2002

A Study of How Well Lower Secondary Students Use Calculators to Solve Computation Problems

Rachel Shipley
Edith Cowan University

2002

A Study of How Well Lower Secondary Students Use Calculators to Solve Computation Problems

Rachel Shipley
Edith Cowan University

USE OF THESIS

A Study of How Well Lower Secondary Students Use Calculators to Solve Computation Problems

By

Rachel Shipley, BA (Ed)

A Thesis Submitted in Partial Fulfilment of the
Requirements for the Award of

Bachelor of Education (Honours)

at the School of Education,
Faculty of Community Services, Education and Social Sciences,
Edith Cowan University

Date of Submission: 24th June, 2002.

Abstract

The main aim of this study was to determine how well students used their calculators to obtain the correct answer to a problem (effective calculator use). The study has also considered whether students used their calculators as efficiently as possible, in order to answer questions expediently (efficient calculator use).

This research made use of a Calculator Computation Test and Answer Sheet which was used for checking the accuracy of subjects' answers as well as recording which keys they pressed to obtain their answer. These were developed for the study. The subjects were drawn from Years 8, 9 and 10 of a suburban senior high school. In addition to the above instruments the researcher interviewed twelve of the 141 subjects involved in the study after the completion of the Calculator Computation Test.

In considering how effectively students were able to use a four-function calculator the students in the study rated very poorly. Students were unable to use the calculator well, made many errors in the use of the calculator and also did not know of all the functions which the calculator had. In terms of efficient calculator use, of the items which students answered correctly, 63% were answered in a highly efficient way by students and this is encouraging. The concern is that still 37% of the time students were spending too much time trying to work out how to use their calculator in order to answer a question at all.

Another question which this study aimed to address was whether there was a significant difference between gender and calculator use. It was found that at Year 8 level the females scored lower on the test, although the difference was not significant. At Year 9 level there was no significant difference and at Year 10 level the males scored significantly lower.

The way in which students used and reacted to calculators was very interesting. During interview some students made comments which alerted the researcher to how they viewed their calculators. Some students were willing to believe any answer which the calculator offered, and this was evident from comments like: 'I just feed it into my calculator' and 'I just let my calculator do it'. However, other students were more sceptical and questioned the validity of the answer, as was apparent when hearing comments like 'Did I get it wrong?', and having asked how the student knew an answer was right to hear the reply, 'I normally do it twice'. Some students relied heavily on their calculators, while others did not use them, as shown by comments like, 'I just figure it out in my head'.

The results of this research showed that there is much to be done in the area of curriculum development for the explicit teaching of the use of four-function calculators. There are also questions which have evolved as a result of this research that suggest the need for further research in this area.

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgment any material previously submitted for a degree or diploma in any institution of higher education;

(ii) contain any material previously published or written by another person except where due reference is made in the text; or

(iii) contain any defamatory material.

Signature

Date ...24th June 2002...

Acknowledgments

The author would like to acknowledge the assistance of the staff and students at the school where the study was conducted for their help and support. Thanks also go to Dr Jack Bana for his time, his expertise and his patience during the long period of his supervision of my work. Finally, thanks to my family and friends for their support and encouragement during the years it has taken me to complete my studies.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

Background to the Study

Calculators became readily available in the early 1970s and since then there has been a great deal of discussion about whether or not students should actually use the calculators in mathematics classrooms. In their meta-analysis of seventy-nine studies, Hembree and Dessart (1986) noted the concern that "the use of such devices would displace attention to paper and pencil skills" (p. 83). Debates have focussed on paper and pencil skills versus calculator use. The main concern seems to be that students will lose their individual computation skills and come to rely on their calculator and their calculator skills in order to solve problems (Cortese, 1989; Groves & Cheeseman, 1992; Tyler, 1980). Research has also focussed on comparisons between paper and pencil skills with or without calculator use (Dick, 1988; Hembree & Dessart, 1992). According to Hembree and Dessart (1986) "comparisons of calculator treatment and traditional instruction without calculators seems sufficiently investigated" (p. 97). Calculators have been regarded by some as a boon and by some as a burden but as Cockcroft reports "it is clear that the arithmetic aspects of the primary curriculum cannot but be affected by the increasing availability of calculators" (Department of Education and Science, 1982, p. 113).

Computers followed hot on the heels of calculators and became readily available before calculators had any foothold in the classroom. It is interesting to note from Hembree and Dessart (1986) as they cite Suydam (1981) that "the bulk of calculator research appeared from 1976 through 1980, at which time research attention seemed to turn towards the microcomputer. Study of the calculator then displayed a sharp decline" (p. 1). Computers were accepted as a valuable tool to facilitate learning, and in many ways computers overshadowed calculators.

At present many students are allowed to use calculators in the classroom but are not necessarily being given any direct instruction on how to use the calculator to solve problems. The Curriculum Development Corporation Guidelines suggest that

calculators should be used and that it is in fact the teacher's responsibility to "ensure that the calculator is used both as an instructional aid and a computational tool" (Curriculum Development Centre & Australian Association of Mathematics Teachers, 1987, p. 1). There are many other supporting documents and directives which urge teachers of mathematics to fully integrate calculators into their teaching and learning programs (Department of Education and Science, 1982; Curriculum Programmes Branch, 1989; Australian Education Council, 1991). Despite this fact it seems that many teachers either do not allow students to use calculators in all areas of mathematics, or if they do allow calculator use they do not actively teach the student to use the calculator effectively (Tyler, 1980). Upon reaching high school most students would find a calculator on the book list, but to use the calculator it is often a case of teaching themselves, despite the support for integrating the calculator into the curriculum (Duffin, 1991; Maftoon, 1982). Because many students are not taught how to use a calculator and calculators are not integrated into the curriculum there is little variation in how calculator usage is addressed at different year levels.

Rather than a planned approach to teaching skills related to calculator use, students are often expected to 'pick it up' as they go along. In the ideal situation calculator usage would become more involved as more difficult concepts are addressed and the calculator is used to do increasingly difficult computations. This would mean a great variation in the level of calculator proficiency at different year levels. As Student Outcome Statements are beginning to be implemented in Western Australian schools we may see a change. The Outcome Statements set out eight levels at which students can achieve proficiency in calculator use (Curriculum Council, 1998; Education Department of Western Australia, 1998a, 1998b). The concern will be that the documents supporting the Outcome Statements will have as little effect as previous documents supporting the integration of calculator use in the curriculum.

Very little research has been conducted into how well students use calculators. In order to truly consider whether policy has had any effect in the implementation of calculator use it would be necessary to test students and see how well they use calculators in the classroom. In order to consider this issue a research study was set up which involved a sample of Year 8, 9 and 10 students from a public school in the

Perth outer metropolitan area. One aim of the study was to consider what stage students were at in terms of their mastery of the calculator and related skills. A further consideration was whether age and gender were a factor in the acquisition of calculator skills.

The Significance of the Study

Secondary students generally use calculators every day in class and at home. At the present time four-function calculators can be found in nearly every home. They are often given as free gifts and are relatively inexpensive to purchase. It is important to note that although mathematics educators feel that four-function calculators are easy to use, not everyone experiences this. Many people who use calculators are dubious about using them and often have no way of knowing whether the calculator has produced the correct answer or not. Because of this many people are reluctant to use calculators and seem to have little expertise in using calculators efficiently.

This study looks at how four-function calculators are used. The study considers whether or not the correct answer is found using the calculator, and also whether or not the answer is found in an efficient manner. The experience of the researcher suggests that even if students suspect that there is a quicker way of finding an answer they will tend to use the longer method whereby they can be more confident that they have the correct answer. However, the correct answer is not always the result, even when a long method of solution has been used.

There are many reasons why this may occur. Perhaps students have not been directly instructed in the use of a calculator (four-function or scientific). Perhaps it is a phobia of any aspect of mathematics, or perhaps it is a lack of understanding about how the calculator operates. Very little research has considered the way in which students use the calculator as a tool. The results of this study may help educators to focus on this issue and evaluate the way in which students use their calculators in the mathematics classroom.

The results of the research should make mathematics educators more aware of what students need to learn in relation to calculator skills. Many educators who find the calculator a useful tool themselves may not consider the option that a student may not know how to use a calculator to solve a problem. Calculators are used by some mathematics educators to assist in teaching students about number relationships and these teachers need to encourage others to do the same. It is also crucial that once an educator has taught a concept, they have some way of assessing whether the student has learned that concept. Perhaps this is another way in which this research may be found useful. The instrument used in the study could be easily transferred for use in the classroom to assess whether students are using their calculators effectively and efficiently or not. This is just one facet of how the study could assist educators in addressing the concerns which follow naturally when the issue of calculator use is raised.

Statement of the Problem

Very little has been done to consider the way in which calculators are used by students in our schools. There has been little study into how effectively students use calculators to get the correct answers to calculation problems, or how efficiently students use calculators. Researchers have not considered whether students' abilities with the calculator increase as they get older, or if they improve due to direct instruction, although we may assume that to some extent this would be the case. Research needs to be conducted to consider these questions in greater depth.

The study set out to consider how effectively and efficiently students use their calculators. That is, how well students understand the machines they are using and whether they use them in the most efficient way to answer the questions that are set. Obviously we do not want students wasting their time in class, so that is one reason why this aspect has been considered. Also, students spend so much time using calculators, it is important to consider whether or not they actually think about what they are doing and whether or not they reflect on the answers that they obtain with their calculator (Mills, 1991).

No significant research has been found which considers whether males or females use calculators more efficiently or to great effect. Is it gender or individual preference which determines whether or not a student can use a calculator 'better', or is it some other factor? Do some students check whether the answer that they obtain when using the calculator is reasonable, and if so, what causes them to do this? These questions may have been considered previously but they have not been researched or documented and that is what this study sets out to do.

Research Questions

The following questions were addressed in this study:

1. How effectively do Year 8-10 students utilise calculators to solve computation problems?
2. How efficiently do Year 8-10 students utilise calculators to solve computation problems?
3. To what extent do year level and gender influence effective calculator use?
4. To what extent do year level and gender influence efficient calculator use?
5. How do students combine estimation, mental computation, pencil and paper and calculator use to solve computation problems?

Definition of Terms

The research questions focus on the terms "effective" and "efficient" calculator use. Effective calculator use was defined, for the purpose of this study, as the use of the calculator to obtain the correct solution to a computation problem. Efficient calculator use, as defined by Fielker, "can be measured by the number of keys one must press" (1992, p. 33). Efficient calculator use has thus been defined as the use of the calculator to achieve the correct solution to the problem using a minimum number of key presses.

Chapter 2: Review of Related Literature

The purpose of this chapter is to consider previous research. Some of the research considered provides useful background information, while other studies outlined suggest possible explanations for some of the findings of the current research. The chapter first considers research in general, then technology in general. Following this is more specific discussion about calculators. Literature which considers the procedural aspects of the study are considered at the end of the chapter.

Focus of Previous Research

Hembree and Dessart (1986) conducted a meta-analysis into all relevant studies of calculator usage. The meta-analysis set out to consider the effects of calculator use on students' "composite operational skills" (p. 86). Attitudes towards mathematics and how the calculator affected peoples' attitudes towards mathematics varied depending on the age and ability of the student. Hembree and Dessart (1986) had many interesting comments to make about the effect of the calculator on students. They were also concerned with the scope and utility of the studies that had been carried out up to 1986. It is their belief that "comparison of calculator treatment and traditional instruction without calculators seem sufficiently investigated" (Hembree & Dessart, 1986, p. 1). Most of the studies considered by Hembree and Dessart looked at this aspect of the introduction of the calculator so there is little need for more studies of this nature, in their opinion.

In considering calculators in Western Australian Primary Schools, Sparrow and Swan (1997), by means of a teacher questionnaire, revisit the question of how readily calculators are used in the classroom. They also considered the way in which calculators were used, although not how well the calculators were used. It was found that the calculator tended to be used to perform complex calculations, to check work or to play calculator games as a reward. It would be beneficial to know whether, when performing complex calculations, the students obtained the correct solution to the

problem set. The current study sets out to consider this, although students in a different age bracket, lower secondary rather than primary age students, are being targeted here.

Research should now focus on exactly how calculators are being used. The extent to which calculators are used in conjunction with other methods of solution also needs to be determined. Whether calculators are used to assist in getting the correct solution to a problem should be considered. How age and gender affect how well students use calculators should also be investigated. Research should also consider whether calculators are being used to greatest effect in classrooms.

