple this with the results that they ‘agreed’ that ‘doing maths made them nervous’ and the evidence of mathophobia becomes more clear.

On the other hand, over half of the students (59%) ‘disagree’ to ‘strongly disagree’ with the statement that ‘maths is boring’. Students also demonstrated disagreement on the following statements:

- I tend to zone out in mathematics class;
- I fear maths more than any other subject;
- I cringe when I go to maths class; and
- I am afraid to ask questions in maths class.

This seems to suggest that students are not automatically predisposed to just hating mathematics.

The weighted analysis shows that students ‘disagreed’ with the statement ‘I’m afraid I won’t be able to keep up with the rest of the class’, however, it is worth noting that a strong conviction existed in agreement with this statement with half of the students indicating ‘agreement’ or ‘strong agreement’.

It is also worth noting that the analysis of the teacher interview (see Appendix [E]) indicated an issue of mathematics anxiety in the Irish mathematics classroom. The teacher noted that many students make statements such as ‘I hate maths, I’m no good at maths and I will never be any good at maths’.

These findings show that Irish students do suffer from feelings of helplessness, feelings of inability and feelings of fear towards the mathematics discipline.
4.2 How are students’ attitudes towards mathematics affected by the use of the calculator?

The questionnaire contained a series of statements about student attitudes towards the usage of calculators in mathematics and students were asked to indicate their level of agreement with each statement (Strongly Agree, Agree, Disagree, and Strongly Disagree). The statements were divided into three sections:

- Anxiety towards calculator use in mathematics;
- Negative thoughts towards calculator use in mathematics; and
- Enjoyment of calculator use in mathematics.

4.2.1 Anxiety towards calculator use in mathematics

A series of statements contained in the questionnaire looked at students’ anxiety towards the usage of the calculator in mathematics as detailed in Table 4.2:

---

2 For further breakdown see Appendix [I], Chart no.2
I do not feel comfortable when I learn maths using a calculator

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>4</td>
<td>18</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>6.25%</td>
<td>12.5%</td>
<td>56.25%</td>
<td>25%</td>
<td>(Disagree)</td>
</tr>
</tbody>
</table>

The thought of using a calculator in maths activities frightens me

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>14</td>
<td>17</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>3.13%</td>
<td>43.75%</td>
<td>53.12%</td>
<td>(Strongly Disagree)</td>
</tr>
</tbody>
</table>

I am worried about using a calculator because I don’t know what to do if something goes wrong

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>4</td>
<td>17</td>
<td>11</td>
<td>3.22</td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>12.5%</td>
<td>53.12%</td>
<td>34.38%</td>
<td>(Disagree)</td>
</tr>
</tbody>
</table>

The use of the calculator confuses me

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>2</td>
<td>19</td>
<td>11</td>
<td>3.28</td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>6.25%</td>
<td>59.37%</td>
<td>34.38%</td>
<td>(Disagree)</td>
</tr>
</tbody>
</table>

Table 4.2 Frequency table of students responses to anxiety towards calculator usage

Strongly Agree (1.00 – 1.49), Agree, (1.50 – 2.49), Disagree (2.5 – 3.49), Strongly Disagree (3.50 – 4)

Students displayed minimal anxiety levels towards the usage of the calculator in mathematics. In Table 4.2, students demonstrated considerable collective disagreement with the following items:

- I do not feel comfortable when I learn maths using a calculator (81% disagreed):
- The thought of using a calculator in math activities frightens me (97% disagreed):
- I am worried about using a calculator because I don’t know what to do if something goes wrong (88% disagreed); and
- The use of the calculator confuses me (94% disagreed).
4.2.2 Negative thoughts towards calculator use in mathematics

A series of statements contained in the questionnaire looked at students’ negative thoughts towards the usage of the calculator in mathematics (Table 4.3). The students acknowledged that calculators are a good tool for calculation but not for their learning of mathematics with 69% students indicating either ‘strong agreement’ or ‘agreement’ with this statement. Students also agreed that they understood mathematics better if they solve the problem with paper and pencil.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculators are good tools for calculation, but not for my learning of maths</td>
<td>6 (18.75%)</td>
<td>16 (50%)</td>
<td>5 (15.62%)</td>
<td>5 (15.63%)</td>
<td>2.28 (Agree)</td>
</tr>
<tr>
<td>I think learning to use a calculator wastes too much time in the learning of maths</td>
<td>0 (0%)</td>
<td>2 (6.25%)</td>
<td>18 (56.25%)</td>
<td>12 (37.5%)</td>
<td>3.31 (Disagree)</td>
</tr>
<tr>
<td>I feel that calculators should not be used in math test</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>11 (34.37%)</td>
<td>21 (65.63%)</td>
<td>3.66 (Strongly Disagree)</td>
</tr>
<tr>
<td>I feel that calculators should not be used for math homework</td>
<td>0 (0%)</td>
<td>2 (6.25%)</td>
<td>13 (40.62%)</td>
<td>17 (53.13%)</td>
<td>3.47 (Disagree)</td>
</tr>
<tr>
<td>Calculators should only be used to check my answers once I have worked the problems with pencil and paper</td>
<td>0 (0%)</td>
<td>11 (34.37%)</td>
<td>10 (31.25%)</td>
<td>11 (34.38%)</td>
<td>3 (Disagree)</td>
</tr>
<tr>
<td>Using a calculator in maths will cause me to forget how to do basic computational skills</td>
<td>3 (9.37%)</td>
<td>9 (28.13%)</td>
<td>12 (37.5%)</td>
<td>8 (25%)</td>
<td>2.78 (Disagree)</td>
</tr>
<tr>
<td>I understand mathematics better if I solve problems with paper and pencil</td>
<td>4 (14.37%)</td>
<td>14 (43.75%)</td>
<td>9 (28.13%)</td>
<td>5 (15.62%)</td>
<td>2.47 (Agree)</td>
</tr>
</tbody>
</table>

Table 4.3 Frequency table of negative thoughts towards the use of the calculator

Strongly Agree (1.00 – 1.49), Agree, (1.50 – 2.49), Disagree (2.5 – 3.49), Strongly Disagree (3.50 – 4)

The students acknowledged that calculators are a good tool for calculation but not for their learning of mathematics with 69% students indicating either ‘strong agreement’ or ‘agreement’ with this statement. Students also agreed that they understood mathematics better if they solve the problem with paper and pencil.

3 For further breakdown see Appendix [I], Chart no.3
On the other hand, students were largely positive that they should be allowed to use calculators for mathematics homework (94% in agreement), and for the Junior Certificate Mathematics examination (100% in agreement). Interestingly, almost two-thirds of the students (63%) ‘disagree’ to ‘strongly disagree’ that using a calculator will cause them to forget how to do basic computational skills. Also, students ‘disagreed’ with the statements ‘that learning to use a calculator wastes too much time in the learning of maths’ and ‘calculators should only be used to check my answers once I have worked the problems with pencil and paper’. These responses seem to indicate a strong overall support for the use of the calculator in mathematics.

4.2.3 Enjoyment of calculator use in mathematics

A series of statements contained in the questionnaire looked at students’ enjoyment of calculator use in mathematics (Table 4.4)\(^4\).

\(^4\) For further breakdown see Appendix [I], Chart no.4
<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculators make mathematics fun</td>
<td>4</td>
<td>15</td>
<td>10</td>
<td>3</td>
<td>2.38</td>
</tr>
<tr>
<td></td>
<td>12.5%</td>
<td>46.88%</td>
<td>31.25%</td>
<td>9.37%</td>
<td></td>
</tr>
<tr>
<td>Maths is easier if calculators are used to solve problems</td>
<td>15</td>
<td>16</td>
<td>1</td>
<td>0</td>
<td>1.56</td>
</tr>
<tr>
<td></td>
<td>46.88%</td>
<td>50%</td>
<td>3.12%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>I prefer to do all the calculations with the use of the calculator</td>
<td>10</td>
<td>10</td>
<td>12</td>
<td>0</td>
<td>2.06</td>
</tr>
<tr>
<td></td>
<td>31.25%</td>
<td>31.25%</td>
<td>37.5%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>I want to get better at using a calculator to help me with mathematics</td>
<td>10</td>
<td>15</td>
<td>7</td>
<td>0</td>
<td>1.91</td>
</tr>
<tr>
<td></td>
<td>31.25%</td>
<td>46.88%</td>
<td>21.87%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>I enjoy using a calculator in mathematics activities</td>
<td>7</td>
<td>20</td>
<td>5</td>
<td>0</td>
<td>1.94</td>
</tr>
<tr>
<td></td>
<td>21.87%</td>
<td>62.5%</td>
<td>15.63%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>The thought of doing mathematics activities without the use of a calculator frightens me</td>
<td>7</td>
<td>9</td>
<td>16</td>
<td>0</td>
<td>2.28</td>
</tr>
<tr>
<td></td>
<td>21.87%</td>
<td>28.13%</td>
<td>50%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>I enjoy investigating mathematics problems using a calculator</td>
<td>9</td>
<td>16</td>
<td>6</td>
<td>1</td>
<td>1.97</td>
</tr>
<tr>
<td></td>
<td>28.13%</td>
<td>50%</td>
<td>18.75%</td>
<td>3.12%</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.4 Frequency table of students’ enjoyment of calculator use

Strongly Agree (1.00 – 1.49), Agree, (1.50 – 2.49), Disagree (2.5 – 3.49), Strongly Disagree (3.50 – 4)

As reflected in Table 4.4, the student participants were very enthusiastic about the use of the calculator in mathematics. Of student participants, 59% ‘agree’ to ‘strongly agree’ that calculators make mathematics fun, and 63% of students ‘agree’ to ‘strongly agree’ that they prefer to do all calculations with the use of the calculator. 84% of student participants indicated that they enjoy using the calculator in mathematics, and 78% indicated that they would like to get better at using the calculator.

Almost all student participants (97%) ‘agree’ to ‘strongly agree’ that maths is easier if calculators are used to solve problems. The percentages of these responses indicate students’ positive reactions to the use of the calculator in mathematics.
However, student responses were somewhat mixed when it came to student dependency on the use of the calculator in mathematics. 50% of students ‘agree’ to ‘strongly agree’ that the thought of doing mathematic activities without the use of the calculator frightens them whereas, 50% of students disagreed with the statement.

4.3 **Is there a significant difference between students’ pre-test score (without the aid of a calculator) and post-test score (optional use of the calculator)?**

The pre-test (see Appendix [B]) measured a student’s ability to carry out a mental maths assignment without the aid of a calculator. The post-test measured a student’s ability to carry out a mental maths assignment with the optional use of the calculator. The results are analysed under four headings:

- Overall student performance;
- Performance by students according to ability level;
- Performance by students according to mathematics content area; and
- Calculator usage.

4.3.1 **Overall student performance**

It is evident from table 4.5 below that with calculator access a significant change in mathematical performance occurred among the student respondents\(^5\).

