Effectiveness and Efficiency of Calculator Use for Computation in Years 8-10

Jack Bana
Edith Cowan University
<j.bana@ecu.edu.au>

Rachel Shipley
Cyril Jackson Senior College
<rshipley@cyriljackson.wa.edu.au>

A sample of 141 Year 8-10 students in a suburban secondary school was given a computation test to complete by using a four-function calculator. Students were required to record all their key presses for each item in order that they could be assessed on their efficiency of calculator use. There was a small increase in effectiveness of calculator use over the three year levels, but efficiency actually fell away in Year 10. Overall, only 62 percent of students used their calculators highly efficiently.

For more than 20 years, policy and curriculum documents have promoted the use of calculators at all year levels of school mathematics (NCTM, 1980; Cockcroft, 1982; Australian Education Council, 1991; AAMT, 1996; Education Department of Western Australia, 1998; NCTM, 2000). Meta-analyses of earlier research in the 1970s and 1980s showed a tendency to focus on comparisons between paper and pencil skills with or without calculator use (Suydam, 1982; Hembree & Dessart, 1986, 1992). Gradually there was a shift towards investigating the role of calculators *per se* in school mathematics programs, particularly in the primary school sector, with an increasing focus on the calculator as a tool for learning mathematics (Groves & Cheeseman, 1992; Groves & Stacey 1998).

Scientific calculators have long been used in mathematics programs in the final years of secondary schools, and now these are being replaced by graphing calculators. However, despite this extensive use over about two decades, the use of calculators in the first high school years has been slower to eventuate. It would be true to say that the use of the basic four-function calculator in primary schools is still very sporadic. Sparrow and Swan (1997), in an extensive survey of primary teachers in Western Australia, found that while teachers generally favoured the use of calculators, this support was heavily qualified. Thus their use was very limited indeed. The four-function calculator is regarded as an essential tool for everyday living, yet how well are people able to use them? If they are not used much in primary school, then will this handicap students at the high school level in using scientific and graphing calculators? Little is known about how well students use calculators. It is probably true to say that for many students, they have largely had to fend for themselves in learning to use a calculator.

The purpose of this study was to determine the effectiveness and efficiency of use of a basic four-function calculator by students in the first three years of high school (Years 8-10) in a Perth suburban secondary school. Effective calculator use was defined in terms of the percentage of correct calculations. Efficient calculator use, as suggested by Fielker, "can be measured by the number of keys one must press"(1992, p. 33). Efficiency of calculator use has thus been defined for this study in terms of the number of key presses required to achieve the correct solution to a calculation.

B. Barton, K. C. Irwin, M. Pfannkuch, & M. O. J. Thomas (Eds.) *Mathematics Education in the South Pacific* (Proceedings of the 25th annual conference of the Mathematics Education Research Group of Australasia, Auckland, pp. 108-114). Sydney: MERGA. ©2002 MERGA Inc.

Methodology

Subjects

The sample consisted of six classes, ranging from 25-35 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 level in that both the top and bottom stream classes in the three cohorts were not used in the study. The reason for this was that it was considered that more useful information could be obtained from students in the middle groups as there was a broad cross-section of abilities among these cohorts. If students from the very top stream in each year level had been chosen, the majority of questions would have been answered correctly and little information would result. Similarly, if students from the bottom stream had been chosen it was expected that a significant number of questions would have been answered incorrectly.

Instruments

A Calculator Computation Test (CCT) was developed, piloted and then modified for the study. It consisted of 16 items, half of which were non-contextual, and the remainder were items presented in context. All items involved computations which could be carried out with a four-function calculator. An answer sheet was developed for the test, including a grid for each item to enable students to record their individual calculator key presses for that item. The same test was used for all three year levels in order to more readily determine the changes in calculator effectiveness and efficiency across Years 8-10. A semi-structured interview schedule was developed for use in a follow-up to the CCT with a sample of 12 students (four from each year level). Modifications to this schedule were made as appropriate for individuals, based on their CCT results and on their responses during interview.