Technology in General

Larry Cuban (1986), in his book *Teachers and Machines – The Classroom Use of Technology Since 1920*, does not mention how calculators have affected the classroom. Does this mean that calculators have had no impact? One reason for his omission of calculators may be that they are not used across the curriculum. Cuban discusses in great depth how effectively innovations such as radio, television, video and computer are embraced by teachers. Cuban stresses "how rarely teachers have used machines in their classrooms since the 1920's" (1986, p. 51). He also cites Maftoon: "it has been found that teachers reject or at least resist change because of failure to recognise the need for improvement" (1982, p. 45). Perhaps this is why the focus of studies so far has been on whether or not we need calculators, and some researchers suggest that students must maintain their paper and pencil skills. The focus of research so far highlights the maintenance of paper and pencil skills and ignores any consideration of how well calculator skills have been developed and replaced the need for paper and pencil skills. Past research has also ignored how calculators can help other aspects of the learning of mathematics. Mills (1991) states that "calculators are seen by some as a major threat to the development of numerical skill" (p. 12). However, calculators are being neglected as significant aids to learning.

Attitudes to Calculators

Many studies about calculators involved research in which teachers and/or students had positive attitudes towards calculators and their use as a tool in the classroom (Kaiser, 1991; Thompson, 1992). This positive attitude tends, in general, to develop many years after the initial introduction of the calculator. Kaiser (1991), for example, recounts a personal experience in which there was a positive approach to calculator use. Unfortunately no indication is given of how well students used their calculators – only that they enjoyed using them. This may merely be the novelty effect of having a new 'toy' that they were allowed to play with in class. In their meta-analysis of 79 studies Hembree and Dessart (1986) found that the students "using calculators showed a better attitude toward mathematics and better self-concept in mathematics than students not using calculators" (p. 83). This finding was supported in their 1992 meta-analysis of nine further studies. The studies mentioned here deal with research concerning teachers' and/or students' attitudes to the use of the calculator.

Arnold (1998) categorises some of the impediments to the use of mathematical technology as "institutional" (p. 196), these being the constraints imposed by physical factors such as access to available equipment. It is Arnold's belief that the more difficult constraint to overcome is the "perception of the very nature of mathematics, as it is found in schools" (1998, p. 196).

Calculator Use in the Classroom

There are many school, state and national policies, some of which were outlined in the previous chapter, which support the use of calculators in the mathematics classroom. The implementation of these policies has not resulted in the universal use of calculators in a meaningful way in many classrooms. Many factors, such as time constraints and motivation of teachers, have impeded the use of calculators in the primary classroom. In support of this claim Sparrow, Kershaw and Jones (1994) state that "no wealth of evidence or strength of policy will effect change in primary school mathematics unless teachers adopt practices which embrace the everyday purposeful

use of calculators" (p. 52). While this is the case students are not arriving at secondary school with the calculator skills which the secondary mathematics teacher will assume they have.

It is important to note here that even if students in different classes are taught the same content in the same format there are likely to be differences in the educational experience of the students in one class when compared to the students in the other class (Relf, 1992). There are, in fact, likely to be differences between the experience of students within the one class and Relf (1992) believes that the focus should be on achieving desirable outcomes for the students rather than ensuring that all students receive the same input.

In considering how students use calculators in the classroom there are studies which have looked at the type of activities for which students use the calculator. There have also been studies which have focussed on the way topics can be taught with the use of the calculator. Lee (1998) is of the view that "calculators have encoded in them the rules and conventions of number" and "a student in possession of a calculator has immediate access to this repository of knowledge" (p. 38). In order to access this repository of knowledge, however, the student must first have a relational understanding of the rules and conventions. If the student is accessing this repository of knowledge you would expect them to be using the calculator effectively and efficiently.

Calculators and Accuracy

Mills (1991) actually considered some of the problems which may arise when using calculators. He witnessed that "all children (interviewed) believed in the infallibility of the machine . . . no child considered checking an answer subsequent to using the calculators" (p. 14). This could lead to ineffective calculator use and incorrect answers to problems. The study undertaken here looks at the extent to which this occurs, in a sample of students interviewed.

Interviews conducted in the current study aim to consider the extent to which students consider the appropriateness of a calculation. Questions asked endeavour to establish whether the student estimated an answer or simply believed the answer which they obtained on their calculator. Hembree and Dessart (1992), in their meta-analysis of nine studies, confirm that using calculators in the learning of mathematical concepts is likely to have a positive effect on student performance when dealing with problem solving and computation in class and test situations.

Gender Differences

In a discussion of self-confidence and how it relates to mathematical achievement Eisenberg (1991, p. 154) discusses the attribution theory. This theory has been considered in many surveys and the results have been inconclusive but the general premise on which the theory is based has been found to be of merit. In short it is believed that if a student succeeds, a male student is more likely to attribute it to internal factors showing a belief in his ability, whilst a female student is more likely to attribute her success to external factors such as luck or easy test questions. Paradoxically, if a student experiences failure, a male is more likely to blame external factors and have his self-esteem remain intact, while a female is likely to blame internal factors such as lack of skill or poor preparation on her own behalf. Whilst the results of the surveys considering this theory have been inconclusive Eisenberg (1991) has found that "many individuals hold these intrinsic/extrinsic perceptions of themselves – and that these perceptions are highly correlated with mathematics achievement" (p. 154). Thus it is important to consider gender issues in the current study.

In Support of this Study

Rowland (1992) makes the point that much of the discussion concerning calculators has stemmed from "projects . . . set up and pursued more or less exclusively as curriculum development projects as opposed to research projects (and) tend to arise out of convictions rather than questions" (p. 28). Rowland (1992) goes on to consider

Hembree and Dessart's 1986 meta-analysis and its findings. In Rowland's opinion, "there is a need for more analogous research with four-function calculators" (p. 28). His point seems justified and the current study addresses this aspect.

In a study into mental computation in primary school mathematics (McIntosh, Bana & Farrell, 1995) the researchers felt that "it should be stressed that real life computation involves mental computation and/or calculator use so classroom teaching should emphasise these aspects rather than traditional paper and pencil algorithms" (p. 38). Studies into how students solve computation problems should emphasise these aspects. The current study sets out to consider the second aspect, as to how students use their calculators to solve computation problems.

It is believed that some students will deal better with 'number type' questions and some students with 'word type' questions. The instruments used in this study have been set out as 'number' problems and questions which call for similar methods of solution but which are set out in context, or as 'word' problems. Some students may have a better understanding of how to approach a question if it is set out in context. It is also possible, Clarkson (1991) suggests, that some students may make errors when dealing with word problems due to comprehension errors. The current study is concerned with the way in which students use their calculators and, recognising that language competence may be a factor, the problems have been set out in both number and word form in order to allow students to display their calculator competence regardless of their language competence.

Pilot Study

It was considered necessary to conduct a pilot study for several reasons. After the instruments were designed there was a need for a test run in order to refine the test questions and protocols. Gay (1992) suggests that "beginning researchers gain valuable experience from a pilot study" (p. 112). The pilot study consisted of six subjects, but as Gay (1992) points out "even a small-scale pilot study, based on a

small number of subjects can help in refining procedures, such as instrument administration and scoring routines" (p. 112). This was certainly the case and the pilot study, although small, was invaluable.

The pilot study gave the researcher some indication of the type of questions that would be asked by the subjects during data collection. This gave the researcher the opportunity to clarify the instructions given to subjects as well as having ready a standard set of responses to commonly asked questions. Based on the responses of subjects in the pilot study the scoring of the test and the cut-off marks for how efficiently subjects used the calculator were determined.

Instruments

In order to collect the data which was needed, a comprehensive set of computational problems had to be developed. As well as this a simple way for students to answer the questions set and record the required information was needed. Burns (1994) suggests that "the model questionnaire is designed in four parts: the introduction, warm-up questions, the body of the study and demographic questions" (p. 352). As you will note in Chapter 3, the model outlined here was the design favoured by the researcher for the current study. The basic guidelines outlined by Burns (1994) were followed in the current study but the introduction was given verbally (see Appendix B) with brief directions on the students' answer page (see Appendix A). Warm-up questions were also presented verbally, and on the overhead projector (see Appendix B). The body of the study involved a Calculator Computation Test and Answer Sheet (see Appendix A). To maintain anonymity for the subjects demographic questions were contained on a separate Data Card (Appendix C).

Interview

In order to address the research questions adequately, an interview was required as part of the data collection. Some discussion with the student was necessary to compare how students answered the questions during the data collection phase of the

research to how they would answer the question in classroom circumstances with their own equipment. Burns (1994, p. 361) considers one of the most important advantages of the interview to be “flexibility”. In the current study the researcher felt that valuable information would be gained by watching the interviewee’s non-verbal response when asked to complete or answer a question. Gay (1992) feels that “the interviewer must have a written guide which indicates which questions are to be asked and in what order, and what additional prompting or probing is permitted” (p. 232). An interview guide was used and is set out in Appendix D. The nature of the questions being asked, however, meant that the questions and their order varied from subject to subject depending on their responses to the initial test. To account for this, interview questions were drawn from a common bank and selected and ordered prior to each interview.

Chapter 3: Methodology

This chapter outlines the demographic for the study. The procedures followed and the instruments used are described in detail. The chapter concludes with an outline of the guidelines used for data analysis as well consideration of the limitations of the study and ethical considerations.

Subjects

The sample was composed of six classes, ranging from 20-28 students per class, with two classes from each of Years 8, 9 and 10. The total sample was 141 students, comprising 64 females and 77 males. The sample was drawn from a suburban senior high school and the classes were from the middle streams in each year. The reason for this was that it was believed that more useful information was to be gathered from students in the middle groups as there was a broad cross-section of abilities among this group. It was considered that if students from the top stream had been used the majority of questions would have been answered correctly and little information would result. Similarly, if students from the bottom stream had been sampled it was expected that the majority of questions would have been answered incorrectly. The other factor concerning this decision was that the majority of students reside in the middle or mainstream and therefore the sample more adequately represented the population being considered than would students from the top or bottom streams.

Instruments

Calculator Computation Test

The instruments include a Calculator Computation Test (CCT) containing 16 questions, a Sample Answer Sheet and an Answer Sheet (see Appendix A). The CCT contained sixteen questions, eight of which were non-contextual and eight of which were contextual. The same set of sixteen questions was presented to all year levels. The purpose of setting the same set of questions was to check the development of

calculator skills more readily from Year 8 through to Year 10. It was felt that some students may answer computation questions better if they were set out on a page like a 'regular' maths problem while others may prefer to have some more meaningful question that they are likely to encounter in everyday life. The purpose of the study was to consider how the subjects used calculators so it was important that the students encounter a variety of questions which tested their calculator skills as well as trying to ensure that students knew what was being asked in a question.

Interviews

Once the data from the CCT had been examined, four students from each year level were interviewed using the prescribed Interview Protocol (see Appendix B). During the CCT students were required to use only calculators for computation so this was obviously a contrived situation. In order to consider the extent to which students' actions during the CCT exemplified what they would normally do in class, follow-up interviews were conducted. This technique was to examine the way in which students use calculators in conjunction with other skills. Selected responses to interview questions are set out in Appendix E.

Pilot Study

A pilot study of six students was conducted in order to refine the instruments. Two students from each of Years 8, 9 and 10 were involved and the students were not drawn from classes intending to take part in the study. The Data Collection Protocol was followed as set out in Appendix B. The pilot study was used to determine how long students would require to complete all tasks set. It was found that the students required one hour to complete both the examples and the questions set out in the CCT. From the pilot study it followed that the students had varied level of expertise in using the calculator and each student involved in the pilot study had strengths and weaknesses in different areas of calculator use.

A wide range of questions were asked to gather information regarding how students used their calculator. After the pilot study only minor changes were made to some

questions in the CCT. The Data Collection Protocol was modified to clarify the directions given to students in the sample. The changes made were based on the questions asked by students in the pilot study to clarify what was required of them.

Procedure

Calculator Computation Test

The study made use of the Calculator Computation Test (CCT) and interview. The study was carried out over a one-week period and required each student to complete the CCT under guidance from the researcher. Four students from each year level were then interviewed within two days of the initial CCT being administered.

All students were given the same type of four-function calculator to use and were given some practice in its use. Each student was also given a Data Card (see Appendix C) to complete. The Data Card contained the number of the student's answer paper and the students were asked to complete the card by filling in relevant personal details. Students were given a Sample Answer Sheet and led through several examples of how to complete the Answer Sheet. Following this they were given the CCT and Answer Sheet and asked to work through each of the questions in the prescribed manner and complete the Answer Sheet provided. This procedure is set out in the Data Collection Protocol (see Appendix B).