---

\(^5\) For further breakdown see Appendix [H], Chart no.1
Student Participants N {32}

<table>
<thead>
<tr>
<th></th>
<th>Pre-test</th>
<th></th>
<th>Post-test</th>
<th></th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>78%</td>
<td>Mean</td>
<td>91%</td>
<td></td>
<td>3.4</td>
</tr>
<tr>
<td>Sd</td>
<td>19.51</td>
<td>Sd</td>
<td>10.51</td>
<td></td>
<td>(LE)</td>
</tr>
</tbody>
</table>

Table 4.5 Overall student performance (pre-test vs. post-test)

\( t = \text{(tabular, } \alpha = .01) \); LE = Large Effect

On the pre-test student participants scored an average mean score of 78%. In comparison, student participants scored an average mean score of 91% on the post-test, an average increase of 13% in proficiency when the calculator was available. These results indicate a statistically significant difference between the pre-test and post-test scores. The effect size of 3.4 associated with this difference is large (Cohen, 1988). Interestingly, 9% of students reported 0% calculator usage in the post-test but yet their performance levels increased from the pre-test. This observation indicates that the presence of the calculator alone may have promoted an increase in a student’s performance (possibly through reduced anxiety levels).

4.3.2 Performance by students according to ability level

In order to analyse, the effect of calculator usage on low-ability students versus high-ability students, the results are grouped by the students’ ability (Higher or Ordinary level). Table 4.6 shows a significant difference in the respective pre-test and post-test mean scores of each ability group in favour of calculator access.
<table>
<thead>
<tr>
<th></th>
<th>Performance by Honour level students N [10]</th>
<th>Performance by Ordinary level Students N [22]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest Pre-test Score</td>
<td>54%</td>
<td>35%</td>
</tr>
<tr>
<td>Highest Pre-test Score</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Pre-test Mean Score</td>
<td>90%</td>
<td>73%</td>
</tr>
<tr>
<td>Standard Deviation (Pre-test)</td>
<td>13.8</td>
<td>19.09</td>
</tr>
<tr>
<td>Lowest Post-test</td>
<td>78%</td>
<td>56%</td>
</tr>
<tr>
<td>Highest Post-test</td>
<td>99%</td>
<td>100%</td>
</tr>
<tr>
<td>Post-test Mean Score</td>
<td>93%</td>
<td>90%</td>
</tr>
<tr>
<td>Standard Deviation (Post-test)</td>
<td>6.2</td>
<td>11.77</td>
</tr>
<tr>
<td>Mean Gain</td>
<td>3%</td>
<td>17%</td>
</tr>
<tr>
<td>Computed t-value</td>
<td>0.73 (SE)</td>
<td>3.72 (LE)</td>
</tr>
</tbody>
</table>

Table 4.6 Student performance (pre-test vs. post-test) by ability level

\[ t = \text{(tabular, } \alpha = .01) ; \text{ SE = Small Effect; LE = Large Effect} \]

As reflected in table 4.6, the more-able students studying at higher level did not benefit from access to a calculator to the same extent as their less-able counterparts studying at ordinary level\(^6\). Student participants studying junior cycle mathematics at ordinary level registered the highest mean gain, with an average increase of 17% in proficiency when the calculator was available. The effect size associated with this difference is large (Cohen, 1988). Interestingly, the lowest pre-test score by an ordinary level student was 35% (5% below the standardised pass rate) in comparison with the lowest post-test

\(^6\) For further comparisons see Appendix [H], Chart no.2 and Chart no.3

53
score by an ordinary level student 56% (16% above the standardised pass rate) an increase of 21%.

The greatest gain registered by an ordinary level student was 47%; student 15 had a score of 53% in the pre-test and a score of 100% in the post-test (student reported 100% calculator usage in the post-test) (see Appendix [H]). This increase in a student’s score may indicate this student’s level of proficiency in the use of the calculator.

Student participants studying junior cycle mathematics at higher level registered an average increase of 3% in proficiency when the calculator was available. The effect size associated with this difference is small (Cohen, 1988). Although the effect was small, the lowest pre-test score by a higher level student was 54% in comparison with the lowest post-test score by a higher level student 78%, an increase of 24%.

4.3.3 Performance by students according to mathematics content area

Table 4.7 provides a breakdown of the students’ performance on the pre-test (without calculator access) and post-test (with optional calculator access) by mathematics content area.  

---

7 See also Appendix [H], Chart no.1
<table>
<thead>
<tr>
<th>Content Area</th>
<th>Student Participants N [32]</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Percent of Calculator usage</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>Sd</td>
<td>Mean</td>
<td>Sd</td>
</tr>
<tr>
<td>Order of Operations</td>
<td></td>
<td>9.47</td>
<td>3.45</td>
<td>10.81</td>
<td>2.58</td>
</tr>
<tr>
<td>Integers</td>
<td></td>
<td>29.22</td>
<td>4.4</td>
<td>30.66</td>
<td>3.61</td>
</tr>
<tr>
<td>Fractions</td>
<td></td>
<td>17.88</td>
<td>8</td>
<td>23.78</td>
<td>0.74</td>
</tr>
<tr>
<td>Decimals</td>
<td></td>
<td>12.84</td>
<td>5.45</td>
<td>17.38</td>
<td>4.16</td>
</tr>
<tr>
<td>Percentages</td>
<td></td>
<td>14.53</td>
<td>6.46</td>
<td>15.59</td>
<td>6.14</td>
</tr>
</tbody>
</table>

Table 4.7 Student performance (pre-test vs. post-test) by content area

\( t = (\text{tabular}, \alpha = .01); \text{NE = No Effect; SE = Small Effect; ME = Medium Effect; LE = Large Effect} \)

The students registered the greatest significant difference between their pre-test and post-test scores in the fractions section, followed by the decimal section, the order of operations and integers. The least gain by student participants between their pre-test and post-test scores was in the section on percentages; although there was a gain in the students score (in favour of calculator access) it was not statistically significant.

It is evident from the analysis of the post-tests that many students were unable to use the calculator for the calculation of percentages. These students may not have received the appropriate instruction for the calculation of percentages using a calculator. Therefore,

---

See also Appendix [H], Chart no.5
the calculator was of no benefit to these students when carrying out the section on percentages. An interesting observation made was that the content area of fractions which has saw the greatest average increase in its score also reported the highest level of calculator usage. This observation may indicate two things:

- that a students’ proficiency in calculator use can lead to greater achievement gains (as seen in the post-test); or
- that a student’s’ proficiency in calculator use for specific mathematical computations has created student’s’ reliance on the calculator to the point of being unable to perform the computation by paper-and-pencil (as seen in the pre-test).

Table 4.8 provides a breakdown of the students’ performance grouped by their ability level, by mathematics content area.

<table>
<thead>
<tr>
<th>Item</th>
<th>Honours N (10)</th>
<th>Ordinary (22)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test Mean</td>
<td>Post-test Mean</td>
</tr>
<tr>
<td>Order of Operations</td>
<td>9.5 3.93</td>
<td>10.2 3.06</td>
</tr>
<tr>
<td>Integers</td>
<td>30.3 2.19</td>
<td>31.2 1.4</td>
</tr>
<tr>
<td>Fractions</td>
<td>21.5 4.76</td>
<td>23.8 0</td>
</tr>
<tr>
<td>Decimals</td>
<td>15.7 3.77</td>
<td>17.8 2.14</td>
</tr>
<tr>
<td>Percentages</td>
<td>13 6.76</td>
<td>14.41 6.77</td>
</tr>
</tbody>
</table>

Table 4.8 Student performance (pre-test vs. post-test) by content area & ability level

\( t = (\text{tabular, } \alpha = .01); \text{ NE} = \text{No Effect}; \text{ SE} = \text{Small Effect}; \text{ ME} = \text{Medium Effect}; \text{ LE} = \text{Large Effect} \)
As reflected in table 4.8, the calculator had the most significant effect on ordinary level students’ performance in the section on fractions with an average increase of 31% in proficiency when the calculator was available, and in the decimal section with an average increase of 28% in proficiency when the calculator was available. The least gain by ordinary level students was in the section on percentages; and by higher level students in the section on order of operations.

4.3.4 Calculator usage

An interesting point of observation from the administering of the tests was the extent to which students with access to calculators continued to use the paper and pencil method. The average calculator usage reported by higher level students in the post-test was 37% in comparison with 66% usage reported by ordinary level students. In the post-test, 20% of higher level students chose to answer all questions on the post-test using paper and pencil methods in preference to the calculator.

4.4 Teachers’ attitudes towards the use of the calculator

The teachers’ attitudes were assessed during a semi-structured interview format (see Appendix [D]) and all verbal explanations were recorded and transcribed (see Appendix [E]). The teacher was given a consent form that explained the study (see Appendix [F]). The teacher was informed that a pseudonym (Sarah) would be used where necessary for his/her name.

Four themes were extracted from the interview data. These themes included:

- teachers’ attitudes towards the use of the calculator in mathematics;
- areas of the mathematics curriculum that influence the teacher to integrate calculators into the curriculum;

---

9 See also Appendix [H], Chart no.4
10 See also Appendix [H], Chart no.5
• time spent during mathematics instruction training students to effectively use a calculator; and
• do school policies exist for the use of the calculator in mathematics?

**Teacher’s attitudes towards the use of the calculator in mathematics**

Sarah’s attitude to calculator use in mathematics at junior certificate level was very positive. She stated that calculators should ‘definitely’ be used for mathematics at junior certificate level but emphasized that the calculator’s introduction should be postponed until the second year of the junior cycle mathematics curriculum. Sarah reasoned that in the first year of the mathematics curriculum at junior certificate level students need to learn the basic mathematical skills which are taught in first year (i.e. integers and fractions) without the aid of a calculator. She stated that students who use the calculator for the learning of these basic mathematical skills do not learn the mathematical methods involved in solving such mathematics problems. Sarah was concerned that the calculator presents the student with an answer but does not show students how to solve the mathematical problem. The example given by the teacher to convey this point was that:

> *if a student were to add \( \frac{3}{4} + \frac{1}{4} \) they need to learn that they must firstly get the lowest common denominator of 3 and 4, divide into the bottom and multiply by the top*

*(Teacher, 2010)*

Sarah found that if students failed to learn the method involved in solving a problem such as the adding of two fractions they would struggle later on when they would be presented with an algebraic equation in fraction form which cannot be solved with the use of a calculator. She emphasized that students need to learn the methods in order to select the appropriate method to solve mathematical problems. Sarah approved of the use of the calculator by her students for mathematics work in class, for homework and for use in the junior certificate examination once students have learned the basic mathematical skills of the junior cycle curriculum.
4.4.1 Positive effects

Sarah saw time management as one of the main benefits in permitting calculator use in the teaching and learning of mathematics. She commented that with the aid of the calculator, students are freed from the burden of looking up the log tables and carrying out needless paper-and-pencil calculations such as long multiplication. Sarah reported that the time saved enabled students to spend more time concentrating on solving other mathematical problems.

Sarah indicated that the calculator has greater benefits for low-ability students. For the low-ability student, the calculator increases their confidence levels, relieves feelings of mathematical anxiety, and improves their attitude towards the mathematics discipline. She reported that students who sat the foundation level junior certificate examination were totally reliant on the calculator. She felt that these students would not have achieved a pass grade without the aid of a calculator.