Procedure

All students were given the same type of four-function calculator to use. The CCT was administered to each of the six classes over the course of one week. During the CCT students were required to use the calculators for every computation. This was obviously a contrived situation since, in normal circumstances students would choose between mental, calculator and paper-and-pencil computation strategies; or some combination of these (Swan & Bana, 2000). Thus, students were forced to use the calculator for every item in order to display a measure of their calculator effectiveness and efficiency in each case. Students were given several practice examples to familiarise them with the calculator provided, and to clarify the requirements for recording all key presses for each computation item. The answer sheet used by students had the structure shown in Figure 1 for all 16 items. They were required to record the key presses in the grid, then check that the recorded sequence did provide the answer stated. If not, the process had to be repeated until a match was obtained. This requirement was implemented to maximise the likelihood of a *bona fide* record of key presses for each item.

Question No. _____ Answer: _________ Checked: _____

Figure 1. Grid to record solution and calculator key presses for each CCT item.

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 – twelve students in all – inclusive of both genders and a range of ability in calculator use were individually interviewed, and the interviews were audio-taped. Interviews were conducted within two days of administering the CCT in order to maximise students' retention of how they went about the CCT. Students brought their own calculator to the interview in order to compare how they would normally have used their calculator for particular items, as opposed to how they used the one supplied. Students were asked to re-do questions directly from the CCT as they did in the class test, to do questions with their own calculator, and to explain if they would normally have done the question differently in class. The interviewees were questioned in detail re the processes used, and their understanding of the calculator and of the computations carried out.

Results and Discussion

The results of the Calculator Computation Test (CCT) were analysed for effectiveness of calculator use (correct responses) and to determine how efficiently the students used the calculator. Only the correct responses were considered when determining efficiency of calculator use. The level 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 required to answer the question effectively).

The percentages of students correct on the CCT – thus indicating the effectiveness of calculator use – are shown in Table 1. The performances are only at a moderate level, and increases across the three year levels are small, considering that all students were given the same items. It was not possible to determine to what extent this was due to inadequate calculator skills. However, it was clear that performance was largely due to difficulties with the arithmetic. For example, many students had problems with items involving the rule of order of operations. This was confirmed in the interviews where some students were also unaware that their scientific calculator took account of this rule of order. Items involving fractions also proved difficult, with one student freely admitting at interview that he had "never been very good at fractions", and others making similar statements. It was also evident from the interviews that most students did not make use of estimates to check the reasonableness of results, but put blind faith in what the calculator displayed. They were obviously not in the habit of estimating before calculating, which is a key mathematical process, especially when using calculators or computers for computation.

Table 1
Summary of Percentages Correct 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	141	51	14.5	19	88

The percentages of the three defined efficiency ratings for all students in the sample are shown in Table 2. Only correct responses were used when determining efficiency levels. The percentage of students using highly efficient methods climbed from 62 per cent in Year 8 to 69 percent in Year 9, but then fell away to 55 per cent in Year 10. These students typically use a scientific calculator rather than the four-function calculator supplied. It may

Table 2
Percentages of Efficiency of Calculator Use for Students in Years 8, 9 and 10

Year Level	N	Highly Efficient	Reasonably Efficient	Inefficient
8	46	62	25	13
9	51	69	22	9
10	44	55	33	12
Total	141	62	27	11

be that as student use of scientific calculators increases over the three year levels, 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. Another factor may be that that the Year 10 students have limited practice with basic arithmetic calculations in their school mathematics program. The overall results show that little more than three-fifths of the Year 8-12 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 thus probably receive little further tuition in calculator use. The most common inefficient actions were as follows:

- The "=" symbol was keyed in unnecessarily;
- Zero was keyed in when not required; and
- Expressions were re-keyed into the calculator.

Of the 12 students interviewed, most had limited knowledge of how to use the memory on the four-function calculator or on their own scientific calculator. This could also be seen in the patterns of key presses for the CCT items. They remembered a result and keyed it in again later. Also, many were unaware that their scientific calculator took account of the rule of order of operations. Another aspect of concern was that some of the students interviewed did not know what the square root key did. Few knew how to enter a fraction into a calculator. Of those who had a fraction key on their own calculator, one half of them did not know it was there and few knew how to use it. The following extract from one interview with a Year 10 student illustrates this problem, as well as exemplifying student difficulties with fractions.

I. How would you do $25^3/_7 + 18$ on your calculator?

S. Well . . .

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. OK. So how would you do it.?

S. Well, um . . .

I. 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.

It seems likely that even if students were using their own more familiar scientific calculator, they would probably have made the same errors. Of the students interviewed, most stated that they would generally not write anything down when completing the given items, but would do the computation in their head, with their calculator, or not at all. The key-press patterns and the follow-up interviews indicated that many students had little or no knowledge of some of the fundamental aspects of the calculator, such as the continuity of operations in the register, or the constant function attached to the "=" key. Also, as already stated, far too many students had limited knowledge of how the calculator's memory function could be used.