Interview

Students were selected for interview according to their performance in the Calculator Computation Test (CCT). A male and female from each year level who scored above the mean for that year level and a male and female who scored below the mean were interviewed. Thus four students from each year level, inclusive of both genders and a range of ability in calculator use were interviewed – twelve students in all.

The Interview Protocol (see Appendix B) was followed when conducting the interviews and all interviews were audio-taped, with the students' permission, in order to be transcribed and analysed. The students, when interviewed, were seated opposite the interviewer at the same table. A portable recording device with built-in microphone was used, as it was considered less intrusive to students than other devices available. Where possible students brought their own calculator along in order to compare how they would normally have used their calculator to do particular questions as opposed to how they used the one supplied. Students were again asked their permission to audio-tape the interview. The students were then led via questions from the interviewer to re-do questions directly from the CCT as they did in the test, to do questions with their own calculator, and to explain if they would normally have done the question differently in class. A comprehensive list of the questions asked at interview by the researcher can be found in Appendix D.

Design of the Study

Theory

The major purpose of this study was to determine how effectively and efficiently students use their calculators in order to obtain correct answers to computation problems. For the purpose of the study it was assumed that calculators should be used in the mathematics classroom (Hembree & Dessart, 1986, 1992; Suydam, 1982). If calculators should be used it makes sense that they should be used to obtain the correct answer to the problem. Often calculators are used but the correct answer is not obtained (Mills, 1991).

The Calculator Computation Test was administered to 141 students and the data gathered from this was analysed to provide quantitative information. In order to support the findings of the quantitative analysis a sample of the subjects were interviewed individually following the CCT. The interviews were analysed to provide a qualitative view of the results and to validate the findings which were surmised from the CCT.

In order to consider how well students use calculators it was important to 'see' what a student did on their calculator when answering a computation question. With a sample of 141 students it would be impossible to watch each student's every key press. It was necessary to find some way of getting students to record what keys they had pressed to answer a particular question. An answer sheet was designed such that the students used the calculator to find an answer to the question asked, and then they recorded what keys they had pressed. The grid depicted in Figure 1 was used so that the students could easily record the keys they pressed as they completed an item of the CCT.

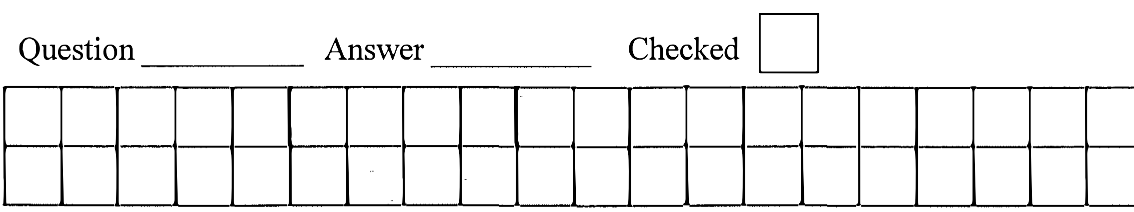

Figure 1: Sample of Answer Grid

Data Analysis

The results of the Calculator Computation Test (CCT) were analysed, firstly to ascertain the number of correct solutions obtained by each subject. After this each correct answer on the CCT was examined to see how efficiently the calculator was used by the student. Based on the results of the CCT the students' responses to questions on the test were categorised. Only the correct responses were considered when determining efficiency of calculator use. Responses were rated as highly efficient, reasonably efficient or inefficient according to the number of key presses recorded. The response was rated as highly efficient if there were zero, one or two key presses more than the most efficient method of solution possible using the calculator provided. It was rated as reasonably efficient if there were three to ten key presses more than the most efficient method possible. It was rated as inefficient if there were more than ten key presses above the most efficient method possible. Recording of key presses which could not give the answer stated were ignored. The data was tabulated according to the percentage of correct answers on the entire CCT for all students, and then for each year level and by gender within each year level.

A sample of students were interviewed to ascertain the extent to which they would have answered the computation questions using another method if they had been allowed. Students were questioned about their use of estimation, mental computation and paper and pencil skills as well as calculator use in the normal classroom situation. Students' responses were recorded. Their answers were analysed and are discussed, with reference to anecdotal notes, at the end of the next chapter.

Limitations

This study involved students from only one metropolitan senior high school and because of this the generalisability of the results is somewhat limited. Students were required to use a calculator provided by the researcher, which all students in the study are likely to have encountered at some stage. The use of a common calculator was necessary for the purpose of the study. This limitation did not allow students to use their own calculator and in order to consider how students would be likely to use their own calculator in a classroom setting a sample of students were interviewed.

This study used a set of questions considered familiar to all students in the sample. However, some students had problems understanding how to answer some of the questions asked. In this case mathematical knowledge rather than calculator skill was inadvertently being tested. This was kept in mind when analysing the data as a possible confounding factor when addressing the research questions. The issue was most evident when students failed to attempt questions during the CCT and was confirmed by several students who were queried about this at interview.

It was considered necessary to hold the interviews with students as soon as possible after the initial testing had taken place. This was so that the effect of other variables on the subject to be interviewed was minimised, and also to facilitate the students' recall of what they did in the CCT. So that the students did not get a chance to know all about the instruments prior to completing them and to once again minimise the effect of other variables on the subjects it was important that all data be collected from the various groups in a short space of time, otherwise confounding factors may have influenced the subjects' answers to the CCT. All CCTs were conducted within three

days and all interviews, as previously stated, were conducted within two days of initial testing, in the hope that any factors likely to affect the subjects being interviewed would be kept to a minimum.

Ethical Considerations

Throughout the data collection phase of the research it was important to maintain the anonymity of the subjects involved. This was so that honest answers to the questions asked could be expected. During the CCT students were given a card with a number on it asking for their personal details. It was explained to the students that the information would only be used to get an indication of the age and gender of the people sitting the test and so that the students to be interviewed could be located. In order to select subjects for the interview the tests displaying the desirable data were selected and then the student's name was found by referring to the data card with the appropriate number. At no time during the interview phase was the student's name used. The interviews were audio-taped and the interviewer assured the students that the interview was confidential. Once the data collection was completed all data was kept in a secure area. In order to ensure students' peace of mind, students were debriefed after the interview period and their problems with the test discussed. The researcher endeavoured to maintain the peace of mind and anonymity of the subjects involved in the study at all times.

Students' responses to the CCT are set out in some detail in the following chapter. Analyses of student responses in the CCT and at interview are outlined, as well as consideration of the effect of a student's age and gender on their responses.

Chapter 4: Analysis of Results

In this chapter the results of the Calculator Computation Test (CCT) are looked at in some detail. The CCT consisted of 16 items. The first eight items were not written in context and students were expected to compute the answers to the eight items using only their calculators and then record their result on the answer grid. The second eight items (Items 9-16) were written in context and that required students to interpret the question and then determine which operations were required before proceeding to compute the answer to the question on their calculator. The results for each of these 16 items are discussed in this chapter.

When considering students' prior knowledge the "Units" which students were expected to have been taught from the Unit Curriculum, set out in Lower Secondary Mathematics for Western Australian Schools (Ministry of Education, c1988) are cited. The year level, shown in parentheses, is the year at which the Unit was typically taught and Level 6 units were not considered, as none of the students in this study had studied Level 6 units at the time of the research. The Unit Curriculum is being considered here because it governed the curriculum taught at many of the independent schools and most government schools, including the school at which the study was conducted. It is still used as a guide by many schools although the Curriculum Framework is now being implemented. The Curriculum Framework states that "an outcomes approach . . . means shifting away from an emphasis on what is to be taught and how and when" (Curriculum Council, 1998, p. 14). This means that there is no way of knowing when a group of students will have been taught a particular concept, it will depend on their individual stage of development and their understanding of the concepts being considered.

As previously indicated, efficiency of calculator use was determined by the number of key presses which a subject used to answer a question effectively. Only correct responses were considered when determining efficiency of calculator use. Efficiency was rated as highly efficient (0-2 key presses more than the minimum required),

reasonably efficient (3-10 key presses more than the minimum required), or inefficient (more than 10 key presses above the minimum number required to answer the question effectively).

Item Analysis

In the following sections the results have been tabulated to show the accuracy of responses to each item of the CCT as well as the efficiency with which students calculated their correct responses. The first sixteen tables, one for each item of the CCT, are all of the same format. The first row of the table shows the number of subjects being considered at each year level. The table is then structured to show the percentages of correct responses. These results, displayed in the second row, are broken down to show the percentage of correct responses at each year level and then by gender, before displaying the total percentage of correct responses to the item. The remainder of the table looks at how efficiently the correct responses were calculated. Considering Table 1, over the page, the total number of respondents who answered this question accurately was 133 (94% of 141); and of these, 99% or 132 respondents answered the question reasonably efficiently. Note that only correct responses were considered when calculating how efficiently a question was answered.

All of the subjects who took part in this research were given the same set of sixteen items. All students should have been capable of understanding the questions as the content had already been covered as part of their mathematics course. Some students will have had more chance to consolidate their understanding of particular concepts or have different methods of solution, this will be considered during discussion of that particular item.

Item One

$7 \times 7 \times 7 \times 7 =$ __________

The results for this item are shown in Table 1, on the following page.

Table 1: CCT Item 1 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	98	88	98	97	92	94
Highly efficient (%)	2	0	0	0	1	1
Reasonably efficient (%)	98	100	100	100	99	99
Inefficient (%)	0	0	0	0	0	0

Effectiveness of calculator use

The majority of students had no problem answering this question correctly. The mistakes made on this question appeared to be careless or random errors rather than systematic ones. The students who were asked about this question at interview gave the impression that the question was so easy there was no need to check the answer. It is possible that students skipped the checking part outlined in the data collection protocol and simply ticked the box assuming they had answered the question correctly. Although there was no significant difference between ages or gender of students and their responses to the item, it is worth noting that in Years 8 and 10 no females answered the question incorrectly while in Year 9 a similar number of males and females answered incorrectly.

Efficiency of calculator use

The majority of students who answered this question correctly answered the question reasonably efficiently (99%), which means that they took between three and 10 key presses more than the minimum required to answer this question. For this particular item, all of the students who answered the question reasonably efficiently took three key presses more than were necessary to answer this question accurately.

In the Unit Curriculum (Ministry of Education, c1988) the concept of indices is taught explicitly in Units 2.4 (Year 8) and 4.4 (Year 9) and implicitly, as part of scientific notation, in Unit 3.4 (Year 9) and in revision for concepts taught in Unit 5.4 (Year 10). Due to the fact that all of the students in the study had had the opportunity to learn about indices it was expected that students would identify that this question involved indices and that it could be done using a particular button on a scientific calculator.

Seven of the eight students asked about this item at interview were aware that the question could be done more efficiently using the "power" button of a scientific calculator but none of the students were aware that using a four-function calculator the question could be done more efficiently than simply typing the expression into the calculator.

One Year 8 student commented that she used a four-function calculator in primary school "but we didn't really figure out a quicker way to do things" (Appendix E). As indicated by Table 1, virtually all students used eight key presses when it was possible for the item to be done using only five key presses. Although this does not seem like a large number, if many such items were to be attempted or if the item involved numbers of more than one digit, the time saved would be significant. It is interesting to note that only one key press is saved by doing this question on a scientific calculator, so for this particular question the scientific calculator is only slightly more efficient if used well.

Item 2

$16 \times 24 - 470 =$ ________

Table 2: CCT Item 2 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	93	88	100	92	95	94
Highly efficient (%)	100	100	100	100	100	100
Reasonably efficient (%)	0	0	0	0	0	0
Inefficient (%)	0	0	0	0	0	0

Effectiveness of calculator use

This item was straightforward using any calculator so the number of students at Year 8 and Year 9 level that answered the question incorrectly was surprising. Students who answered the question incorrectly were reluctant to type the question straight into

the calculator and get an answer, as they thought that there was some 'trick' and several students felt that they had to 'do' something because of 'BIMDAS' (the acronym used by many students to help them remember the Rule of Order of Operations). Rule of Order of Operations (ROO) is covered in Unit 2.4 (Year 8) and it is likely that it would be revised in preparation for Unit 5.4 (Year 10) when learning about operations involved in solving problems with real numbers. It is not taught specifically at Year 9 level which could be the reason for more students at Year 9 level answering this question incorrectly, presumably because they think they need to consider ROO and their recollection of the rule may be less clear than students who have just studied the rule.