4.4.2 Negative effects

One of the main concerns expressed by Sarah in relation to the use of the calculator in mathematics is students’ expectation of the calculator. She stated that students view the calculator as a ‘magical device’ that should be able to answer every possible mathematical problem. Sarah found that students do not question the answer the calculator presents. They are disappointed when they are unable to solve a mathematical problem through the use of the calculator reported the teacher. Students still need to know and be able to do mathematics; the calculator is only a helping hand.

Sarah reported that some students have demonstrated an over-reliance on the calculator, using the device to perform basic arithmetic e.g. $28 \div 7$. It was her opinion that it was students who had frequently used a calculator in primary school who had now begun to rely on the calculator to carry out basic arithmetic such as multiplication. She claimed that basic arithmetic ‘the tables’ were no longer being memorized by students in primary schools who regularly used the calculator.
Sarah stated that another disadvantage to the use of calculators arises during mathematics examinations when a mathematical problem can be automated on a calculator, students write down an answer and may not show their working. If a student gives an incorrect answer and shows some working, marks for method can be awarded. However, if a student gives an incorrect answer without any workings shown, then marks cannot be awarded. She also stated that some examination questions require students to show their workings. Therefore, even if a student answers the question correctly but workings are absent then only partial marks are awarded.

Sarah reported another disadvantage of calculator use was that students come to rely on a particular make and model of calculator. The difficulty for a student arises when their calculator is mislaid or broken. She stated that during exam situations, low ability students have been known to panic through the loss of their calculator and their inability to use a different make or model of calculator.

**Areas of the mathematics curriculum influence the teacher to integrate calculators into the curriculum**

When Sarah was asked to identify areas of the mathematics curriculum where the calculator was particularly useful, she identified two particular areas of the mathematics curriculum: area and volume, and trigonometry.

**Time spent during mathematics instruction training students to effectively use calculator**

Sarah found that teaching students to use the calculator takes a long time and needs careful attention. She found that by ensuring students can effectively use the calculator; the greater the impact the calculator has on students’ mathematical performance.

**Do school policies exist for the use of the calculator in mathematics?**

Sarah reported that no school policy on the use of calculators has existed in any of the five Irish post-primary schools she has worked in. However, she felt that the development of a whole school policy on calculator use is essential. It was her opinion
that all mathematics teachers should be “singing from the same hymn sheet” in relation to calculator use.

Sarah stated that she had a policy of no calculator access in the first year of the junior cycle curriculum while other teachers within the same school promoted the use of the calculator by first years. For this reason, Sarah experienced ill-feeling from both her own students and from the parents of these students, as a mathematics classroom without the use of a calculator was labelled as ‘hard work’.

4.5 Summary of major findings

- Of student participants 50% admitted that doing maths made them nervous, and 53% of student participants indicated that they were afraid that they would not be able to keep up with the rest of the class. These responses would suggest that an issue of mathematics phobia/anxiety does exist in the Irish mathematics classroom.
- 3% of student participants indicated that they experienced anxiety when using a calculator.
- Fewer than 13% of student participants worried about using a calculator because they wouldn’t know what to do if something went wrong. This concern was also expressed by the teacher who stated that many low ability students experience panic when they are unable to use a particular make or model of calculator.
- Over two-thirds of student participants ‘agree’ to ‘strongly agree’ that calculators are good tools for calculation but not for their learning of maths, and agreed that they understood maths better if they solved the problem with paper and pencil. The teacher was also of the belief that students need to master mathematical concepts or procedures first by paper-and-pencil methods before using the calculator.
- Almost two-thirds (63%) of student participants disagreed that through the use of calculators they would forget how to do basic computation. The teacher
expressed the opinion that students will forget these basic computational skills if they too frequently use the calculator for the calculation of basic arithmetic.

- Half of student participants ‘agree’ to ‘strongly agree’ that the thought of doing mathematical activities without the use of the calculator frightens them. This percentage would suggest that students rely on the calculator, perhaps due to the confidence in mathematics earned by these students brought about by calculator usage in mathematics. The teacher stated that for the low-ability student, the calculator increases their confidence levels, relieves feelings of mathematical anxiety, and improves their attitude towards the mathematics discipline.

- The mean increase of 13% in proficiency when the calculator was available would suggest that calculator access has a significantly large effect on the mathematical performance of students.

- The more-able higher level students did not benefit from access to a calculator to the same extent (3% average increase in proficiency) as their less-able ordinary level student counterparts (17% average increase in proficiency).

- Students benefited most from calculator usage in carrying out the fractions section of the post-test. The least gain was seen by the section on percentages. This gain may have been greater if students had been proficient in the use of the calculator.

- When students had access to a calculator during the post-test, the ordinary level student chose to solve one third of the questions using paper and pencil methods in preference to the calculator in comparison with the higher level student who chose to solve almost two-thirds of the questions using paper and pencil methods. This indicates that although students had access to a calculator they showed a strong reliance on their paper-and-pencil skills.

- The teacher saw time management as one of the main benefits in permitting calculator use in the teaching and learning of mathematics. The time saved can be spent spending more time on solving mathematical problems.

- The teacher felt that the development of a whole school policy on calculator use is essential for the effective implementation of the calculator in the classroom.
Chapter Five

5 Discussion

The main purpose of this Study was to explore the effects of calculator usage on post-primary mathematics students’ at junior cycle level. This Study achieves this goal by examining the effect of calculator usage on students’ mathematical performance; the attitudes of students and teachers toward calculator usage; and student attitudes towards the mathematics discipline. This chapter reflects on the main research findings from chapter 4 in light of the literature review from chapter 2.

5.1 Does an issue of mathematics phobia exist in Irish post-primary schools?

It is evident from the literature review that there is a growing concern about the low level of mathematical skills of Irish students emerging from post-primary school education. A negative attitude towards mathematics or issue of “mathophobia/mathematics anxiety”, a fear of mathematics, is apparent in Irish society today (IUA, 2008). The importance of students’ attitudes to mathematics has been identified as a factor of their success in the subject of mathematics.

This Study’s results would suggest that student participants were generally very positively disposed towards the mathematics discipline. However, issues of mathematics anxiety can be identified for a number of the student participants. The evidence obtained (as outlined in Section [4.1]) would indicate that there is a perception among Irish students that mathematics is difficult. The analysis of the teacher’s attitudes (as outlined in Section [4.1]) showed that many students fear mathematics and suffer from feelings of frustration or helplessness about their mathematical ability. As discussed in the literature review, these emotional feelings have been identified as psychological symptoms of mathematics anxiety (Cemen, 1987; Haralson, 2003). The analysis as part of this Study showed that the student participants’ attitudes toward mathematics found that just over half of students said that doing mathematics made
them nervous (see Table 4.1). The evidence obtained for this Study supports the view of the IUA (2008) that a level of mathematics anxiety exists for Irish post-primary students, with 23% of the student participants stating that they cringe when going to mathematics class and 25% of the student participants stating that they fear mathematics more than any other subject (see Table 4.1). The results showed that 38% of the student participants were fearful of asking questions during mathematics class and 41% of the student participants indicated that they tend to “zone out” during mathematics class (see Table 4.1). This supports the findings of other research observations that students who suffer from mathematics anxiety are incapable of classroom participation (Tobias, 1993; Mahony et al, 2008). The finding of this Study would also suggest that the mathematics discipline is regarded as monotonous by many students.

Overall, the results obtained for this Study suggests that educators need to focus on improving the mathematics classroom environment in order to reduce issues of mathematics anxiety and foster positive attitudes towards the mathematics discipline.

5.2 How are students’ attitudes towards mathematics affected by the use of the calculator?

5.2.1 Anxiety towards calculator use in mathematics

Although most of the findings from the literature review indicated that students hold positive attitudes towards calculator usage in mathematics, Ruthven (1995) stated that some students hold negative attitudes towards calculator usage in mathematics. As noted in the literature, these students find that calculator usage does not aid them in the learning of mathematics as they lack confidence in the calculator mode of calculation. The evidence obtained (outlined in Section [4.2.1]) from this research paper found minimal levels of anxiety existed towards the usage of the calculator in mathematics among the student participants. Only one of the student participants stated that the thought of using a calculator in mathematics frightened him/her. These results demonstrate that since Ruthven’s claim in 1995, students have rapidly moved in the
direction of technology; the calculator has become ubiquitous supporting Abdullah *et al* (2005) claim that students from this era have had a broad exposure to calculator usage and have a positive acceptance of the use of the calculator in the mathematics classroom.

From the literature, the report “Pressing the right buttons: calculator use in schools and Junior Cycle Mathematics” (*Surgenor et al*, 2007) reported that one of the main perceived disadvantages of calculator use in the mathematics classroom was students’ difficulty in using the calculator. The results obtained (outlined in Section [4.2.1]) from this Study found that only two of the student participants stated that the calculator confused them. An assumption made in this Study is that since 2004 there has been a substantial increase in calculator usage within Irish post-primary schools (*Close et al*, 2008). *Close et al* (2008) found that 81.1% of Irish third year students surveyed in 2008 stated that they used a calculator ‘often’ in the mathematics classroom, when fewer than 1% reported using a calculator ‘often’ in 2000. The evidence obtained for this Study further suggests that students today have become fluent in technology and no longer perceive the calculator as difficult.

### 5.2.2 Negative thoughts towards calculator use in mathematics

In the literature, the report “Pressing the right buttons: calculator use in schools and Junior Cycle mathematics” (*Surgenor et al*, 2007) reported that students who were ‘negatively disposed’ to the calculator and felt that calculator usage would make them lazy, had lower performance levels on each of the calculator tests in comparison with students who did not hold such views. The evidence obtained (outlined in Section [4.2.2]) in this Study indicated that student participants were in acknowledgement that calculators are good tools for calculation but not for their learning of mathematics. The results of this Study could maybe indicate that many Irish students fear that the calculator does not engage the brain and will make them lazy (*Surgenor et al*, 2007). However, there is considerable support in the literature review that when used appropriately, calculators enhance students learning of mathematics (*Hembree & Dessart*, 1992; *Gilchrist*, 1993; *Smith*, 1997; *NCTM*, 2000; *Ellington*, 2003). From the
evidence obtained in this Study, it could therefore be suggested that it is of paramount importance that the Department of Education and teachers need to address the myth that calculators make students lazy.

As discussed in the literature review, the main fear cited by critics is that calculator usage within the mathematics classroom could affect a student’s mastery of basic computational skills acquired through the traditional paper-and-pencil methods (NCTM, 1974). The evidence presented as part of this Study found that the student participants ‘disagreed’ that calculator usage would cause them to forget how to do basic computational skills supporting findings by Ellington (2003) who found that students who used a calculator during instruction and testing maintained their paper-and-pencil skills, both in basic computational skills and problem solving.

The results obtained for this Study found that calculator use should not be confined to the mere checking of work supporting claims from Ellington (2003) that the calculator should have a pedagogical role in the mathematics classroom.

5.2.3 Enjoyment of calculator use in mathematics

From the literature review, Linn (2000) found that too much of mathematics instruction is spent teaching students how to use a calculator instead of teaching mathematics computation and mathematics problem solving skills. The evidence obtained (outlined in section [4.2.3]) found that a significant majority of student participants (94%) ‘disagreed’ with Linn’s statement, and 78% of student participants stated that they would like to get better at using the calculator, supporting claims by Abdullah et al (2005) that students from this ‘era’ have had a broad exposure to calculators and have a positive acceptance of the use of the calculator in the mathematics classroom.