It is beyond the scope of this paper to examine the results for each of the 16 items in the CCT. However, the results for two items – one non-contextual and one presented in context are given in Table 3 and Table 4 respectively. They exemplify the types of items used in the CCT. Table 3 show that students had very limited success with this item, and this was chiefly due to the rule of order of operations being ignored. Loss of efficiency of calculator use for students with correct responses was generally caused by a lack of appropriate use of the calculator's memory functions. Results for the contextual item in Table 4 indicate that the majority of successful students were highly efficient in their calculator use, while others tended to perform unnecessary extra calculations. It was considered that both contextual and non-contextual items should be used in the study. However, no valid comparisons could be made since the two sets did not have matched items.

Table 3
CCT Item 3 Percentages of Students Correct and their Calculator Efficiency

Item 3: $63 \times 3 - 19 \times 4 =$ ________

	Year 8	Year 9	Year 10	Females	Males	Total
Number of students	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

Table 4
CCT Item 16 Percentages of Students Correct and their Calculator Efficiency

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?

	Year 8	Year 9	Year 10	Females	Males	Total
Number of students	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

Conclusions and Implications

The results show that there was limited growth in calculator effectiveness over the Year 8-10 levels. In particular, students continued to have significant problems with fractions and with the rules of order of operations. The arithmetic content tested in the CCT would normally have been well covered by Year 8, but students still had significant deficiencies through to Year 10. Thus, it is essential that a regular review of the relevant knowledge and skills be maintained over years 8-10. This is vital for effective everyday usage, as well as to enhance the students' overall mathematical ability, especially in the algebra strand. Particular attention needs to be paid to the process of estimation, since this seemed to be lacking in students' calculator use, yet is so essential for effective and meaningful computation.

With only 62 percent of the Year 8-10 students judged to be highly efficient in their calculator use, it is clear that far many students lacked the necessary skills in this area. It is probably the case that mathematical ability is one contributing factor. However, the major cause is clearly a lack of knowledge of the tool itself. There seem to be two main related reasons for this. Firstly, there is very limited calculator use by students in primary schools before they enter secondary school in Year 8. And secondly, students have been given insufficient instruction on the use of calculators. Calculators should be used much more extensively at the primary school level as a learning tool, rather than as a calculating tool.

At the same time, there needs to be a shift from paper and pencil algorithms to calculator algorithms. In this way, students should improve their skills in using calculators more effectively and efficiently.

It is recognised that the calculator computation test used in this study was somewhat contrived in that students were forced to use their calculators whether they wished to or not. Also, the requirement to record all the key presses was also an abnormal situation. Thus it would be useful to follow this up with more individual interviews where students have computational choice, and to check out their calculator use by direct observation. This should also be extended to scientific and graphing calculators to assess the levels of efficiency of calculator use with these tools.

References

Australian Association of Mathematics Teachers. (1996). *A statement on the use of calculators and computers for mathematics in Australian schools.* Adelaide: AAMT.

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

Cockcroft, W. (1982). *Mathematics counts.* (The Cockcroft Report). London: Her Majesty's Stationery Office.

Education Department of Western Australia. (1998). *Outcomes and standards framework: Mathematics student outcome statements*. Perth: EDWA.

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

Groves, S., & 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.

Groves, S., & Stacey, K. (1998). Calculators in primary mathematics: Exploring number before teaching algorithms. In L. J. Morrow and M. J. Kenney (Eds.). *The teaching and learning of algorithms in school mathematics* (pp. 120-129.). Reston VA: National Council of Teachers of Mathematics.

Hembree, R., & 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.

Hembree, R. & 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.

National Council of Teachers of Mathematics. (1980). *An agenda for action.* Reston, VA: NCTM.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: NCTM.

Sparrow, L., & Swan, P. (1997). *Calculator use in Western Australian primary schools.* Perth: MASTEC.

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.

Swan, P., & Bana, J. (2000). Computational choice: The reason behind the choices. In J. Bana & A. Chapman (Eds). *Mathematics education beyond 2000.* Proceedings of the 23rd Annual Conference of the Mathematics Education Research Group of Australasia (pp. 580-587). Perth: MERGA.