Although there is little difference in the accuracy of answers from males and females, it should be noted that at Year 8 level all the males answered the question effectively while only 88% of the females did so, and at Year 9 level there was very little difference between the number of males and females who answered the question accurately.

Efficiency of Calculator Use

Item 2 was answered highly efficiently by all students at all year levels. The item was straightforward and the most efficient way of computing the answer was to type the question straight into the calculator as it was written.

Item 3

$63 \times 3 - 19 \times 4 =$ __________

The results for this item are shown in Table 3, on the following page.

Table 3: CCT Item 3 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	20	14	18	14	19	17
Highly efficient (%)	56	57	0	22	47	38
Reasonably efficient (%)	44	43	88	78	47	58
Inefficient (%)	0	0	12	0	7	4

Effectiveness of calculator use

This question was answered poorly by all students at all year levels, both male and female. Students asked at interview were all aware that ROO needed to be considered. Some students were aware that they could do the question in the order given using a scientific calculator but some students said that even with a scientific calculator, they 'did it themselves anyway', which meant changing the order in which they keyed the information into the calculator. After doing this some students found the correct answer, although inefficiently, and some students were unable to obtain the correct solution to the problem. The difference between the number of correct responses at each year level is not significant and this may be because ROO is only taught explicitly in Unit 2.4 (Year 8) and knowledge of this concept is assumed after that.

Efficiency of calculator use

As already mentioned few students answered this question effectively. Using a four-function calculator only 17% of the students responded to this item with the correct answer. At Year 8 and 9 levels just over half of the students answered highly efficiently, although they had to remember parts of the answer in their head in order to do this. The remainder of the students in Years 8 and 9 answered reasonably efficiently, but still had to remember parts of the answer to obtain a solution to the problem. At Year 10 level none of the students answered highly efficiently; the majority answered reasonably efficiently, with one student answering inefficiently.

Even using the scientific calculator, when asked to at interview, many students added in an extra 'equals' sign which was not required, or they felt they had to write down

parts of the answer in order to complete the question. This resulted in at least one and sometimes up to seven extra key presses to complete this question with a scientific calculator. None of the students who responded correctly to this item were able to complete the question using a four-function calculator without remembering parts of the question. Students had been asked to complete the item using only the calculator but were unable to do this.

Item 4

$34 + 6 \div 13 \times 8 =$ __________

Table 4: CCT Item 4 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	4	16	2	6	9	8
Highly efficient (%)	100	100	100	100	100	100
Reasonably efficient (%)	0	0	0	0	0	0
Inefficient (%)	0	0	0	0	0	0

Effectiveness of calculator use

This item, similar to Item 3, involved ROO. Very few students answered this question accurately, particularly the Year 10 group. This could be explained in part by the fact that students in Year 8 and Year 9 had covered the content more recently than students in Year 10, but if this were the case you would expect to see a similar anomaly in the responses to Item 3. Another possibility is that students misread the question. In considering the students' responses to questions asked at interview the most likely reason for the poor results to this question is that students were unaware of how to deal with the division part of the question.

Efficiency of calculator use

All students who responded accurately to Item 4 answered the question highly efficiently. In order to do this they had to change the order in which the question was keyed into the calculator. Once this was recognised, the correct answer was efficiently computed.

Item 5

$2{\cdot}8 - 6{\cdot}7 \div 5 =$ __________

Table 5: CCT Item 5 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	11	8	2	8	6	7
Highly efficient (%)	80	75	0	80	60	70
Reasonably efficient (%)	20	25	100	20	40	30
Inefficient (%)	0	0	0	0	0	0

Effectiveness of calculator use

This item involves the use of ROO as well as the ability to deal with decimals. It was answered poorly by students at all year levels, but as with Item 4 a lower percentage of the students in Year 10 answered the question correctly than students at Year 8 or Year 9 level.

Efficiency of calculator use

Only 7% of respondents answered this question correctly, 10 students in all. Of the five Year 8 students four answered highly efficiently and one reasonably efficiently showing that most students who were able to answer the question were able to rearrange the order as required. Four Year 9 students responded correctly. Three of these students responded highly efficiently and one reasonably efficiently. One Year 10 student answered correctly and answered reasonably efficiently. It is possible that these results are due to the fact that these Year 8 students had used four-function

calculators more recently and regularly than students in higher years. Students in higher years may be more used to using the scientific calculator to solve problems. This is particularly relevant when considering items involving ROO, since although some students do not recognise it, they do not need to change the order in which the question is keyed in when using a scientific calculator.

Item 6

$^{68}/_{79} \times 83 =$ ________

Table 6: CCT Item 6 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	74	90	86	83	84	84
Highly efficient (%)	94	98	100	100	95	97
Reasonably efficient (%)	3	2	0	0	3	2
Inefficient (%)	3	0	0	0	2	1

Effectiveness of calculator use

This item required students to realise that the vinculum of the fraction represented division and was to be computed on the calculator using the division key. Responses were fairly similar regardless of age, although there was a notable increase from Year 8 to Year 9. Gender difference in responses was not significant at Year 10 level but in Year 9 all females responded correctly while at Year 8 level males recorded significantly more accurate answers.

Efficiency of calculator use

The majority of students answered this question with a high level of efficiency. Students who responded less than highly efficiently added in extra 'equals' signs that were not required and retyped parts of the question, which was not necessary. Most

students managed to type the question straight in, realising that the vinculum of the fraction was keyed in as a division sign and so answered the question highly efficiently.

Item 7

$25^3/_7 + 18 =$ _________

Table 7: CCT Item 7 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	30	14	11	20	17	18
Highly efficient (%)	86	86	40	77	77	77
Reasonably efficient (%)	14	14	60	23	23	23
Inefficient (%)	0	0	0	0	0	0

Effectiveness of calculator use

This item required an understanding of ROO. From Item 6 it is clear that a high percentage of students were aware of how to deal with questions involving fractions. The responses to this question indicate that understanding of the concept of ROO and how to compute these items in a four-function calculator diminishes as age increases. As previously suggested, it is possible that this is due to the fact that this concept is not taught explicitly at Year 9 and Year 10 levels, but it is assumed that students will understand this concept at the higher levels. The other possibility here is that at Year 8 level students have a greater understanding of the concept, while by Year 10 level students are less concerned with the concept and rely on having a calculator capable of computing the correct result.

Efficiency of calculator use

At Year 8 and Year 9 level a high percentage of students (86%) answered highly efficiently and the remainder reasonably efficiently. At Year 10 level a lower

percentage (40%) answered highly efficiently than at the lower year levels, with a higher percentage answering reasonably efficiently. This could be for the same reasons as previously stated for Item 6.

Item 8

$100 - 30 \times {}^{11}/_{12}$ = ________

Table 8: CCT Item 8 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	4	10	0	6	4	5
Highly efficient (%)	100	100	100	100	100	100
Reasonably efficient (%)	0	0	0	0	0	0
Inefficient (%)	0	0	0	0	0	0

Effectiveness of calculator use

This item was the most poorly handled of the sixteen items on the CCT. The item required students to consider fractions and the ROO. It should be similar to the previous item in terms of the level of difficulty which suggests that the students who responded accurately to Item 7 should also have been able to answer this question accurately. With the order of the question rearranged and a subtraction rather than addition making the order relevant, fewer of the responses to this item were accurate.

Efficiency of calculator use

All students who responded accurately to this item answered in a highly efficient manner.

Item 9

What would it cost to buy 7 exercise books for 35¢ each, 3 pens for $1 each and a calculator for $23·95?

Table 9: CCT Item 9 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	61	57	61	58	61	60
Highly efficient (%)	36	48	41	35	47	42
Reasonably efficient (%)	61	52	52	59	51	55
Inefficient (%)	4	0	7	5	2	4

Effectiveness of calculator use

This item is similar to Item 3 in that it involves only adding and multiplying, and the ROO needs to be considered. The question is in the context of money and was dealt with much better by students at all year levels. This may be because students could work out the answer mentally or because in the context of money it was easier for students to realise which operations needed to be completed first. Student responses to this item were interesting because there was very little difference in accuracy of responses as age of subjects increased. It may be that as age increased less care was taken with the item as it appeared to be very straightforward. The most common error made when computing the answer to this question was that 35¢ was keyed into the calculator as 35 rather than 0·35, which is an interpretation error rather than a computation error.

Efficiency of calculator use

More students answered this question reasonably efficiently than highly efficiently. A smaller percentage of students answered the question inefficiently. Those answering inefficiently tended to add each of the items individually rather than multiplying. Females were slightly less efficient than males in answering this question, tending to choose slower methods of solution, although the difference was not significant.

Item 10

If you had \$50, how much money will you have left after you buy a hot dog for \$1·65, 2 drinks for \$1·75 each, an icecream for \$1·80 and 6 lollies for 5¢ each?

Table 10: CCT Item 10 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	30	18	32	34	19	26
Highly efficient (%)	21	11	36	18	33	24
Reasonably efficient (%)	43	56	14	41	27	35
Inefficient (%)	36	33	50	41	40	41

Effectiveness of calculator use

This item is another in which ROO needs to be considered, the operations involved are subtraction and multiplication. The answer to the question was not computed as accurately by as many students as the answer to Item 9 although it is similar in content and context. The most common error was again in the interpretation of the question rather than the computation, students tended to compute the cost of the goods rather than the change expected from \$50.

Efficiency of calculator use

The method of solution for this question varied greatly and because of this the question was answered across the spectrum of efficiency. At Year 8 and Year 9 levels the majority of students answered reasonably efficiently, fewer students answered inefficiently and an even lower percentage of students answered highly efficiently. At Year 10 level half of the students answered inefficiently, with approximately 36 percent of students answering highly efficiently and the remainder answering reasonably efficiently. More Year 10 students answered highly efficiently than students in lower year levels, possibly due to a higher skill level. More Year 10 students also answered inefficiently than at lower year levels, possibly due to the ability to problem solve in an inefficient way to find the correct answer rather than simply answering incorrectly.

Item 11

If soft drink costs $1·30 a can, how many cans of soft drink can be purchased with $21·10?

Table 11: CCT Item 11 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	65	86	95	84	81	82
Highly efficient (%)	100	98	100	100	98	99
Reasonably efficient (%)	0	0	0	0	0	0
Inefficient (%)	0	2	0	0	2	1

Effectiveness of calculator use

Item 11 was a very straightforward division question and if the students recognised this they tended to answer the question correctly. The problem required students to change the order of the numbers from the way they were written in the question before entering them into the calculator. The majority of students had no difficulty realising this but those students who responded incorrectly to this item were in three categories, with approximately the same number of students in each category. The first two groups showed no indication of how to do the question either by not attempting the question or by incorrect operations (i.e. addition or subtraction instead of division). The third group of students did not change the order of the numbers before entering them into the calculator so ended up with a decimal answer less than one. It is interesting to note that this did not strike them as strange, showing that they will often believe anything that the calculator "tells" them.

As year level increased so did the number of correct responses to this item, which is what you would expect, as students have more experience with interpreting questions at each succeeding year level. Students questioned at interview were aware that they could check the answer to this question using multiplication. This was one of the few items in which all students asked were able to check the answer to and feel confident with the accuracy of their answer.

Efficiency of calculator use

Only one student answered the question set out in Item 11 inefficiently, the remainder of the students answered the question highly efficiently. The question was a fairly straightforward one in the sense that if a student worked out how to solve the problem it was easy to answer efficiently. The student who answered inefficiently added the price of cans until all the money was 'spent', presumably counting the number of times he had added the price at the end.

Item 12

The table below shows the amount of money which you have:

Money denomination	*Number you have*
$20 note	*1*
$10 note	*0*
$5 note	*1*
$2 coin	*1*
$1 coin	*2*

If you spend $18·70 on a T-shirt and you have to share the change equally with your friend, how much money will you each receive?

Table 12: CCT Item 12 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	35	51	52	45	47	46
Highly efficient (%)	38	81	30	38	64	52
Reasonably efficient (%)	31	19	57	48	25	35
Inefficient (%)	31	0	13	14	11	12

Effectiveness of calculator use

Item 12 is very similar to Item 11 but the information is presented in a different format. At the end of the question students needed to realise that sharing required division. The item was not answered accurately by as many students as in Item 11, possibly because there were a few more steps required to complete this question in Item 12 (i.e. addition at the beginning of the question and division at the end) which allows more opportunities for mistakes to be made.