The results obtained in this Study found that the majority of students stated that mathematics is easier if the calculator is used to solve problems lending support to the idea that the calculator will improve students’ ability to solve problems (Dunham & Dick, 1994).
Ellington (2003, 2006) and Hembree and Dessart (1986) stated that the calculator has the potential to make mathematics a more enjoyable and positive experience. Countryman and Wilson (1991) reported that students who used a calculator in mathematics were enthusiastic about mathematical fundamentals. Kaiser (1994) reported that after a few weeks of calculator usage within the mathematics classroom, students were more eager to attend mathematics class. The results obtained for this Study mirror the findings above. This Study found that student participants are enthusiastic about calculator usage in mathematical activities; and for the investigation of mathematical problems. Orton (1992) recommended calculator use to help students construct their own understanding of arithmetic. The evidence obtained (outlined in section [4.2.3]) for this Study indicated that the calculator has the potential to make the mathematics discipline ‘fun’ supporting Tsao’s (2006) claim that students who are exposed to a constructivist-based learning approach gain positive attitudes toward the topic.

5.3 Is there a significant difference between students’ pre-test score (without the aid of a calculator) and post-test score (optional use of the calculator)?

5.3.1 Overall student performance

The research evidence obtained (outlined in section [4.3.1]) for this Study found that a statistically significant difference existed between students’ pre-test mean score (without calculator access) and students’ post-test mean score (with optional calculator access). The significance of difference between the pre-test mean score and the post-test mean was found by applying Cohen’s d. The results indicate that calculator usage improved the mathematical performance of student participants in the subject of mathematics at post-primary junior cycle level. This supports Hembree and Dessart (1986), Kaiser (1994), Smith (1997) and Ellington (2003, 2006) separate assertions in this area.
The evidence obtained in this Study found that with calculator access:

- student participants made less computational errors supporting claims from NCTM (2000) that calculator usage will support students’ computational abilities;
- student participants calculated more quickly and efficiently reducing computational time thus allowing them to complete more questions in accordance with the findings of Pomerantz and Waits (1997) and the National Research Council (1990); and
- student participants attempted more questions as advised by Suydam (1976).

From the results obtained it could also be suggested that the significant difference in student participants mean test scores may have been caused by the enthusiasm and confidence promoted through calculator access as suggested by Wheatley (1980), Hembree and Dessart (1986) and Pennington (1998). Also, the calculator may have acted as an anxiety reducer thereby increasing the student participants’ confidence, hence giving support to the findings of Boers and Jones (1993), Dunham (1991) and Dunham and Dick (1994).

An interesting observation of this Study was that 9% of student participants reported 0% calculator usage in the post-test but yet their performance in the post-test was greater than their performance in the pre-test. This may indicate that the presence of the calculator alone promoted an increase in student participants’ mathematical performance. Therefore it could be suggested that the calculator’s presence generated positive feelings in student participants about the post-test leading to an increase in their confidence, thereby leading to an increase in the mathematical performance of student participants.

5.3.2 Performance by students according to ability level

The data results obtained (outlined in section 4.3.2) for this Study found that calculator usage, improves students’ performance in the subject of mathematics, with higher achievement gains for the ordinary level student participants. The results showed that
the higher level student participant saw an average increase of 3% in mathematical proficiency in comparison with the ordinary level student participant who saw an average 17% increase in mathematical proficiency. This would indicate that calculator access may not be as important for higher level students, perhaps due to their efficient computation strategies or due to a ceiling effect. A ceiling effect is said to occur when a high proportion of student participants receive the maximum score available in the pre-test leaving no space for improvement in their performance in their post-test score.

5.3.3 Performance by students according to mathematics content area

The research evidence obtained (outlined in section [4.3.3]) for this Study found that student participants registered the greatest significant difference between their pre-test and post-test scores in the fractions section, followed by the decimal section, the order of operations and integers. The least gain by student participants between their pre-test and post-test scores was in the section on percentages; although there was a gain in the student participants score (in favour of calculator access) it was not statistically significant. This may suggest that many student participants were not proficient in the use of the calculator for certain areas of the post-test. Student participants need to be aware of all of the features on the calculator in order to be able to select the appropriate method and feature to reach the correct solution to the mathematical problem presented. The results indicate that many student participants may not have received appropriate instruction in the usage of the calculator and were therefore unable to make full use of the technology available to them. This result highlights the importance of a student’s need to become proficient in calculator usage in order to solve problems efficiently.

5.3.4 Calculator usage

The research evidence obtained (outlined in section [4.3.4]) for this Study found that many student participants chose paper-and-pencil methods in preference over the calculator during the post-test. The average calculator usage reported by higher level student participants in the post-test was 37% in comparison with 66% usage reported by ordinary level student participants. In the post-test, 20% of higher level student
participants chose to answer all questions on the post-test using paper-and-pencil methods in preference over the calculator. From the research results obtained for this Study, it could be suggested that the presence of the calculator in the post-test expanded the mathematical ability of student participants but did not replace their mental and paper-and-pencil skills. This observation supports findings from Ellington (2003) that students maintained paper-and-pencil skills during instruction and testing when the calculator was available and findings from Smith (1997) who reported that calculator usage did not hinder students’ development of paper-and-pencil skills.

5.4 What are teachers’ attitudes towards the use of the calculator in post-primary schools?

Teacher’s attitudes towards the use of the calculator in mathematics

The evidence obtained (outlined in section [4.1]) for this Study indicated that mathematics teachers were very positive towards the usage of the calculator in the mathematics classroom. In accordance with Suydam (1976) the teacher interviewed for this Study felt that in order for students to be successful in their mathematics learning they must learn the ‘basics’ first without the aid of the calculator, as opposed to the usage of the calculator in conjunction with traditional mathematics as suggested by Hembree and Dessart (1986). This research result obtained in this Study also gives support to findings by Antonijević (2005) that students with no calculator access in the mathematics classroom must “master all needed abilities and skills in the area of calculating”, consequently these students attain better test scores in mathematics.

5.4.1.1 Positive effects

The analysis of the Teacher attitudes for this Study (outlined in section [4.4.1]) in relation to the usage of calculators in mathematics highlighted two main advantages in calculator use: time management and the effect of calculator use on low-ability students. The Teacher indicated that calculator usage freed students from the burden of looking at the log tables and carrying out needless paper–and-pencil calculations such as long
division, allowing them to concentrate on solving other mathematical problems. This supports Pomerantz and Waits (1997) claim that there is little mathematical thinking involved in doing tedious mathematical computations such as long division, and the Irish Mathematics Teachers’ Association (1980) argument that the calculator enables students to concentrate on mathematical ideas rather than on routine computations.

The second significant advantage highlighted by the Teacher is that calculator usage helps students, particularly those of a lower ability;

- to become more confident in their mathematical ability, reaffirming the findings of Stuart (2000);
- relieve issues of mathematics anxiety as had been suggested by Boers & Jones (1993), Dunham (1991) and Dunham & Dick (1994);
- increase enthusiasm in accordance with Countryman and Wilson (1991), Pennington (1998), and Wheatley (1980); and
- improves their attitude toward the mathematics discipline, supporting Hembree and Dessart’s (1986) claims.

The research evidence obtained for this Study supports Suydam (1976) assertion that for low-ability students the non-use of the calculator would condemn them to a life without arithmetic. The Teacher noted that for the low-ability student particularly those studying mathematics at foundation level, the calculator is not a crutch but their only way of accessing the right answer.

5.4.1.2 Negative effects

The analysis of the Teacher attitudes for this Study (outlined in section [4.4.2]) in relation to the usage of calculators in mathematics dwells on two concerns in calculator usage: a student’s relationship with the calculating device and the dependency problem. The first concern is that students’ especially low-ability students become accustomed to a particular make and model of calculator and establish a relationship with the machine. For the student, the process of becoming accustomed to a calculator is both slow and complex because it requires sufficient time to achieve the organization of procedures.
The research evidence obtained stated that when students suddenly have no access to the calculator that they have grown accustomed to, they panic and become unable to perform within the mathematics classroom or within a mathematics examination. To date academic research and literature has not adequately described or investigated the emotional dependence that can exist between a student and the calculator nor the negative attitude or anxiety created when the calculator is taken away. In 1980’s Ireland, an argument against the use of the calculator was the fear that the calculator would malfunction during a state examination (Surgenor et al, 2007). However this debate was only concerned with the device presenting the student with an incorrect answer and not the impact of this malfunction on a student’s anxiety levels. Further research that investigates this relationship between the student and the calculator may be useful in the future.

The second concern identified in the results obtained in this Study was the fear that students may become over-reliant or dependent on the calculator; the risk of the calculator serving as a “crutch” for students, linking in with findings from Usiskin (1978) and Mc Cauliff (2004). Suydam (1982) stated that no evidence had been found to suggest that elementary students become calculator dependent. However, the Teacher indicated that students who come to regularly use the calculator in their primary school education were now showing signs of dependency on the calculator for basic computations within their post-primary mathematics classroom. This observation supports Engineers Ireland (2008) claim that the reliance on calculators in early school years will lead to a general decline in some aspects of a student’s numeracy skills and also of Hembree and Dessart’s (1986) assertion that calculators have a negative impact on the paper-and-pencil skills of students at one particular grade level, fourth grade (primary school). Reynolds and Farrell (1996) suggested in their review of international surveys of educational achievement that the early introduction of calculators into the mathematics classroom, and their too frequent use, is one of the reasons for relatively poor performance of students in mathematics. A similar pattern was evident from the research results of the TIMSS, where the frequent usage of the calculator by fourth grade students was negatively associated with mathematics achievement in several
countries. High performing countries such as Japan, South Korea used the calculator to a lesser degree (Grønmo & Onstad, 2009). Further research looking at this link between a student’s age and calculator dependency could be undertaken to determine an appropriate timing for calculator integration into a student’s education. The research results obtained for this Study identified another type of reliance among students in that students tend not to recheck their answers on the calculator, confirming the findings of Hunsaker (1997) that students do not question an answer presented by the calculator as they believe that the calculator is always right.

**Which areas of the mathematics curriculum influence the teacher to integrate calculators into the curriculum?**

The research evidence obtained (outlined in section [4.1]) showed that calculator usage was particularly important for certain areas of the mathematics curriculum such as area and volume, and trigonometry.

**Time spent during mathematics instruction training students to effectively use a calculator**

The research evidence obtained (outlined in section [4.1]) for this Study highlighted that teaching students to use the calculator efficiently takes time and careful attention. This suggests that by ensuring that students can effectively use the calculator the greater the impact the calculator has on students’ mathematical performance a view further supported by Ellington (2003, 2006) and Kaiser (1994).