Item 12 was a question which involved ROO set out in tabular form and this was dealt with better than the ROO questions presented in Items 1-8 of the CCT. This indicates that the format of the item affects the way in which the student handles the question. The students who responded correctly to this item used a variety of methods of solution and it is important to note that items where a variety of solutions were possible tended to be answered accurately by a higher percentage of students. Perhaps this is because students can choose a method of solution which they feel comfortable with and which they can remember or understand more readily.

Efficiency of calculator use

Item 12 was answered most efficiently by students at Year 9 level. Students at Year 8 level were reasonably evenly distributed when considering how efficiently they answered the question. At Year 10 level a higher percentage of students answered reasonably efficiently, with a lower percentage answering highly efficiently and a smaller percentage of students answering inefficiently. As previously mentioned, there were a variety of methods of solution available which resulted in an effective response to this question and the method chosen determined the efficiency of the response. For instance some students entered $18·70 as 18·7 which saved a key press and some students pressed 'equals' at the end of each operation which used many extra key presses.

Item 13

The table below shows the amount of money which you have:

Money denomination	*Number you have*
$5 note	*3*
$2 coin	*2*
$1 coin	*5*
50¢ coin	*6*
20¢ coin	*4*

If you spend 65% of your money, how much money will you spend?

Table 13: CCT Item 13 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	7	14	14	14	9	11
Highly efficient (%)	0	0	0	0	0	0
Reasonably efficient (%)	33	29	33	33	29	31
Inefficient (%)	67	71	67	67	71	69

Effectiveness of calculator use

This item deals with multiplication, addition and percentage. The calculator used was equipped with a percentage button the same as a scientific calculator so this should not have been any more difficult for students than if they were using their own calculator. However, the question was very poorly answered. Students questioned at interview indicated that it was the percentage part of the item that they had most difficulty with and some did not attempt this question when they saw the percentage sign. The percentage topic is taught as part of Unit 2.4 (Year 8), Unit 3.4 (Year 9), Unit 4.4 (Year 9) and Unit 5.4 (Year 10) and there was an increase in the number of accurate responses at each year level, which is what one would expect. At Year 8 and Year 9 levels the question was answered accurately by a higher percentage of males while at Year 10 level a significantly greater number of females answered the question accurately.

Item 13 was similar to Item 12 in that it was set out in tabular format and required the student to consider the ROO, but the calculation of a percentage was required to correctly answer this question and this was not handled well by many students. It is interesting to note that the basic four-function calculators which the students were provided with also had a percentage key and a square root key and these buttons were not used by students who answered Items 13 and 14 incorrectly.

Efficiency of calculator use

Item 13 was not answered highly efficiently by any of the students who answered accurately. Irrespective of year level, approximately one third of the students answered reasonably efficiently and approximately two thirds answered inefficiently.

Item 14

What number multiplied by itself will give 289?

Table 14: CCT Item 14 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	43	67	86	64	66	65
Highly efficient (%)	40	62	58	59	53	55
Reasonably efficient (%)	0	0	3	2	0	1
Inefficient (%)	60	38	39	39	47	43

Effectiveness of calculator use

This item involved the square root function and students who realised this would have had no problem answering the question, as there was a square root button on the calculator. The square root function is taught as part of Unit 2.4 (Year 8), Unit 4.4 (Year 9) and Unit 5.4 (Year 10), and the fact that the percentage of correct responses increased significantly with each year level suggests that understanding is consolidated for a greater number of students each time the concept is revisited.

Efficiency of calculator use

Responses of the students questioned at interview suggest that it was understanding of the concept rather than ability to use the calculator which governed the efficiency of calculator use. Students who understood the concept simply used the square root key, hence answering the question highly efficiently. Students who did not recognise that this required the use of the square root key simply sat trying answers by trial and error until they found the correct response which would be quite time consuming, causing these students to answer inefficiently. More students were aware of the square root function in Years 9 and 10 than in Year 8, possibly due to the time at which this concept was covered in class. No students in Year 8 or Year 9 answered the question reasonably efficiently. At Year 10 level 3% of students answered reasonably efficiently, simply because in their trial and error method of solving the problem they 'guessed' the answer straight away.

Item 15

The combined score of two basketball teams, the "East" and the "West" is 91 goals. If the "East" scored $^3/_7$ of the goals, how many goals did they score?

Table 15: CCT Item 15 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	17	45	41	27	42	35
Highly efficient (%)	88	100	100	100	97	98
Reasonably efficient (%)	12	0	0	0	3	2
Inefficient (%)	0	0	0	0	0	0

Effectiveness of calculator use

Item 15 involved fractions and was similar to Item 6 but was not handled as well by students. The item required multiplication of a fraction by an integer. A high percentage of responses to this item were inaccurate. There was a significant increase in accuracy of responses from Year 8 to Year 9, but then an insignificant decrease from Year 9 to Year 10 level.

A significantly higher percentage of males answered this question accurately, while for the similar problem in Item 6 the difference was insignificant (i.e. 83% of females and 84% of males answered correctly). This may be due to the fact that the context in which this item was set was more easily related to by the males, but there is no way of confirming this.

Efficiency of calculator use

One Year 8 student responded to Item 15 reasonably efficiently, while the remainder of the students who answered this question accurately answered in a highly efficient manner. The student who answered less efficiently computed $3 \div 7$ then cleared the calculator and re-keyed this answer before multiplying by 91. These are two things which occurred over and over again. Students pressed the 'equals' key whether it was required or not, possibly as a 'just in case' key press, or possibly because they were generally required to write out their working by their teacher and so needed that answer in order to write down that stage of the 'working out'. The second computation which occurred more often than required was that students re-keyed answers rather than continuing to key the next part of the question into their calculator. It was as if they would like to start with a clean slate and press the 'clear' button after each time they pressed the 'equals' sign.

Item 16

Your mother is going to keep 21¢ of every dollar of pocket money you receive to pay for your pet ferret's food. If you earn $43 pocket money, how much will your mother keep to pay for ferret food?

The results for this item are shown in Table 16, on the following page.

Table 16: CCT Item 16 percentages of students correct and their calculator efficiency

	Year 8	Year 9	Year 10	Females	Males	Total
Number of subjects considered	46	51	44	64	77	141
Percentage of students correct	15	43	59	38	40	39
Highly efficient (%)	71	91	73	75	84	80
Reasonably efficient (%)	29	9	23	21	16	18
Inefficient (%)	0	0	4	4	0	2

Effectiveness of calculator use

Item 16 – the final item of the CCT – was a straightforward multiplication problem which the Year 8 and Year 9 students did not handle well, with 15 percent and 43 percent respectively responding accurately, but a higher percentage of Year 10 students (59%) responding accurately to this problem. This item involves multiplication of a decimal by a whole number. The main difficulty appears to be with the interpretation of the question. There was a significant increase in accuracy of responses as the year level increased. At Year 8 level the difference between responses from males and females was insignificant while at Year 9 level a higher percentage of males responded accurately and at Year 10 level a higher percentage of females responded accurately. The most common error which occurred when computing the answer to this question was that students failed to input 21¢ as a decimal (i.e. 0·21), which was the same error made by many students in Item 9. This error should perhaps have been more obvious in this question but only the Year 10 group had a higher percentage of students respond correctly to Item 16 than to Item 9. Students questioned about this problem at the interview seemed to have fewer problems if the item was read to them, which demonstrated that perhaps the students did not read the item carefully when they first encountered it.

Efficiency of calculator use

The majority of students who answered this item correctly also answered in a highly efficient manner. Inefficiency tended to be caused by students keying in extra zeroes which were not necessary to answer the question accurately. There was little

difference in efficiency of answers by students in different year levels. Only one student answered inefficiently – a female Year 10 student who added 0·21 forty three times.

Summary of Results

Table 17, on the following page, shows the number of students who answered each item correctly in order to consider how effectively students used their calculators to solve computation problems. These results were detailed for each item in Tables 1-16, and Table 17 collates these results into one table for the purpose of comparison. Gender differences are shown for each year level in Table 17, but not in the earlier tables.

Accuracy of Answers

Items one and two of the CCT involved calculations which could be keyed directly into the calculator in order to obtain the answer. These items were accurately answered by most students regardless of year level.

Items 3-5 involve Rule of Order of Operations (ROO) and require students to have some knowledge of this concept in order to answer the questions. ROO is a part of the mathematics curriculum in Years 8-10, but obviously students in higher year levels would have had more opportunity to consolidate their knowledge of ROO. Item 3 was answered accurately by more students in higher year levels. Items 4-5 were answered correctly by more students in Year 9 than in Year 8 but not so well by students in Year 10. This may seem to be an anomaly, but perhaps students at Year 10 level had not encountered problems such as this for some time and hence they did not immediately recall how to answer this question. Those students questioned at interview who had not answered these problems correctly indicated that they were unsure of how to enter these questions into a four-function calculator. Interestingly some of these students generally used four-function calculators in class so you would expect them to know how to use these calculators to answer questions which involve ROO, as they had been taught this content. Some students who regularly used scientific calculators in

Table 17: Percentages of students answering CCT items correctly in each year group

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Year 8																
Females																
(N = 26)	100	88	12	4	8	65	19	4	65	35	77	38	8	46	8	19
Males																
(N = 20)	95	100	30	5	15	85	45	5	55	25	50	30	5	40	30	10
Total																
(N = 46)	98	93	20	4	11	74	30	4	61	30	65	35	7	43	17	15
Year 9																
Females																
(N = 19)	89	89	11	11	11	100	26	16	47	21	89	37	11	63	32	26
Males																
(N = 32)	88	88	16	19	6	84	6	6	62	16	84	59	16	69	53	53
Total																
(N = 51)	88	88	14	16	8	90	14	10	57	18	86	51	14	67	45	43
Year 10																
Females																
(N = 19)	100	100	21	5	5	89	16	0	58	47	89	63	26	89	47	74
Males																
(N = 25)	96	100	16	0	0	84	8	0	64	20	100	44	4	84	36	48
Total																
(N = 44)	98	100	18	2	2	86	11	0	61	32	95	52	14	86	41	59
Years 8-10																
Females																
(N = 64)	97	92	14	6	8	83	20	6	58	34	84	45	14	64	27	38
Males																
(N = 77)	92	95	19	9	6	84	17	4	61	19	81	47	9	66	42	40
Total																
(N = 141)	94	94	17	8	7	84	18	5	60	26	82	46	11	65	35	39

class tended to work out ROO questions in parts rather than typing the question straight into the calculator, as they were unaware that their calculator took into account ROO when calculating the answer to the question.

Items 6-8 involved fractions and many of the students interviewed after the CCT were not reluctant to admit that they have "never been very good at fractions" (Year 8 student). Item 6 was answered correctly by a high percentage (74%) of Year 8 students, slightly more (86%) Year 10 students and again more (90%) Year 9 students. Individual students obviously deal better with different types of problems and this could account for the higher percentage in Year 9. Perhaps these students had just finished reviewing this section of the curriculum. This question required students to realise that the vinculum of the fraction means to divide and a reasonably high percentage of students in all years made this connection. Item 7 required students to work with a mixed numeral and this was not handled well by many students. The group of students who dealt with this item best was the Year 9 group and this may be for reasons previously outlined.

The remaining items in the CCT were set out in context and students had to first work out what was required to solve the problem and then use the four-function calculator to solve the problem. Items 9-10 involved ROO and fewer students answered these problems correctly than questions involving ROO in Items 1-8 (non-contextual questions). Perhaps the literacy level of the students affected their ability to answer the question or perhaps students simply did not read the questions carefully enough. Item 10 did not draw as many correct responses as Item 9. It was possible to solve the problem set out in Item 9 using mental computation to do some parts, if students did not follow the instructions given to use only their calculator. By doing this students did not need to rearrange the order in which they entered data into the calculator and hence more students responded correctly to this item than to Item 10, which did not lend itself to solution by mental computation. More correct responses were drawn from students in higher year levels for Item 11 and for all remaining items except for Item 15. This was what was expected as students have had more chance to consolidate their content knowledge and to practise using their calculators the longer they have been at school. For items where this is not the case it may be that students

have had a chance to use more sophisticated equipment to solve the problems being asked, and when they are required to use four-function calculators they may have forgotten how. Some students obviously did not have the required understanding of either the question set or how the calculator works in order to understand how to use the calculator to obtain the correct result.

Efficiency of calculator use

The percentages of the three defined efficiency ratings for all students in the sample are shown in Table 18. Only correct responses were used when determining efficiency ratings. The percentage of students using highly efficient methods of solution climbed from 63 percent in Year 8 to 69 percent in Year 9, but then fell away to 55 percent in Year 10. The Year 10 students typically use a scientific calculator rather than the four-function calculator supplied. It may be that as student use of scientific calculators increases they become less adept at using a four-function calculator such as the one supplied for the CCT. Certainly there was some indication of this possibility in the interviews.

The overall results show that just over three-fifths of the Year 8-10 students used a four-function calculator in a highly efficient manner. It is quite likely that students are expected to have skills in calculator use when they enter secondary school and due to this they may receive little further tuition in the use of the four-function calculator at this level.

Table 18: Summary percentages of Efficiency of Calculator Use for students in Years 8, 9 and 10

Year Level	N	Highly efficient	Reasonably efficient	Inefficient
8	46	63	24	13
9	51	69	22	9
10	44	55	33	12
Total (8-10)	141	63	26	11

The efficiency of calculator use varied according to the method of solution, as previously outlined in the analysis of each individual item. It is important to note that while individual CCT items elicited different levels of efficiency of calculator use there were some operations which caused inefficiency of calculator use in general, and these are listed below:

- zero was keyed in unnecessarily;
- an 'equals' sign was keyed in when it was not required; and
- parts of the question were re-keyed into the calculator.

Age Considerations

It is clear from Table 19 that the mean score on the CCT was higher for students in Year 9 than in Year 8, and similarly higher for students in Year 10 than in Year 9. The numerical difference, however, is quite insignificant, possibly due to the fact that students may not be getting any specific instruction into how to use four-function calculators as they progress through school. It is likely that it is assumed that students know how to use these calculators when they reach secondary school and therefore it is unlikely that teachers would spend much time specifically teaching students how to use them. Scores were also less spread out in higher levels than in lower year levels.

Table 19: Summary percentages of mean scores, standard deviations, minimum and maximum scores on the CCT for students in Years 8, 9 and 10

Year Level	N	Mean	SD	Minimum	Maximum
8	46	45	14·9	19	88
9	51	53	14·1	19	88
10	44	56	12·4	38	81
Total (8-10)	141	51	14·5	19	88

Gender differences

Table 20, on the following page, outlines the average percentage of items in the CCT answered correctly by students in each of Years 8, 9 and 10. The table also shows the average percentages of males and females within each year level.

Table 20: t-test of CCT total scores for males and females

Year	Gender	N	Mean	SD	DF	t-ratio	p
8	Female	26	42	13·5	44	-1·60	0·08
	Male	20	49	16·5			
9	Female	19	51	9·1	49	-0·85	0·33
	Male	32	54	16·5			
10	Female	19	60	12·5	42	2·25	0·03
	Male	25	52	11·5			
Total	Female	64	50	14	139	-0·87	0·32
	Male	77	52	15			

There is a difference between the mean scores (42 for females and 49 for males) for Year 8, but the t-test showed that the difference was not significant ($p < 0{\cdot}05$). The t-test for Year 10 students showed a significant difference ($p < 0{\cdot}05$) between the two means (60 for females and 52 for males). For Year 9 students there was no significant difference between the means of the males and the females. The students' gender at this year level did not affect their results on the CCT. It is interesting to note that at Year 8 level the mean CCT score for females was lower, at Year 9 level there was no significant difference, and at Year 10 level the mean CCT score of females was significantly higher. Overall there was no significant difference between the mean scores of the males and the females.

Information from Interviews

One male and one female who scored above the mean and one male and one female who scored below the mean were interviewed at each year level; a total of four students at each year level or twelve students in total (see Appendix B for the Interview Protocol). During the interview students were given the opportunity to repeat items that they had completed during the data collection phase and explain either how they arrived at the answer or what prevented them from obtaining the correct solution. The students were also asked to complete the items which they had

not finished or had not attempted from the CCT. Students were asked questions about how they filled in the Answer Sheet and also about particular items from the CCT. The other purpose of the interview was to ascertain how students would normally have completed particular items from the CCT without the restrictions placed on all subjects in the study, so giving them the opportunity to display to the interviewer how they could solve the problems set using their own equipment and methods which they would normally use in the classroom situation.

Students did not have the option of writing down their 'working out' for a particular item during the CCT, but those students interviewed who were given that option did not do so, and most said they generally would not write anything down. They would do the question on their calculator, in their head, or not at all. Some students whose calculators had the ability to do the items which involved ROO still worked out these questions manually, storing answers in their head, which indicates that they know very little about how their scientific calculator operates, so they use it as if it were a four-function calculator. Ironically, when faced with attempting these questions with a four-function calculator they had difficulty. Few students knew how to use the memory of the four-function calculator, and the students interviewed were also unsure of how to use the memory function on their own calculator – whether it was a four-function calculator or a scientific calculator.

The other area of concern was that few students knew what the square root button was, nor how to enter a fraction into a calculator. Some of these students, when questioned at interview, stated that they would not have used the square root button on their own calculator. Of the students interviewed who possessed calculators with a fraction key, about half knew it was there and even less knew how to use the fraction key. This indicates that they would probably have had the same results when completing the items involving square root or fraction problems in normal classroom conditions.

Chapter 5: Summary, Conclusions and Implications

This chapter begins by summarising the main aspects of the study, as well as its limitations. This is followed by a discussion of the results. Some of the implications for curriculum, teaching and further research are considered at the end of the chapter.

Overview of the Study

This study was carried out in a suburban senior high school in the Perth metropolitan area. The subjects were the students in six classes; two classes in each of Years 8, 9 and 10. The numbers of student participants were 46, 51 and 44 in the three respective year levels. These students were aged between 12 and 15 years of age.

The instrument, developed specifically for this study, was the Calculator Computation Test (CCT) which consisted of sixteen computation problems (see Appendix A for the Calculator Computation Test). This test was used in a pilot study and refined as a result of the pilot study. The CCT was then administered to the 141 subjects. Whilst completing the CCT, students were required to record the keys they pressed to obtain their answer. The results of the CCT were recorded and categorised immediately following the test, and as a result of this categorisation students were chosen to be interviewed. For the purpose of the study all students completing the CCT did so using a four-function calculator which was provided by the researcher.

The purpose of the study was to consider how well the subjects used a four-function calculator to solve computation problems. The research questions, outlined in Chapter 1, are concerned with how effectively and efficiently students of different year levels and gender solve computation problems with a four-function calculator. The results of the CCT were used to address these questions. Another aim of the study was to consider how students combine different methods of solution to solve computation problems. This final question was addressed by interviewing particular subjects.

The purpose of the interview was to ensure that the researcher had correctly interpreted the subjects' responses to the CCT, as well as to determine ways in which students would have answered similar questions in a normal class setting with the use of their own equipment. Twelve of the 141 subjects were interviewed; four students from each year level. Subjects were chosen after the CCT had been completed and a male and a female who scored above the mean and a male and a female who scored below the mean for that year level were chosen to be interviewed from each of the three year levels. Interviews were recorded and students were asked to complete questions, both as they had in the initial data collection and as they would have done in class.

The study had several limitations. It involved students from only one school and the results therefore have limited generalisability. It was designed only to consider how students used four-function calculators and did not allow students to use their own calculators, although the calculators supplied would have been used by all students at some stage.

Discussion of Results

Issues pertinent to particular questions, along with supporting statistics, have already been considered in Chapter 4. In the following section there is an overall discussion of the results.

Using the four-function calculator

Most of the students in Years 8, 9 and 10 did not display a great deal of proficiency in using four-function calculators. It could be argued that this was because many of the students at this stage of their schooling used scientific calculators. It is important to note that of the twelve students interviewed, all twelve indicated that they generally used a scientific calculator, although they generally used a four-function calculator provided by the teacher on occassions when they forgot their own calculator. It was presumed that the student would know how to use a four-function calculator to solve questions similar to those given in the Calculator Computation Test (CCT).

The students were more successful at solving problems which could be keyed directly into the calculator than those which required them to carefully read the wording of questions or to rearrange the numbers in any way. The majority of subjects had difficulty when considering questions which involved Rule of Order of Operations (ROO) or fractions. Several of the students interviewed did not take advantage of the fact that the scientific calculator accounted for the ROO and in this way they may as well have been using a four-function calculator. It is possible that students are so well versed in paper and pencil solution of ROO questions that they rely on this rather than the functions of the scientific calculator to answer the question. At least some students, however, are unaware of their scientific calculators' capabilities. One Year 8 girl specifically stated that she knew that her calculator had a fraction key but that she did not know how to use it (see Appendix E). From these examples it can be concluded that at least some of the students would have done just as poorly on the CCT using their scientific calculator as they did using the four-function calculator, because they did not make use of the special functions provided by the scientific calculator.

Students tended not to consider whether the answer that the calculator displayed was the right one. Regardless of the calculator used, students needed to be aware of the mathematical concept being tested and be able to estimate the answer in order to assess how reasonable was the answer displayed on the calculator. Whether because of time constraints or lack of knowledge students did not appear to be estimating and checking the answers they gave. This was made evident at interview when subjects considering Question 9 of the CCT commented that they would not pay $271 for the items listed ‘but that is what the calculator said it was’ (Year 8 female).

Effectiveness and efficiency of calculator use in Years 8–10

Overall the Year 10 students performed better on the CCT than the Year 9 students and the Year 9 students performed better than the Year 8 students. In terms of effectiveness as year level increased so did the effectiveness of calculator use. When considering how efficiently student used their calculators there was no absolute as

there was some variation from question to question. In general students in Year 8 tended to use their calculators more efficiently than students in the higher levels, although this is not so for every item in the CCT. Similarly, students in Year 9 also tended to use their calculators more efficiently than students in Year 10. It is possible that students at Year 10 level may not have had regular use of a four-function calculator for some time. It is likely that Year 10 subjects were not as efficient at using the calculators as they had to use trial and error to get the required answer, they may not have immediate recall of how to use the calculator. The method of solution which students used to solve particular problems in the CCT tended to determine how efficiently they answered that question and following is some discussion of the methods of solution used.

Students did not have the option of writing down their 'working out' for a question during the CCT. Students interviewed were allowed to use any method of solution and were then asked how they had arrived at that solution. Of the students interviewed, most did not write anything down and said they generally would not write anything down when answering most of the questions. They would generally do the computation on their calculator, in their head, or not at all.

Students generally performed better on items which were presented numerically or in tabular form than on questions of a similar type and difficulty which were presented in a written form in context. It would appear that comprehension of the question being asked may be a confounding factor in considering the solution of computation problems set out in context.

Even when students obtained the correct solution to a problem they often did not use the most efficient method of solving the problem. The results reveal that lower secondary students (students in Years 8-10) have some difficulty using four-function calculators to answer computation problems efficiently and effectively. It is unlikely that these students knew how to use the calculators and forgot – more likely that primary school students are equally ineffective and inefficient at using four-function calculators to solve computation problems. One explanation for this might be that "there is, in fact, very little calculator use in primary classrooms" (Sparrow & Swan,

1997) despite policies put in place to ensure integration of calculators into the classroom. This is an important point for consideration. It is expected by many educators that students arrive at secondary school able to use basic four-function calculators proficiently but research suggests that this is not the case. One Year 8 girl explained that she used these four-function calculators in primary school 'but we didn't really figure out a quicker way to do things' (see Appendix E).

Gender differences

At Year 8 level males were shown to score higher than females on the CCT, although the difference was not significant. At Year 9 level no significant difference was found between the average score of male subjects and the average score of female subjects. In Year 10, females were found to score significantly higher than males on the CCT. This suggests that at an earlier age males were more proficient in using the four-function calculator to solve computation problems, but at some point over the three years females overtake and are found to be more proficient in using the four-function calculator to solve computation problems.

Implications

The results of the study suggest the following implications for curriculum development and teaching practice in the mathematics classroom.

- Students need to be made more aware of exactly how to use four-function calculators at primary school, and even at lower secondary level they need to be specifically taught how to do particular problems on the four-function calculator.
- Students need to be encouraged to experiment with all the buttons of the four-function calculator.
- The Calculator Computation Test and Answer Grid, together or separately, could easily be used by teachers in classrooms to gauge their students' understanding of the uses of their calculator (four-function or other types of calculator).
- Some students deal better with questions which are presented numerically or in tabular form but questions should not always be presented in this way. Questions

should be presented in numerical or tabular form to develop a high skill level. It is also necessary to expose students to a wide variety of questions set out as word problems and in context to make them more familiar with how to solve these problems.

- Finally, it needs to be realised that in real life many of our students will only have four-function calculators in their homes to assist them in answering questions just like the ones set out in the CCT. It is therefore important that they are proficient at using four-function calculators, and not just the more sophisticated technology available, to solve problems.