**Do school policies exist for the use of the calculator in mathematics?**

The evidence obtained (outlined in section [4.1]) for this Study highlighted the importance of implementing a clear calculator policy within the post-primary mathematics education system. Where no calculator policy existed, teachers within the same school teaching at the same grade employed different policies of calculator usage. It could therefore be suggested that a clear calculator policy could play an important role in teaching students how to appropriately use the calculator. No discussion on an
efficient calculator usage policy was evidenced in the literature review. As such, this area could also form the basis for further research in the future.
Chapter Six

6 Summary, Conclusions and Recommendations

The purpose of this Study was to investigate the effects of calculator usage on post-primary mathematic students at junior cycle level. This chapter summarises the findings, draws conclusions, makes recommendations, and presents suggestions for future research.

6.1 Summary

Mathematical proficiency is playing an increasingly essential role for living and working in today’s modern society. Students who have a poor level of mathematical ability will have limited opportunities to pursue higher levels of education and to compete for quality careers. All Irish students need to achieve mathematical proficiency; however, many Irish students are not confident about their mathematical ability. A negative attitude or anxiety toward the mathematics discipline is thought to plague learners at every level of Irish post-primary schools (IUA, 2008). So there is a challenge in the Irish education system to provide Irish students with the mathematical knowledge, skills, understanding and confidence needed for life and work in the 21st century.

The NCTM recommends the use of the calculator in supporting students’ computational abilities in enhancing the learning of mathematics at every grade level from kindergarten through to college (NCTM, 2000). However, this view is not shared by all. Engineers Ireland (2010) have proposed that the Irish Minister for Education should ban or withdraw calculators at both primary and post-primary levels up to and including the Junior Certificate, reporting that the reliance on calculators in early school will interfere with a student’s mathematical ability.

The most recent Irish research conducted in the area of calculator usage looked at the effects of calculator usage on students studying for the Junior Certificate in the years
2001 and 2004, but it could be said that since 2004 students have become more fluent in
the usage of technology (Close et al., 2004). Therefore, it could be suggested that there
is a need for more up-to-date research. Close et al. (2008) claimed that few studies have
been completed on teachers’ attitudes toward calculator usage in the Irish mathematics
classroom. It was the aim of this Study to narrow the research gap in these respects.
This Study intended to investigate the following research questions:

1) Is there evidence of the existence of math phobia in Irish post-primary schools?
2) Are students’ attitudes towards mathematics affected by the use of the calculator and
   if so, how?
3) Is there a significant difference between students’ pre-test score (without the aid of a
   calculator) and post-test score (optional use of the calculator)?
4) What are teachers’ attitudes towards the use of the calculator in post-primary
   schools?

6.2 Question 1 - Is there evidence of the existence of math phobia in Irish post-primary schools?
Evidence in the literature review suggests that a student’s mathematical ability is
strongly influenced by their attitude to the mathematics discipline rather than their
cognitive skill. This Study identified that an issue of mathematics phobia/anxiety exists
for some of the student participants, potentially affecting their mathematical ability.

6.2.1 Recommendations
To lessen a student’s mathematics anxiety, teachers need to capitalise on the use of the
calculator in the mathematics classroom. The appropriate use of the calculator would:

- Encourage students to become active participants in their own learning as
  indicated in the research evidence in this Study. The literature review (outlined
  in section [2.2]) highlighted that students who were exposed to a constructivist-
based learning approach in a mathematics classroom gained positive attitudes towards the topic.

- Expand students’ mathematical ability. As discussed in the literature review (outlined in section [2.3]) if a student’s performance level in mathematics increases, their enthusiasm towards the mathematics discipline will also increase.
- Increase students’ confidence levels. The calculator provides students with additional problem solving tools and the ability to check answers in a private, non-threatening way. This feature of calculator use provides an environment for students, one in which they would not feel ridiculed and may be motivated to persevere.

6.3 Question 2 - Are students’ attitudes towards mathematics affected by the use of the calculator and if so, how?

The research results obtained for this Study indicated that students overall attitudes to mathematics are positively affected by the presence of the calculator. Students believe that the calculator has the potential to make the study of mathematics more enjoyable. This Study identified that with calculator access students are more confident about their mathematical ability and enthusiastic about solving mathematical problems. Students viewed the calculator as more than just a simple computational device but a pedagogical tool that facilitates their mathematical exploration. Students’ reported enthusiasm in relation to the learning of mathematical concepts through the use of the calculator and were eager to become proficient in the use of the calculator.

6.3.1 Recommendations

Teachers should encourage students to use the calculator for the exploration of mathematical problems. This exploratory activity in mathematics has a number of advantages:
• It will encourage students to become active rather than passive learners. The literature review noted that students who are active in constructing their own understanding of mathematical concepts gained positive attitudes towards mathematics.

• As students use the calculator to explore possible solutions to a mathematical problem, their problem solving skills will develop.

6.4 Question 3 - Is there a significant difference between students’ pre-test score (without the aid of a calculator) and post-test score (optional use of the calculator)?

The research evidence obtained for this Study found that a statistically significant difference existed between student participants pre-test mean score (without the aid of the calculator) and student participants post-test mean score (optional use of the calculator). The results obtained demonstrated that the use of the calculator can increase students’ performance levels in a basic computational mathematics test with higher achievement gains for ordinary level students. By mathematical content area, the greatest significant difference between student participants’ pre-test and post-test scores was in the section on fractions. The least gain by student participants between their pre-test and post-test scores was in the section on percentages. The results demonstrated that the availability of the calculator alone may have promoted an increase in students’ results.

6.4.1 Recommendations

It was evident during this Study and from the Study results that many students were not proficient in the use of the calculator for certain mathematical areas. The following recommendations can be made in this respect:

• Teachers may not be proficient in the use of the calculator. Therefore, it would be recommended that teachers are provided with professional training in
calculator use in order to facilitate and enhance the use of the calculator in mathematics.

- If students are to make effective use of the calculator in a mathematics examination, they need to have frequent opportunity to practise using their calculator, so that they become familiar with the calculator, with all of its features and to be confident in its use.

6.5 Question 4 - What are teachers’ attitudes towards the use of the calculator in post-primary schools?

The results obtained for this Study indicate that teachers are generally very positive towards the usage of the calculator in mathematics. The Teacher interviewed reported that calculator use leads to increased speed and accuracy of students’ mathematical computations. The Teacher pointed out that calculator use freed students from the burden of looking at the log tables and carrying out needless paper–and-pencil calculations, allowing them to concentrate on solving other mathematical problems. The Teacher stated that the calculator helps students, particularly those of a low-ability, to become more confident in their mathematical ability; relieves issues of mathematics anxiety; increases enthusiasm; and improves attitudes toward the mathematics discipline. The Teacher stated that calculator use empowers lower ability students to solve mathematical problems that they may not have attempted if they had to perform them by paper-and-pencil methods alone.

The Teacher was concerned that students especially lower ability students become accustomed to a particular make and model of calculator and establish a relationship with the machine. For a low-ability student, the process of becoming accustomed to a calculator is often slow and complex as students require sufficient time to achieve the organization of procedures. When students do not have access to the calculator they have grown accustomed to they may ‘panic’ and be unable to perform mathematically as a result. The Teacher expressed a fear that the indiscriminate use of the calculator by students during their primary school education encourages laziness in students. The
Teacher reported that these students already show signs of calculator dependence, unable to recall basic mental computations without the aid of the calculator. Another fear expressed by the Teacher in relation to a students’ dependency on the calculator is the trust students have in the calculating device, students do not challenge results presented by the calculator.

The Teacher asserted that the introduction of the calculator into a student’s education should be withheld until second year of their post-primary education, until students have mastered the basic mathematical computations required for the post-primary Junior Certificate curriculum. The Teacher stated that a lot of time is required to teach students how to effectively use the calculator. The longer students have access to the calculator the greater the impact the calculator has on students’ mathematical performance. The Teacher also highlighted the importance of implementing a clear calculator policy within the post-primary mathematics education system. At present, many post-primary schools have no calculator usage policy in place allowing teachers teaching at the same grade level to employ different policies of calculator usage.

6.5.1 Recommendations

- Teachers need to give students every opportunity to develop familiarity with basic computational skills first without the use of the calculator. The calculator is there to ‘complement’ a student’s mathematical learning ‘not to replace’ it (Pomerantz and Waits, 1997).
- Educators need to develop a clear calculator usage policy. Teachers of the same grade or level should be implementing the same policy in relation to calculator use to help avoid an inconsistent mathematical learning experience for students of the same level nationally.
- Teachers need to take time to teach students how to effectively and efficiently use the calculator, as well as make students aware of the calculator’s limitations.
6.6 Conclusion

We live in an age where technological innovations such as the calculator have a profound effect on the way we live and learn. This Study investigated the effects of calculator usage on post-primary mathematic students at junior cycle level. The research evidence obtained from this Study would suggest that if used appropriately, the calculator offers an opportunity for pedagogical enhancement and improvement of the quality of a student’s learning environment in mathematics. This Study showed that calculator use freed students from the burden of looking at the log tables and carrying out needless paper–and-pencil calculations, allowing them to concentrate on solving other mathematical problems. This Study revealed that calculator use makes students feel more confident about their mathematical ability; reduces mathematics anxiety; leads to an increase in students’ performance in mathematics; and positively affects students’ attitudes towards the mathematics discipline. However, it cannot be overlooked that many research studies have shown that the introduction of the calculator into a student’s learning environment doesn’t always demonstrate positive results. Critics fear that the calculator will serve as a ‘crutch’ for students, impairing students’ ability to execute simple mathematical computations, resulting in students’ mathematical illiteracy. This Study would suggest that a mathematics curriculum without calculator access would only serve to alienate many students from the mathematics discipline.

In conclusion, this Study would recommend that if students are given appropriate instruction on when it is best to use the calculator and when is it best to use paper-and-pencil methods, the calculator will not pose a threat to a student’s mathematical ability.

6.7 Limitations and Recommendations for Future Research

- The overall results of this Study indicate that calculator usage can improve the mathematical performance of students’ from the Donegal area at post-primary junior cycle level. However, the Study is limited. The small number of student participants and the limited geographic area restricts the generalisability of this
Study. As such, the findings cannot be applied to the whole population of junior cycle mathematics students in Ireland. Therefore, this Study should be repeated with more participants using a wider geographic area, perhaps as part of a national research programme supported by the Department of Education.

- The students who participated in this Study had been exposed to calculator use for approximately six years of their education i.e. from fourth class primary school to third year post-primary school. Future research should look at the long term effects of prolonged exposure to calculator use, at how early the calculator should be introduced and under what circumstances its use should be encouraged and when it should be discouraged.

- In addition, the number of teachers interviewed is not statistically significant and may not have been sufficient to identify all teacher attitudes towards calculator usage. Further research is needed to identify all teacher attitudes towards calculator usage.

- This Study did not look at the reasons for the student participants’ mathematics anxiety. Future research should look at causes of mathematics anxiety among Irish students, find out the extent to which students suffer from mathematics anxiety and look at ways of preventing a student’s initial development of mathematical anxiety.

- This Study looked at ways in which educators or teachers could strive to lessen mathematics anxiety; it did not look at ways of preventing mathematics anxiety. It therefore could be suggested that future Irish research should focus on ways of preventing mathematics anxiety in students. Such research could be facilitated by looking at the subject matter both from an educational perspective and a psychological perspective.