The results of this study leave a lot of questions that may be considered in further research.

- How well do primary school students use four-function calculators?
- How well do upper secondary students use four-function calculators?
- What is the explanation for gender differences found in this study?
- How well do students use scientific calculators?
- How well do students use graphics calculators?
- If calculator skills were specifically taught using four-function calculators in the classroom, would this improve the students' proficiency in using the four-function calculators?

This study set out to look at the way in which students in a specific age group made use of readily available technology to solve particular types of questions. In this age of sophisticated technology it is easy to forget that many students need to be shown how to use a basic four-function calculator to solve problems. Many people would say "Why bother?", as surely these students can use a scientific calculator, a graphics calculator or a computer to solve these questions. The reality is that often the four-function calculator is the only calculator available. Many students are unaware of how to use their own calculator effectively and efficiently, regardless of what type of calculator it is. Sometimes this is because of misconceptions about what the calculator can or can not do, sometimes it is due to a lack of familiarity with the calculator or the mathematical concept. Regardless of why, the fact remains that

students could certainly use the four-function calculator to answer questions more effectively. Students could certainly use their calculators in a more efficient way when solving computation problems effectively. This is the challenge for educators, to ensure that students of all ages and genders are able to use this technology in an effective and efficient way.

References

Arnold, S. (1998). Technology and Mathematics Education: From Calculators to Multimedia. In Nerida Ellerton (Ed.) *Issues in mathematics education.* (pp. 173-198). Perth: MASTEC.

Australian Education Council. (1991). *A national statement on mathematics for Australian schools.* Carlton, Victoria: Curriculum Corporation.

Burns, R.B. (1994). *Introduction to research methods.* Melbourne, Longman Chesire.

Clarkson, P.C. (1991). Language Comprehension Errors: A Further Investigation. *Mathematics Education Research Journal, 3*(2), 24-33.

Cortese, B.A. (1989, August). It doesn't add up (Letter to the editor). *The West Australian*, p. 10.

Cuban, L. (1986). *Teachers and machines: The classroom use of technology since 1920.* New York: Teachers College Press.

Curriculum Council. (1998). *Curriculum framework.* Perth: Curriculum Council.

Curriculum Development Centre and The Australian Association of Mathematics Teachers, Inc. (1987). *A national statement on the use of calculators for mathematics in Australian schools.* Canberra: Curriculum Development Centre and The Australian Association of Mathematics Teachers.

Curriculum Programmes Branch. (1989). *Learning Mathematics Handbook: Pre-primary to stage seven mathematics syllabus.* Perth: Ministry of Education, Western Australia.

Department of Education and Science. (1982). *Mathematics counts.* (The Cockcroft Report). London: Her Majesty's Stationery Office.

Dick, T. (1988, April). The continuing calculator controversy. *Arithmetic Teacher*. 37-41.

Duffin, J. (1991). Mathematics for the nineties: A calculator aware curriculum. *Mathematics Teaching, 136*(3), 56-62.

Education Department of Western Australia. (1998a). *Mathematics outcome statements*. Perth: Education Department of Western Australia.

Education Department of Western Australia. (1998b). *Overview outcome statements.* Perth: Education Department of Western Australia.

Eisenberg, T. (1991). On Building Self-Confidence in Mathematics. *Teaching Mathematics and its Applications, 10*(4), 154-158.

Fielker, D. (1992). Calculator algorithms. *Micromath, 8*(1), 33-35.

Gay, L.R. (1992). *Educational Research*, 4th edition. New York: Maxwell Macmillan International Editions.

Groves, S. and Cheeseman, J. (1992). *Calculators in primary mathematics: Changing expectations and curriculum issues.* Paper presented at the joint conference of the Australian association for Research in Education/New Zealand Association for Research in Education, Deakin University, Geelong.

Hembree, R. and Dessart, D.J. (1986). Effects of hand-held calculators in precollege mathematics education: A meta-analysis. *Journal for Research in Mathematics Education, 17*(2), 83-99.

Hembree, R. and Dessart, D. J. (1992). Research on calculators in mathematics education. In J.T. Fey & C.R. Hirsch (Eds.). *Calculators in mathematics education: 1992 yearbook* (pp. 23-32). Reston, VA: National Council of Teachers of Mathematics.

Kaiser, E. (1991). One point of view: Calculators in the classroom. *Arithmetic Teacher, 39*(2), 6.

Lee, O.T. (1998). Calculators as interactive personal interfaces. *Australian Senior Mathematics Journal. 12*(2), 38-45.

McIntosh, A., Bana, J. & Farrell, B. (1995). Mental Computation in School Mathematics. Perth, MASTEC.

Maftoon, J. (1982, February). ITV: Are Teachers Using It? *T.H.E. Journal*, 45.

Mills, S. (1991). Children's ideas about calculators. *Mathematics Teaching, 134*(3), 12-15.

Ministry of Education. (c1988). *Lower Secondary Mathematics for Western Australian Schools.* Perth: Ministry of Education, Western Australia.

Relf, S. (1992). The Same but Different: Individualised Schemes in Mathematics. *Teaching Mathematics and its Applications, 11*(3), 97-104.

Rowland, T. (1992). Inadmissible evidence. *Micromath, 8*(1), 27-28.

Sparrow, L., Kershaw, L. & Jones, K. (1994). Calculators: Research and curriculum implications. Perth: MASTEC.

Sparrow, L. & Swan, P. (1997). Calculator Use in Western Australian Primary Schools. Perth: MASTEC.

Suydam, M. N. (1981). Research Report; What are calculators good for? *Arithmetic Teacher, 34*(6), 22.

Suydam, M. (1982). *The use of calculators in pre-college education: Fifth annual state-of-the-art-review.* (Contract No. 400-80-0007). National Institute of Education, Ohio: Calculator Information Centre.

Thompson, V. (1992). Teaching mathematics with technology: How to win people and influence friends: Calculators in the primary grades. *Arithmetic Teacher, 39*(5), 42-44.

Tyler, K. (1980). Some comments on calculators in junior schools. *Mathematics Teaching, 90*(3), 19-20.

Appendix A - Instruments
Calculator Computation Test
Years 8, 9 and 10

1. $7 \times 7 \times 7 \times 7$ = ______________

2. $16 \times 24 - 470$ = ______________

3. $63 \times 3 - 19 \times 4$ = ______________

4. $34 + 6 \div 13 \times 8$ = ______________

5. $2{\cdot}8 - 6{\cdot}7 \div 5$ = ______________

6. $\frac{68}{79} \times 83$ = ______________

7. $25\frac{3}{7} + 18$ = ______________

8. $100 - 30 \times \frac{11}{12}$ = ______________

9. What would it cost to buy 7 exercise books for 35¢ each, 3 pens for $1 each and a calculator for $23·95?

10. If you have $50·00, how much money will you have left after you buy a hot dog for $1·65, 2 drinks for $1·75 each, an icecream for $1·80 and 6 lollies for 5¢ each?

11. If soft drinks cost $1·30 a can, how many cans of soft drink can be purchased with $21·10?

12. The table below shows the amount of money which you have:

Money denomination	Number you have
$20 note	1
$10 note	0
$5 note	1
$2 coin	1
$1 coin	2

If you spend $18·70 on a T-shirt and you have to share the change equally with your friend, how much money will you each receive?

13. The table below shows the amount of money which you have:

Money denomination	Number you have
\$5 note	3
\$2 coin	2
\$1 coin	5
50¢ coin	6
20¢ coin	4

If you spend 65% of your money, how much money will you spend?

14. What number multiplied by itself will give 289?

15. The combined score of two basketball teams, the "East" and the "West" is 91 goals. If the "East" team scored $\frac{3}{7}$ of the goals, how many goals did they score?

16. Your mother is going to keep 21¢ of every dollar of pocket money you receive to pay for your pet ferret's food. If you earn \$43 pocket money, how much will your mother keep to pay for ferret food?

Calculator Computation Test
Years 8, 9 and 10
Sample Answer Sheet

SAMPLE: If I say "Compute 45 divided by 3" then you are likely to press the keys

4	5	÷	3	=

on your calculator.

Your task is to:

1. Answer the question using your calculator.

2. Record your answer in the space given.

3. Write the key presses you used in the grid given.

4. Press the recorded keys on your calculator using exactly the key presses you have recorded.

5. Check your answer and if it is correct tick the appropriate box.

Example:

Question 1 Answer 15 Checked ✓

4	5	÷	3	=															

6. If the answer is different put a cross in the appropriate box and repeat the procedure.

Example:

Question 1 Answer 7·5 Checked ✗

4	5	÷	3	=															

Question 1 Answer 15 Checked ✓

4	5	÷	3	=															

7. Move onto the next grid and continue with the next question.

ALL CALCULATIONS MUST BE PERFORMED ON YOUR CALCULATOR

Calculator Computation Test
Years 8, 9 and 10
Answer Sheet for Sample Questions

Use the grids below to answer the sample questions which will be read out to you.

Question ____________ Answer ____________ Checked ☐

Question ____________ Answer ____________ Checked ☐

Question ____________ Answer ____________ Checked ☐

Question ____________ Answer ____________ Checked ☐

Question ____________ Answer ____________ Checked ☐

Question ____________ Answer ____________ Checked ☐

Calculator Computation Test
Years 8, 9 and 10
Answer Sheet

Question ______________ Answer ______________ Checked ☐

Question Answer Checked ☐

Question Answer Checked ☐

Question Answer Checked ☐

Question ______________ Answer ______________ Checked ☐

Appendix B - Protocols

Data Collection Protocol

Following is a transcript of what the researcher said during the data collection phase of the study. The data was collected from six groups of subjects at separate times and the transcript below was used to ensure that the same information was given to each group.

I want to start by thanking you for your cooperation. In a moment I am going to hand out the information you will need and then explain what I would like you to do.
Please save any questions for the time being.

<Hand out a Data Card and Sample Answer Sheet to each student. >

I am going to read the directions from this sheet of paper so that I don't forget to give you any information.
The reason I want you to complete this activity today is so that I can collect some information about the way calculators are used. Because of this I want you to use your calculator to answer the question, even if an answer can easily be worked out in your head I want to see how you would work out the answer on the calculator.
I can't come and watch how each of you answers the question using your calculator because there are too many of you, so I want you to complete the answer sheet given in a particular way, this will make it easier for me to work out what you have done when I read through your answer sheet.
Because I am looking at how each person uses the calculator I want you to work through the questions given on your own; please do not discuss it with anyone else; just write down how you worked out the answer to the question, that is what I am interested in.
I would first like you to write your name and the information asked for on the Data Card and I don't want you to write your name on any other pieces of paper, this is so that no one will know which answers are yours by just looking at the Answer Page. This activity is just to see how calculators are used and I don't need to know who has used the calculator when I mark the Answer Sheet. I might want to ask you some questions about what was done to answer Question 9 on Answer Sheet D15 afterwards, and then I can look up whose answer sheet that is to find you.

< At this point students are encouraged to play with the calculator for a couple of minutes and they are told that this calculator does not work out rule of order for them and that the memory may be useful. An example of how to use the memory is given at this stage:
Example: >

Clear the memory by pressing the RM button on the top left of your calculator twice.
Put something into your memory by pressing the M^+ button, for example 2×5 then M^+ will display 10 on the screen as 10 has been added to your memory. To check what is in your memory now press the RM button once.
Take something out of your memory by pressing the M^- button, for example 3 then M^- will display 3 on the screen as three has been taken from your memory.

If you press the RM button once now you should have the number seven displayed on your screen. To clear the memory press the RM button again.

Now we will go through a question together and fill in the sample answer sheet and you can ask me any questions if you don't understand what you are being asked to do. I want to remind you now that you must use your calculator to answer <u>every</u> question, even if you can do the question in your head.

Please look at the page with "Sample Answer Sheet" written at the top.
The first sample question is done for you to show you how to complete the sheet.
We will read through this sample together. <Read>

< List of sample questions (These will be displayed on the overhead projector or the blackboard)
Sample question 1: "Calculate 45 divided by 3"
Sample question 2: "Calculate 6 divided by 10"
Sample question 3: Calculate 54 take away 100" >

Now we will go through sample question two and I want you to go through each step as I tell you to, so that you don't forget any steps the first time.
First you need to write in the question number <Pause>, then you need to use your calculator to find the answer to the question. <Pause>
Write the answer to the question down. <Pause>
Now you need to recall what keys you pressed on your calculator and write them down in the boxes of the grid. Use one box to write down each key press. <Pause>
Press the exact keys on your calculator that you have written down and see if you get the same answer. If you do, tick the "Checked" box. If you didn't get the same answer you need to put a cross in the "Checked" box to show me that you don't want to use that answer.
The aim here is to check that you have written down the correct key presses.
You now have to do that question again if you did not tick the "Checked" box, trying to remember which keys you press so that you can write them down correctly. <Pause>
Any questions? <Pause>
Now work through sample question three yourself in exactly the same way as we have just worked through sample question two. If there are any questions about how to fill in the form, now is the best time to ask me. <Pause>
<Allow time for students to complete this sample question, then hand out the Calculator Computation Test>
Now I want you to work through each question in the same way that you worked through the sample questions.

< Students should be allowed enough time to work through all questions. Once students have finished ask them to place the pages on the desk so that the sample sheet is first, the question sheet next and the answer sheet(s) last.
Collect all sheets of paper.
Thank the students for helping with the study and tell them that you will let them know what you have found. >

Interview Protocol

Set out below is a transcript of what the researcher said during the interview phase of the study. Twelve subjects were interviewed at separate times and the transcript below was used to ensure that the same information was given to each class.

< Once the student is in the room and seated opposite the interviewer the interviewer should say: >

The reason that I have asked you to come here is so that I can watch you do some of the questions which you did on the questionnaire. I want to watch you so that I can see if I am reading the answer sheets correctly. I need to know if I understand what you have done, so I will ask you to work through some questions and I will watch you. I am going to tape what we say so that if I ask you a question I will have your answer on tape. This is so that I don't forget your answer and it saves you having to repeat your answer so that I can write it down. Is that O.K. with you?

It is important to note that students have already given their permission and their parents permission in writing for this to occur. The whole process of Data Collection and interview has been explained to them in a letter read to them by their maths teacher, which they then received a copy of. The student is merely being asked their permission to tape the session here in case they forgot or changed their mind about being taped.

< Ask the student to work through several items, asking relevant questions when appropriate, such as "Is that how you did that question on the test, can you remember?" >

Now I want you to work through this item (pointing to the item), but this time I want you to do the question how you normally would. If you want to write anything down you can, or if you want to work something out in your head instead of using the calculator you can. Try and work out the answer the way you would normally.

< Ask the student to work through several items (to be selected after the "Calculator Computation Test" has been completed by the student), asking relevant questions when appropriate. >

Questions will include:

"Can you show me exactly how you did this question in the test, do you remember?"

"How would you have done this question if you were allowed to use pencil and paper as well as your calculator?"

"Would you have done this question differently if you didn't have to use your calculator? If so, how?"

"Can you do this question in a different way?"

"Did you estimate the answer to check if the calculator was right?"
"How could you check the answer to this question?"
"Why didn't you complete this question?"

(For a comprehensive list of possible interview questions see Appendix D)

< Ask the student if they have any questions.
Thank the student for their time and their help.>

Appendix C - Data Cards

Number: ______________ **Name:** ______________ **Date of birth:** ______________ **Age:** _____ **Sex(M/F):** _____ **Class:** __________ **Year:** ___	**Number:** ______________ **Name:** ______________ **Date of birth:** ______________ **Age:** _____ **Sex(M/F):** _____ **Class:** __________ **Year:** ___
Number: ______________ **Name:** ______________ **Date of birth:** ______________ **Age:** _____ **Sex(M/F):** _____ **Class:** __________ **Year:** ___	**Number:** ______________ **Name:** ______________ **Date of birth:** ______________ **Age:** _____ **Sex(M/F):** _____ **Class:** __________ **Year:** ___
Number: ______________ **Name:** ______________ **Date of birth:** ______________ **Age:** _____ **Sex(M/F):** _____ **Class:** __________ **Year:** ___	**Number:** ______________ **Name:** ______________ **Date of birth:** ______________ **Age:** _____ **Sex(M/F):** _____ **Class:** __________ **Year:** ___

Appendix D - Interview Questions

Interview questions were selected by the researcher prior to the interview. In order to select interview questions the researcher considered the subjects' answers to the Calculator Computation Test(CCT).

Interview questions were selected according to:
- whether or not a question on the CCT was answered by the subject;
- whether or not an answer given on the CCT was correct;
- whether the steps listed on the CCT resulted in the answer given; and
- whether the subject answered the question on the CCT in an efficient manner.

Interview Questions

Have you used a calculator like this before? (Indicating the four-function calculator.)

Do question number ____ exactly how you did it on the test.

Can you think of any other way you could do that question on your calculator?

Why did you change the question around so that you did the times first? Why did you do it like that?

See how you have pressed equals here and equals here, do you need to press that?

How would you do that question?

If you were using your own calculator how would you have done that?

Would you have changed the order around like this if you were using your own calculator?

You would have done it exactly the same way?

Does your calculator do rule of order for you, do you know?

Why didn't you do that question?

Could you do that question now?

Can you think of a way of doing that question using less key presses?

What answer did you get?

Did you get the same answer when you checked it?

If I said you could write down notes or working out while you were doing that question, would you have written anything?

If you are working out a question (in class) do you often use pencil and paper to jot down notes while you are going?

Can you do this question the way you would if you were just sitting in class doing it?

Do you think you would be able to do this question just using the calculator, without holding numbers in your head?

Could you do this question using the memory function in the calculator?

Is there a difference between what you got on your calculator and what you got on the four-function calculator?

Why is this answer positive and this answer negative?

How did you get this answer?

Are there any buttons that you pressed that you probably didn't need to press?

Did you check that answer to see if it was right?

Have you heard of square root before?

What does the line on the fraction mean?

Why did you write this down, when your calculator gave you this answer?

Why do you think that answer is different?

Do you think that this is the correct answer?

Does that seem like a more reasonable answer?

What do you think might be the correct answer?

Can you see where you might have gone wrong?

Do you think you would be happy to pay that if you went into a shop?

Would you pay that much money for that (indicating the goods in question)?

Do you remember how you did that?

Do you want to try it again?

Did you need that equals sign?

Why would you put brackets in?

What would you do if you didn't have a fraction key?

What did you do?

Without looking at what you did, can you try and do that question?

. . . and then what did you do?

What are you worried about?

What looks wrong about that?

What would you have done?

Why would you do that?

Can you think of another way of doing that question?

Would you press the memory key at all?

Would you just type the question straight into your calculator?

Would you remember that number in your head or would you write it down?

Do you know how you would do that?

What answer did you get?

How do you think you went on the Calculator Computation Test?

What did you just do, can you explain it to me?

Does this calculator have a square root button?

Would you have pressed an equals sign there?

Would you do it exactly like that?

Appendix E - Selected Responses to Interview Questions

Below are a few excerpts from interviews with students. This selection of pertinent examples are of interest for a variety of reasons and particularly support some of the researcher's findings.

I is used to signify that the interviewer is speaking.
S is used to indicate that the subject is speaking.
* is used to indicate that part of the interview not considered relevant was omitted.

Year 8 student (female)

I: Now, the first question, $7 \times 7 \times 7 \times 7 =$
Can you think of another way you could do that on your calculator?
S: Well, we've got a power button.
I: So, what would you do?
S: So I'd press seven to the power and I'd write four and it would give it to me straight away?
I: Right, and it would give it to you, so that would be quicker wouldn't it?
S: Mm.
I: O.K. Do you know any way on this where it would be quicker?[Indicating the four-function calculator.]
S: Um. Not on this.
I: Did you use a calculator like this at primary school?
S: Yeah, but we didn't really figure out a quicker way to do things.
*
I: O.K. If you were using your own calculator how would you have done that? Would you have changed them around like this if you were using your own calculator? [Indicating the student's Answer Sheet]
S: Yeah. I would have done it the same way.
I: You would have done it exactly the same way? Does your calculator do rule of order for you, do you know?
S: Um, I don't know. I just change, do it my own way anyway.
*
I: O.K. Good, that's good. Question number eleven. Can you think of a way of doing that question with using less key presses? [Pause]
S: [Shakes head]
I: No, O.K.

Year 8 student (male)

I: Have a look at question twelve. Could you just do that on this calculator, [indicating the four-function calculator] exactly the same way as you did it. [Pause]
O.K. So you have just added up all the dollar amounts there. Is that what you've done?
S: Mm.
I: O.K. [Pause]

I: O.K. Thank you, so that's fine. you got the right answer, it's just that I wasn't sure how you managed to get twenty nine, first up. So you actually added your dollar amounts to get that.
S: Yep.
I: O.K. Did you do question thirteen in a similar way, did you?
S: Yep.
I: Yep. O.K. If you had been doing that [indicating question number thirteen] in your own calculator, that one there, how would you have done it? [Pause] Would you have done it any differently? [Pause]
Or would you still have gone five plus five plus five plus two plus two plus one plus one plus one plus one plus one.
S: Um. [Pause]
Yeah.
I: You would have done it exactly the same, O.K. If I said you could write down notes while you were doing it would you have written anything for that question? [Pause]
Or would you have just done it straight on your calculator?
S: Straight on my calculator?
I: If you were in class?
S: Straight on my calculator.

Year 10 student (male)

I: Question eleven. Could you have done that question using less key presses than you used there?
S: Maybe the decimal point, I don't know.
I: O.K. Try doing it without the decimal point and see how you go. [Pause] Same answer, sixteen whole cans?
S: yeah.
I: I noticed that you also didn't press the zero there. When you did this one [indicating the Answer Sheet], did you press the zero?
S: Nah.

Year 10 student (female)

I: O.K. So first of all, if I could just get you to, [Pause] looking at question number one, seven times seven times seven times seven.
S: Mm.
I: If you were doing that on your calculator would you do it differently?
S: Well, I know the squared button, but I don't. There's not a, um, a button that says I can do like, seven times seven times seven times seven, so I just, I, yeah, I typed it.
I: You would just type it straight in?
S: [Nod]
I: O.K., no problem. Looking at question number three. How would you do it, if you were using your calculator?
S: I would do it, um, sixty three times three, and then I would equals it and get the answer.

I: And you would write that down, would you? What was it, one hundred and ninety four?
S: Yep, and then I would do the other one, you are supposed to do the times first aren't ya? Yeah. And then I would get, that's the answer, seventy six. So I would just take.
*
I: Looking at question number seven. How would you do that question?
S: I don't know, I, did I do that? Not really.
I: What confused you? You wrote it down but you didn't get an answer.
S: The three sevens.
I: O.K. How would you do it on your calculator?
S: Well. [Pause]
I: Do you have a fraction button on your calculator?
S: No, oh, I don't know. I don't know how to use that fraction button, but.
I: O.K. So how would you do it?
S: Well, um.
I: Or do you just leave out the fraction questions?
S: No, I don't just leave out the fraction questions, I just, I always have to ask how to do them first, because I don't.
I: O.K. So you're not quite sure how to do them, O.K?
S: Yeah.
*
I: Looking at question number fourteen. The question said, "what number multiplied by itself will give you two hundred and eighty nine, and you've written this answer [Indicating the students Answer Sheet]. One hundred and forty four point five. Did you check to see if that was right? Did you multiply it by itself to see if you got two hundred and eighty nine?
S: I think so. I mustn't of. Is that right?
I: Try it.
S: Um, oh, wait a sec, I'll just see. Yup.
I: O.K. But you multiplied by two, multiplied by itself.
S: Oh. So, like, I can do. So that's not right? That's not right? That answer?

Year 8 student (female)

I: First of all, I'll just get you to have a look at question number one on there. [Indicating the Calculator Computation Test] Can you remember how you did that in the test using this calculator? [Indicating the four-function calculator] Just redo it exactly how you did it. [Pause]
O.K And that's the same answer as you got. Do you think there is a way you could have done it using less keys?
S: Yeah.
I: Try. [Pause]
S: No.
I: How would you have done it on your calculator, the same way, or a different way?
S: Um, do it the same way.
I: Exactly the same way, O.K. Do you want to just do it and check if you get the same answer using your calculator. [Pause]

S: Yep.

*

I: Looking at question number nine, there. [Indicating the Calculator Computation Test] What would it cost to buy seven exercise books for 35 cents each, three pens for a dollar each and a calculator for twenty three dollars and ninety five cents? Can you do that using your calculator? [Pause] 'Cause doesn't that seem huge? You went into a shop and they charged you 271 dollars for that stuff. Do you think you would pay for that?

S: No.

I: What do you think it might be? [Pause]

S: [Shakes head]