- This Study focused on the effects of calculator use on post-primary junior cycle students. Other technologies should also be explored to establish if there are other technological innovations that can help improve the mathematics experience for students and eliminate mathematics anxiety from the classroom.
This Study did not prescribe an effective instructional strategy for incorporating the calculator into students’ mathematical learning. Research could be undertaken to analyse appropriate calculator use versus ‘mindless button pushing’ of the calculator, and to determine whether students use calculators for mathematical computations that would be better approached by paper-and-pencil techniques or mental estimation (NCTM, 1999).

This Study did not determine an appropriate time for the calculators introduction into students education. Further research looking at this link between a student’s age and calculator dependency could be undertaken to determine an appropriate timing for calculator integration into a student’s education.
7 Bibliography


Abelson, P.H. (1972) 'The Fourth Revolution The Fourth Revolution: Instructional Technology in Higher Education.', *Science Journal Citation*: 177, 4044, 121, Jul 72; *Journal Citation*:


Adams, D.L. (1995) 'The Effect of a Semester of Experience on the Self-Reported Academic and Social-Transitional Anxieties of First-Year Community College Students.', *Journal Citation*:


Burns, M. (1998) 'Math: Facing an American Phobia.', Journal Citation:.


Cangelosi, A. (1996) 'The role of development in connectionist models'.


Cemen, P.B. (1987) 'The Nature of Mathematics Anxiety.', Journal Citation:. 


Fiore, G. (1999) 'Math-Abused Students: Are We Prepared to Teach Them?', *Mathematics Teacher Journal Citation: v92 n5 p403-06 May 1999*.


Fosnot, C. and Twomey, E. (1996) 'Constructivism. Theory, Perspectives, and Practice.', *Journal Citation*.

Frye, S.M. (1991) 'Communicating the Next Message of Reform through the Professional Standards for Teaching Mathematics. ERIC/SMEAC Mathematics Education Digest.', *Journal Citation*.


Myers, M.D. (1997) ‘Qualitative research in information systems.’ MIS Q., 21(2), 241-242


NCTM (National Council of Teachers of Mathematics) (1989)


Orne, M.T. (1962) 'On the social psychology of the psychological experiment: With particular reference to demand characteristics and their implications', American Psychologist, 17(11), 776-783.


Pennington, R. (2006) 'The Effects of Non-CAS Graphing Calculators on Student Achievement and Attitude Levels in Mathematics: A Meta-Analysis Authors: Ellington, Aimee J; A Study To Determine the Effect of Instruction in Effective Use of a Calculator on Test Scores of Middle School Students.', School Science and Mathematics Journal Citation: v106 n1 p16 Jan 2006; Journal Citation:.

Pennington, R. (1998) 'A Study To Determine the Effect of Instruction in Effective Use of a Calculator on Test Scores of Middle School Students.', Journal Citation:.


Pomerantz, H. (1997) 'The role of calculators in math education (Research compiled under the direction of Bert Waits)', Ohio State University.


Robertson, D.F. and Claesgens, J. (1983) 'Math Anxiety--Causes and Solutions.', Journal Citation:


Suydam, M.N. (1982) 'The Use of Calculators in Pre-College Education: Fifth Annual State-of-the-Art Review'. Journal Citation


Tobias, S. (1978) 'Managing Math Anxiety: A New Look At An Old Problem', Children Today Journal Citation: 7, 5, 7-9,36, Sep/Oct 78.


Usiskin, Z. (1978) 'Are Calculators a Crutch?', Mathematics Teacher Journal Citation: 71, 5, 412-3, May 78.


Appendices

Appendix A: Questionnaire administered to student participants

**Student Questionnaire**

*Thank you so much for your cooperation in completing this questionnaire*

Name: __________________________ Date: ____________

**Section 1 - Attitudes toward Mathematics**

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maths is fun</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maths is one of the my favourite classes in school</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maths is boring</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doing maths makes me nervous</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I cringe when I have to go to a maths class</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am afraid to ask questions in a maths class</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I tend to zone out in maths class</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I fear mathematics more than any other subject</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I’m afraid I won’t be able to keep up with the rest of the class in maths</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Most people who are at work use maths in their jobs

Section 2 – Attitudes toward the use of calculators in mathematics

Anxiety towards the use of the calculator in mathematics

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I do not feel comfortable when I learn maths using a calculator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The thought of using a calculator in maths activities frightens me</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am worried about using a calculator because I don’t know what to do if something goes wrong</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The use of a calculator confuses me</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Negative thoughts towards the use of the calculator in mathematics

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculators are good tools for calculation, but not for my learning of maths</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I think learning to use a calculator wastes too much time in the learning of maths</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I feel that calculators should not be used in math tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I feel that calculators should not be used for math homework</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculators should only be used to check my answers once I have worked the problems with pencil and paper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using a calculator in maths will cause me to forget how to do basic computational skills</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I understand mathematics better if I solve problems with paper and pencil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enjoyment towards the use of the calculator in mathematics</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Disagree</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
<td>----------------</td>
<td>-------</td>
<td>----------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Calculators make mathematics fun</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maths is easier if calculators are used to solve problems</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I prefer to do all the calculations with the use of the calculator</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I want to get better at using a calculator to help me with mathematics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I enjoy using a calculator in mathematics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The thought of doing mathematics activities without the use of a calculator frightens me.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I enjoy investigating mathematics problems using a calculator</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix B: Pre-test administered to student participants

Mental Maths Assignment

Tick Appropriate Level ✓

Foundation ☐  Ordinary ☐  Honours ☐

Carry out the following tasks without the use of a calculator – Please attempt all questions

Section 1 - Order of Operations

Question 1
Calculate: \( 3 + 12 + 6 \)

Question 2
Calculate: \( 5 \times 2 + 15 \div 3 + 4 \)

Question 3
Calculate: \( \frac{6 + 5 \times 3}{11 - 4} \)
Section 2 - Integers

Question 4
Calculate: \(-2 + 8\)

Question 5
Calculate: \(3 + 7 - 4 - 6\)

Question 6
Calculate: \(3 \cdot (-5)\)

Question 7
Calculate: \(20 ÷ -4\)
Question 8
Calculate: \[ 5^2 \]

Question 9
Calculate: \[ (-1)^3 \]

Question 10
Calculate: \[ 6 \cdot (-2) - 5 \cdot (-3) - 3 \]

Question 11
Calculate: \[ \frac{18 + 2 \times 3}{2(5 - 1)} \]
Section 3 - Fractions

Question 12
Calculate: $\frac{1}{2} + \frac{1}{3}$

Question 13
Calculate: $\frac{2}{3} \times \frac{1}{4}$

Question 14
Calculate: $\frac{3}{4} - \frac{1}{3}$

Question 15
Calculate: $2 - \frac{1}{4}$
Question 16
Calculate: $\% \times \%$

Question 17
Calculate: $\% \div \%$
Section 4 - Decimals

Question 18
Calculate: \( 10.3 + 4.8 - 8.9 \)

Question 19
Calculate: \( 12.88 + 4.6 - 1.2 \)

Question 20
Calculate: \( 1.1 \times 3.4 \times (6.5) \)
Question 21
Calculate: \( \frac{2.45}{16.32 - 11.20} \)

Question 22
Calculate: \( \frac{3.04 + 4.76}{0.99 - 0.06} \)

Section 5 - Percentages

Question 23
Calculate: Write 15% as a fraction

Question 24
Calculate: Find 10% of €380

Question 25
Calculate: Find 20% of €150
Question 26

Calculate: Find 12 1/4 % of 400 m

Question 27

Calculate: Find 33 1/3 % of 900m
Appendix C: Post-test administered to student participants

Mental Maths Assignment

Tick appropriate level: ✓

Foundation ☐       Ordinary ☐       Honours ☐

Carry out the following tasks with or without the use of a calculator – Please attempt all questions. If you used a calculator in the question please tick the box next to the question.

Section 1 - Order of Operations

Question 1

Calculate: \[ 5 \times 18 \div 3 \]

Did you use a calculator for Question 1? Yes ☐ No ☐

Question 2

Calculate: \[ 7 \times 3 + 10 \div 2 + 4 \]

Did you use a calculator for Question 2? Yes ☐ No ☐
Question 3

Calculate: \[ \frac{8 + 4 \times 3}{12 - 7} \]

Did you use a calculator for Question 3?  Yes [ ]  No [ ]

Section 2 - Integers

Question 4

Calculate:  \[ -6 + 10 \]

Did you use a calculator for Question 4?  Yes [ ]  No [ ]
Question 5
Calculate: \( 8 + 4 - 5 - 2 \)

Did you use a calculator for question 5?  
Yes [ ]  No [ ]

Question 6
Calculate: \( 4 \times 7 \)

Did you use a calculator for question 6?  
Yes [ ]  No [ ]
Question 7
Calculate: \( 28 \div 7 \)

Did you use a calculator for Question 7? Yes ☐ No ☐

Question 8
Calculate: \( 7^3 \)

Did you use a calculator for Question 8? Yes ☐ No ☐

Question 9
Calculate: \( (-2)^5 \)

Did you use a calculator for Question 9? Yes ☐ No ☐
Question 10
Calculate: \(7 \cdot 3 - 2 \cdot 8 - 6\)

Did you use a calculator for Question 7?  Yes No

Question 11
Calculate: \(\frac{14 + 4 \times 4}{2 \cdot (7 \cdot 4)}\)

Did you use a calculator for Question 10?  Yes No

Section 3 - Fractions

Question 12
Calculate: \(\frac{1}{4} + \frac{1}{4}\)

Did you use a calculator for Question 11?  Yes No
Question 13

Calculate:  $\frac{1}{4} + \frac{1}{4}$

Did you use a calculator for Question 13?  Yes  No

Question 14

Calculate:  $\frac{1}{4} - \frac{1}{4}$

Did you use a calculator for Question 14?  Yes  No

Question 15

Calculate:  $3 - \frac{1}{4}$

Did you use a calculator for Question 15?  Yes  No
Question 16
Calculate: $\frac{1}{2} \times \frac{1}{4}$

Did you use a calculator for Question 16? Yes [ ] No [ ]

Question 17
Calculate: $\frac{1}{2} + \frac{1}{4}$

Did you use a calculator for Question 17? Yes [ ] No [ ]
Section 4 - Decimals

Question 18
Calculate: \[ 12.1 + 5.2 - 6.9 \]

Did you use a calculator for Question 18? Yes [ ] No [ ]

Question 19
Calculate: \[ 31.97 \div 3.8 + 2.5 \]

Did you use a calculator for Question 19? Yes [ ] No [ ]

Question 20
Calculate: \[ 5.3 + 2.2 \times 7.3 \]

Did you use a calculator for Question 20? Yes [ ] No [ ]
Question 21

Calculate: \( 2.45 \times (16.32 - 11.28) \)

Did you use a calculator for Question 21?  
Yes ☐  
No ☐

Question 22

Calculate: \( \frac{6.23 + 5.42}{0.76 - 0.51} \)

Did you use a calculator for Question 22?  
Yes ☐  
No ☐
Section 5 - Percentages

Question 23
Calculate: Write 45% as a fraction

Did you use a calculator for Question 1? Yes ☐ No ☐

Question 24
Calculate: Find 10% of €490

Did you use a calculator for Question 2? Yes ☐ No ☐
Question 25
Calculate: Find 20% of €140

Did you use a calculator for Question 25? YES ☐ NO ☐

Question 26
Calculate: Find 12 1/2% of 480 m

Did you use a calculator for Question 26? YES ☐ NO ☐

Question 27
Calculate: Find 33 1/3% of 1200 m

Did you use a calculator for Question 27? YES ☐ NO ☐
Appendix D: Interview questions

- Do you agree with the use of calculators at Junior Certificate level?
- What are the advantages to using a calculator for mathematics?
- Do you believe that the calculator can improve student attitudes towards mathematics?
- Would you have any concerns about the use of the calculator?
- Would you agree that students rely too heavily on the calculator?
- Do you believe that calculators should be used in class?
- Do you believe that calculators should be used for homework?
- Do you believe that calculators should be used in the Junior Certificate examination?
- What areas of the junior certificate mathematics curriculum rely on the calculator?
- What time do you spend during math instruction teaching the students how to use the calculator?
- How many post-primary schools have you worked in?
- In any of the schools you have worked in did school policies exist regarding calculator usage?
Appendix E: Transcribed interview

Do you agree with the use of calculators at Junior Certificate level?

Yes, definitely yes. Not for first year students though.

Why do you disagree with the use of calculators by first year students?

I disagree with using the calculator for the first ten chapters of the junior certificate mathematics book. These first chapters go through basic rules in integers and fractions. If the students don’t learn these basics they haven’t got a clue when they go to start other chapters such as algebra. I certainly don’t agree with the use of the calculator for fractions. I think it is very important for students to learn how to add, subtract, multiply and divide fractions. For example, if a student were to add \( \frac{3}{4} + \frac{1}{4} \) they need to learn that they must firstly get the lowest common denominator of 3 and 4, divide into the bottom and multiply by the top. So that when they get to the algebra chapter and see an algebraic equation in fraction form they can apply these same rules. Otherwise, if the students use a calculator from the first day to do fractions they struggle when it comes to fractions in algebra.

What are the advantages to using a calculator for mathematics?

I think weaker students benefit most through the use of the calculator. These students feel more competent. Another big advantage is the time saved by using calculators especially when it comes to a mathematics exam. For example, working out percentages or looking up log tables. There is no skill involved in looking up log tables. Before the calculator was introduced students spent precious time looking up these log tables when they could have spent more time on solving math problems. I also agree with students using the calculator for long multiplication as this is not an everyday skill.
Also for calculating decimals. These are not necessary skills for students to have. In the workplace people are going to use calculators for this type of maths.

Do you think the calculator can improve student’s attitudes towards mathematics?

Again, the attitudes of weaker students would definitely improve through the use of the calculator. These students would feel that they could do something. They would gain confidence through the reassurance of doing something right. Some students just can’t learn the methods no matter how hard they try. For these students it would definitely raise their profile of maths, definitely. So many students have the attitude I hate maths, I’m no good at maths and I will always be no good at maths.

What about the stronger students, do you think the calculator affects their attitude towards mathematics?

Not as much, they just don’t need it as much as the weaker students.

Would you have any concerns about the use of the calculator?

My main concern would be that kids sometimes rely too much on the calculator. They expect to be able to do everything on the calculator. They think that the calculator should be able to do everything for them. I would be afraid that students would become over-reliant on the calculator for the basics. You would often see first years using the calculator to calculate for example $28 \div 4$. This is crazy; they have just come from National school and can’t do a simple computation. What happened to learning the tables in National school? Students using calculators in national school is just mad. Some students are becoming over-reliant on the calculator from national school. Ok, I must admit this isn’t always the case as some students come from national schools were the calculator is used very little. However, there are students who have used the
calculator almost every day in national school. A huge difference in standards seems to exist between various national schools.

Do you believe that calculators should be used in class?

Yes, but depending on the topic. Again, I would say definitely not for first years.

Do you believe that calculators should be used for homework?

Again, it depends on the topic and again not in first year.

Do you believe the calculator should be used in the Junior Certificate exam?

Yes, but students need to be careful to show their workings. When students use a calculator for all of their workings they tend not to show all of the steps they took in getting their answer. Over the summer I corrected junior certificate scripts and students lost marks for not showing their workings, even if they had the right answer. For example, one question asked the students to total a list of shopping items totaling €7.68 for example and give the change out of €10. If the students didn’t show the working €10 – €7.68 then they lost 3 marks. Another problem with calculators is that students often put the wrong figures into the calculator and receive the wrong answer. Without showing any work, these students would get no marks. Students tend not to recheck their answer on the calculator.

What areas of the junior certificate mathematics curriculum rely on the calculator?

The trigonometry question relies on the calculator. Again, in correcting junior certificate scripts during the summer. I corrected 300 scripts, 20 of these were at Foundation level. I would say approx 5 or 6 thousand students sat the junior certificate foundation level exam. Out of the 20 I corrected, I would say that every one of these students totally relied on the calculator. These students wouldn’t have passed only for the calculator. Every question that excluded the use of the calculator was left blank by
these students. These students had extremely weak maths. Very basic maths skills. I would describe maths as a foreign language to these students. I felt really sad for these students.

**What time do you spend during math instruction teaching the students how to use the calculator?**

Yes, a lot of time is spent teaching students how to use the calculator. For each section you must go through each step, for example showing the students how to add fractions. The difficulty arises when students have different calculators or if a student buys a new calculator and they have to relearn the new calculator. However, we now have an overhead projector that allows us to display the different types of calculator on the overhead so the students can see what buttons to press. Before this, you had to go round the class showing the students how to use the calculator. Every year, we put the required type of calculator on the book list. However, often students end up with wrong calculator.

Weaker students rely so much on their calculator. It has often happened in an exam situation that a student has forgotten their calculator and borrowed one from a friend. These students then panic during the exam when they are unable to use the borrowed calculator. Again, back to students’ over-reliance on the calculator – their own calculator. Weak students especially fear that something might happen to their calculator. They rely on that one calculator and if anything happens to it they panic.

**How many post-primary schools have you worked in?**

I have worked in five different post-primary schools since I graduated. This is not including schools in which I substituted.
In any of these schools did school policies exist regarding calculator usage?

No.

So is it down to each individual teacher?

Yes, it is down to each individual teacher. However, I think that schools should have a school policy regarding calculator usage. Every teacher within the school should be singing from the same hymn sheet. There should definitely be a policy of no calculators for first year students. I don’t allow the use of calculators in my class for first years but other first years are using calculators. So you have the problem of students coming into my class and saying the students down in room 4 are allowed to use calculators. She is the better teacher allowing her students to use a calculator. They have such an easy time compared to us. You are making us work much harder. You also have to deal with parents who want to know why their kid is not allowed to use a calculator and other students in the same year are allowed. So if an overall school policy existed it would makes things a lot easier.
Appendix F: Consent Form

Consent Form

Dear Teacher,

I am a student at the University of Limerick. My Masters thesis is on “The Effects of calculator use on post-primary school mathematics students at Junior cycle level”.

As part of my study I am asking you to participate in an informal interview. The interview will centre on what you think about the use of calculators in mathematics at junior cycle level. Your input is important to me and to my study.

My goal is to analyse the interview in order to understand your attitudes or beliefs about calculator use in mathematical education at junior cycle level. I am also interested in what has led you to the attitudes or beliefs that you hold about the use of calculators in mathematics classes. As part of the thesis, I may use parts of your interview in your own words to demonstrate various attitudes and beliefs held by you. The interview will be audio-taped and later transcribed by me.

In all written materials I will not use your name. The thesis will use pseudonyms.

In signing this form you are agreeing to participate in the interviewing process.

Thank you,

Sabrina O'Donnell
## Appendix G: Recorded Student Performance by content area

### Students Performance in Order of Operation

<table>
<thead>
<tr>
<th></th>
<th>Q 1</th>
<th>Q 1 with Method</th>
<th>Q 2</th>
<th>Q 2 with Method</th>
<th>Q 3</th>
<th>Q 3 with Method</th>
<th>Score without Increase</th>
<th>Score with Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 2</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>Yes</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Student 3</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>No</td>
<td>2</td>
<td>No</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Student 4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>Yes</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 5</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Student 6</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 7</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>2</td>
<td>No</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Student 8</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 9</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Student 10</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Student 11</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>2</td>
<td>Yes</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Student 12</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 13</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 14</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 15</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Student 16</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Student 17</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 18</td>
<td>4</td>
<td>No</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>6</td>
</tr>
<tr>
<td>Student 19</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>3</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Student 20</td>
<td>0</td>
<td>Yes</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Student 21</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 22</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 23</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 24</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 25</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 26</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 27</td>
<td>1</td>
<td>Yes</td>
<td>1</td>
<td>No</td>
<td>1</td>
<td>Yes</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Student 28</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 29</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 30</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Student 31</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>1</td>
<td>No</td>
<td>Yes</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Student 32</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>3.00</td>
<td>3.44</td>
<td>3.13</td>
<td>3.72</td>
<td>3.34</td>
<td>3.66</td>
<td>9.47</td>
<td>10.81</td>
</tr>
</tbody>
</table>
## Students Performance in Integers

<table>
<thead>
<tr>
<th>Student</th>
<th>Score with Question 1</th>
<th>Score with Question 2</th>
<th>Score with Question 3</th>
<th>Score with Question 4</th>
<th>Score with Question 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.56</td>
<td>3.88</td>
<td>3.88</td>
<td>3.63</td>
<td>3.75</td>
</tr>
<tr>
<td>2</td>
<td>3.86</td>
<td>3.86</td>
<td>3.86</td>
<td>3.86</td>
<td>3.86</td>
</tr>
<tr>
<td>3</td>
<td>3.56</td>
<td>3.64</td>
<td>3.64</td>
<td>3.64</td>
<td>3.64</td>
</tr>
<tr>
<td>4</td>
<td>3.56</td>
<td>3.64</td>
<td>3.64</td>
<td>3.64</td>
<td>3.64</td>
</tr>
</tbody>
</table>

Average: 3.82

Score increase

Score decrease

---

Student 1: Yes
Student 2: 4
Student 3: No
Student 4: 4
Student 5: Yes
Student 6: No
Student 7: 4
Student 8: 4
Student 9: 4
Student 10: 4
Student 11: 4
Student 12: 4
Student 13: 4
Student 14: 4
Student 15: 4
Student 16: 4
Student 17: 4
Student 18: 4
Student 19: 4
Student 20: 4
Student 21: 4
Student 22: 4
Student 23: 4
Student 24: 4
Student 25: 4
Student 26: 4

---

**Question 1:** If used, Question 2 with Question 1.
**Question 2:** If used, Question 3 with Question 2.
**Question 3:** If used, Question 4 with Question 3.
**Question 4:** If used, Question 5 with Question 4.

---

**End of Table**
### Students Performance in Fractions

<table>
<thead>
<tr>
<th></th>
<th>Q 1</th>
<th>Q 1 with If used</th>
<th>Q 2</th>
<th>Q 2 with If used</th>
<th>Q 3</th>
<th>Q 3 with If used</th>
<th>Q 4</th>
<th>Q 4 with If used</th>
<th>Q 5</th>
<th>Q 5 with If used</th>
<th>Q 6</th>
<th>Q 6 with If used</th>
<th>Score without</th>
<th>Score with</th>
<th>Increase</th>
<th>Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>4</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>2</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>Student 2</td>
<td>1</td>
<td>Yes</td>
<td>0</td>
<td>Yes</td>
<td>0</td>
<td>Yes</td>
<td>0</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>6</td>
<td>24</td>
</tr>
<tr>
<td>Student 3</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>18</td>
<td>24</td>
</tr>
<tr>
<td>Student 4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Student 5</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Student 6</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>1</td>
<td>Yes</td>
<td>4</td>
<td>No</td>
<td>21</td>
<td>24</td>
</tr>
<tr>
<td>Student 7</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>3</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>23</td>
<td>24</td>
</tr>
<tr>
<td>Student 8</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Student 9</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>16</td>
<td>24</td>
</tr>
<tr>
<td>Student 10</td>
<td>0</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>Student 11</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>Student 12</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>3</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>23</td>
<td>24</td>
</tr>
<tr>
<td>Student 13</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Student 14</td>
<td>0</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>Student 15</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>16</td>
<td>24</td>
</tr>
<tr>
<td>Student 16</td>
<td>0</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>Yes</td>
<td>0</td>
<td>Yes</td>
<td>0</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>Student 17</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Student 18</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Student 19</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Student 20</td>
<td>0</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>8</td>
<td>24</td>
</tr>
<tr>
<td>Student 21</td>
<td>3</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>23</td>
<td>24</td>
</tr>
<tr>
<td>Student 22</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Student 23</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Student 24</td>
<td>3</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>16</td>
<td>24</td>
</tr>
<tr>
<td>Student 25</td>
<td>1</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>3</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Student 26</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Student 27</td>
<td>1</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>No</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>9</td>
<td>24</td>
</tr>
<tr>
<td>Student 28</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Student 29</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Student 30</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Student 31</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>Yes</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>Student 32</td>
<td>3</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>3</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>Yes</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>3.13</td>
<td>3.84</td>
<td>3.28</td>
<td>3.97</td>
<td>3.19</td>
<td>3.97</td>
<td>3.03</td>
<td>4.00</td>
<td>2.84</td>
<td>4.00</td>
<td>2.41</td>
<td>4.00</td>
<td>17.88</td>
<td>23.78</td>
<td>5.97</td>
<td>0.06</td>
</tr>
</tbody>
</table>
# Students Performance in Decimals

<table>
<thead>
<tr>
<th></th>
<th>Q 1 with If used</th>
<th>Q 2 with If used</th>
<th>Q 3 with If used</th>
<th>Q 4 with If used</th>
<th>Q 5 with If used</th>
<th>Score without</th>
<th>Score with Increase</th>
<th>Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Student 2</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Student 3</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>3</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Student 4</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Student 5</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Student 6</td>
<td>4</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Student 7</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Student 8</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Student 9</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Student 10</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Student 11</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>4</td>
<td>No</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Student 12</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Student 13</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Student 14</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Student 15</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Student 16</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Student 17</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Student 18</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Student 19</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Student 20</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>3</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Student 21</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>3</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Student 22</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Student 23</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Student 24</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Student 25</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Student 26</td>
<td>4</td>
<td>4</td>
<td>No</td>
<td>0</td>
<td>4</td>
<td>No</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Student 27</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>1</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Student 28</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Student 29</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>4</td>
<td>No</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Student 30</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Student 31</td>
<td>4</td>
<td>4</td>
<td>No</td>
<td>0</td>
<td>4</td>
<td>Yes</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Student 32</td>
<td>4</td>
<td>4</td>
<td>Yes</td>
<td>3</td>
<td>4</td>
<td>Yes</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>3.47</td>
<td>3.63</td>
<td>2.19</td>
<td>3.59</td>
<td>2.00</td>
<td>3.16</td>
<td>2.78</td>
<td>3.78</td>
</tr>
<tr>
<td></td>
<td>Q 1</td>
<td>Q 1 with If used</td>
<td>Q 2</td>
<td>Q 2 with If used</td>
<td>Q 3</td>
<td>Q 3 with If used</td>
<td>Q 4</td>
<td>Q 4 with If used</td>
</tr>
<tr>
<td>------</td>
<td>-----</td>
<td>-----------------</td>
<td>-----</td>
<td>-----------------</td>
<td>-----</td>
<td>-----------------</td>
<td>-----</td>
<td>-----------------</td>
</tr>
<tr>
<td>Student 1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Student 2</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>0 Yes</td>
<td>0</td>
<td>0 Yes</td>
</tr>
<tr>
<td>Student 3</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>0 No</td>
<td>3</td>
<td>4 Yes</td>
<td>1</td>
<td>4 Yes</td>
</tr>
<tr>
<td>Student 4</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>3 Yes</td>
<td>4</td>
<td>0 Yes</td>
<td>0</td>
<td>1 Yes</td>
</tr>
<tr>
<td>Student 5</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>2 Yes</td>
<td>4</td>
<td>4 Yes</td>
<td>3</td>
<td>4 Yes</td>
</tr>
<tr>
<td>Student 6</td>
<td>4</td>
<td>3 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
</tr>
<tr>
<td>Student 7</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
</tr>
<tr>
<td>Student 8</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>0 No</td>
<td>0</td>
<td>0 Yes</td>
<td>0</td>
<td>0 Yes</td>
</tr>
<tr>
<td>Student 9</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
</tr>
<tr>
<td>Student 10</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 Yes</td>
</tr>
<tr>
<td>Student 11</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 Yes</td>
</tr>
<tr>
<td>Student 12</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
</tr>
<tr>
<td>Student 13</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
</tr>
<tr>
<td>Student 14</td>
<td>4</td>
<td>0 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>0 Yes</td>
<td>0</td>
<td>0 Yes</td>
</tr>
<tr>
<td>Student 15</td>
<td>4</td>
<td>0 No</td>
<td>4</td>
<td>4 Yes</td>
<td>0</td>
<td>4 Yes</td>
<td>0</td>
<td>4 Yes</td>
</tr>
<tr>
<td>Student 16</td>
<td>4</td>
<td>0 No</td>
<td>4</td>
<td>4 No</td>
<td>0</td>
<td>4 No</td>
<td>0</td>
<td>0 No</td>
</tr>
<tr>
<td>Student 17</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
</tr>
<tr>
<td>Student 18</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
</tr>
<tr>
<td>Student 19</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>0</td>
<td>0 Yes</td>
</tr>
<tr>
<td>Student 20</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
<td>0</td>
<td>4 Yes</td>
<td>0</td>
<td>0 Yes</td>
</tr>
<tr>
<td>Student 21</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 Yes</td>
</tr>
<tr>
<td>Student 22</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>3 Yes</td>
<td>4</td>
<td>4 Yes</td>
</tr>
<tr>
<td>Student 23</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
</tr>
<tr>
<td>Student 24</td>
<td>0</td>
<td>0 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>0</td>
<td>1 Yes</td>
</tr>
<tr>
<td>Student 25</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
</tr>
<tr>
<td>Student 26</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
</tr>
<tr>
<td>Student 27</td>
<td>0</td>
<td>0 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
</tr>
<tr>
<td>Student 28</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
</tr>
<tr>
<td>Student 29</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
</tr>
<tr>
<td>Student 30</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
</tr>
<tr>
<td>Student 31</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>4 No</td>
<td>4</td>
<td>3 No</td>
<td>1</td>
<td>4 Yes</td>
</tr>
<tr>
<td>Student 32</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>4 Yes</td>
<td>4</td>
<td>0 Yes</td>
</tr>
</tbody>
</table>

Average: 3.25 3.34 3.50 3.41 3.22 3.34 2.41 2.91 2.16 2.59 14.53 15.59 1.63 0.56
Appendix H: Student Performance Charts

Chart 1: Overall student performance by mathematical content area

![Overall Student Performance by Content Area](image)

**Overall Student Performance by Content Area**

Mark out of 108

- **Order of Operations**
- **Integers**
- **Fractions**
- **Decimals**
- **Percentages**

**Legend**
- Blue line: Without calculator
- Red line: With calculator
Chart 2: Higher level student performance pre-test versus post-test
Chart 3: Ordinary level student performance pre-test versus post-test
Chart 4: Percentage of Calculator usage by Higher level students

% calculator used by Higher Level Students

Percentage of calculator usage

Student Identification Number

Student 17
Student 18
Student 19
Student 20
Student 21
Student 22
Student 23
Student 24
Student 25
Student 26
Student 29

% calculator used
Chart 5: Percentage of Calculator usage by Ordinary level students

[Chart showing percentage of calculator usage for each student]
Appendix I: Student Attitude Charts

Chart 1: Bar Chart representing students’ anxiety towards the mathematics discipline

Item 1 - Maths is fun, Item 2 - Maths if one of my favourite classes in school, Item 3 - Maths is boring, Item 4 - Doing maths makes me nervous, Item 5 - I cringe when I go to maths class, Item 6 - I am afraid to ask questions in a maths class, Item 7 - I tend to zone out in maths class, Item 8 - I fear maths more than any other subject, Item 9 - I’m afraid I won’t be able to keep up with the rest of the class, Item 10 - Most people who are at work use maths in their jobs
Chart 2: Bar Chart representing students’ anxiety levels towards the calculator

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I do not feel comfortable when I learn maths using a calculator</td>
<td>5%</td>
<td></td>
<td>40%</td>
<td>55%</td>
</tr>
<tr>
<td>The thought of using a calculator frightens me</td>
<td>10%</td>
<td>30%</td>
<td>50%</td>
<td>10%</td>
</tr>
<tr>
<td>I am worried about using a calculator because I don’t know what to do if something goes wrong</td>
<td>15%</td>
<td>25%</td>
<td>50%</td>
<td>10%</td>
</tr>
<tr>
<td>The use of the calculator confuses me</td>
<td>20%</td>
<td>30%</td>
<td>40%</td>
<td>10%</td>
</tr>
</tbody>
</table>
Chart 3: Bar Chart representing students’ negative attitudes towards calculator usage

**Item 1** - Calculators are good tools for calculation, but not for my learning of maths, **Item 2** - I think learning to use a calculator wastes too much time in the learning of maths, **Item 3** - I feel that calculators should not be used in math test, **Item 4** - I feel that calculators should not be used for math homework, **Item 5** - Calculators should only be used to check my answers once I have worked the problems with pencil and paper, **Item 6** - Using a calculator in maths will cause me to forget how to do basic computational skills, **Item 7** - I understand mathematics better if I solve problems with paper and pencil
Chart 4: Bar Chart representing students’ enjoyment of calculator usage

**Item 1** - Calculators make mathematics fun, **Item 2** - Maths is easier if calculators are used to solve problems, **Item 3** - I prefer to do all the calculations with the use of the calculator, **Item 4** - I want to get better at using a calculator to help me with mathematics, **Item 5** - I enjoy using a calculator in mathematics activities, **Item 6** - The thought of doing mathematic activities without the use of a calculator frightens me, **Item 7** - I enjoy investigating mathematics problems using a calculator