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Calculator Use in Primary School Mathematics: A Singapore Perspective

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Abstract: The Singapore Ministry of Education is considering whether or not hand-held calculator use should be allowed in elementary-school mathematics classrooms in Singapore. Once the decision is made known to the public, calculator use will become the subject of controversy among educators and parents in Singapore. The purpose of this article is to review what research says about the effects of calculator use in the learning of mathematics in primary schools. The article will also discuss how calculators can be used effectively as a teaching and learning tool to enhance the development of number sense, promote mathematical thinking, and engage pupils in problem solving.

Introduction

Since the development of electronic calculators in the 1960's and the first National Council of Teachers of Mathematics' (NCTM) official position statement on calculator use in 1978, the use of calculators in schools has been a subject of intense debate. In his NCTM president's message, Stiff (2001) addressed this issue again in response to a newspaper article that claimed that calculator use can harm students' ability to learn mathematics and hence is harmful to permit calculator use in primary schools. Stiff pointed out that calculators are powerful tools in mathematics teaching and learning and can be used effectively to promote higher-order thinking and to help pupils become flexible and resourceful problem solvers.

Many researchers have studied the effects of using calculators in primary and secondary mathematics classrooms. These studies tend to focus on the impact of calculator use on students' achievement and attitudes (e.g., VanDevender & Rice, 1984; Williams, 1987), and problem solving (e.g., Szetela & Super, 1987). In addition, there are meta-analyses of research studies on calculator use (Hembree & Dessart, 1986; Ellington, 2003). Generally, the findings support the use of calculators in the mathematics classrooms, especially in the middle and high schools. With the advancement of technology and the affordable cost of calculators, the focus of debate has gradually shifted from whether or not calculators should be used in the classroom to how calculators can be used effectively to promote learning and problem solving. However, there are still some reservations among educators and general public about the use of calculators in the primary grade levels.

Many critics of calculator use often cite Singapore, a high achieving country in mathematics achievement according to the TIMSS study, as an example of a nation that limits the use of calculators to post-primary levels (Mackey, 1999; Izumi, 2000). The stage may be soon changed in Singapore as the Ministry of Education is currently considering the introduction of calculators in Primary 5 and Primary 6 classrooms and making calculators available during tests such as the Primary School Leaving Examination. The impending decision on whether or not to introduce calculators in the primary mathematics classrooms will certainly arouse the interests of parents and educators in Singapore, and start a public debate over calculator use in primary schools. This article examines the myths that exist regarding calculator-use and discusses how calculators can be used appropriately to promote mathematics learning and problem solving in primary schools. It reflects the personal views of the author.

Myths and Facts

1. Calculator use hinders the development of basic arithmetic concepts and skills, especially among the low ability pupils.

Critics of calculator use often present the worst-case scenario of young school leavers who are unable to perform basic computations and attribute the disability to the calculator use in school. Hembree and Dessart (1986, 1992) conducted a meta-analysis of 88 U.S. based research studies of calculator use and reported that appropriate calculator use can in fact improve computational skills of pupils with average ability and have no adverse effects on the computational skills of the low ability pupils and the high ability pupils. A long-term study of calculator use in Sweden (Brolin & Bjork, 1992) confirmed that calculator users in Grade 4 – 6 did not lose skill in paper-and-pencil calculations when compared with pupils in traditional classes. Similar evidence that calculator use does not produce any adverse effect on basic computational ability of pupils in primary schools can also be found in U.K (Shuard 1992). Calculators are not meant to replace paper-and-pencil computation. Mental computation, estimation and the paper-and-pencil computation should continue to be taught in schools. In Singapore, calculators should be available during instruction and testing in upper primary levels only to ensure that the development of appropriate skills of mental and written computation of the pupils is not neglected.

2. Calculator use hinders the development of mental computational skills

Many educators and parents fear that the use of calculators will lead pupils to become too dependent on the calculators, and consequently affect the development of the mental computational skills of the pupils. This fear has not been confirmed. Investigating the long-term effect of calculator use on children's learning of number concepts and skills, Groves and Stacey (1998) could not find any evidence that the third and fourth grade children became reliant on calculators at the expense of their mental computation ability. In fact, they reported that compared to the non-users, the calculator users in their study performed better overall and were able to make appropriate choices of calculating devices. According to them, it is possible to use calculators to help young children to develop number sense and mental computation strategies even before they are taught the formal algorithm.

3. Calculator use does not promote the development of thinking skills.

The calculator is just a tool; it does not 'think'. To solve a problem, the pupils must understand the problem, analyse the problem situation, decide which strategy is appropriate, carry out the strategy, and determine whether or not the answer makes sense. Calculators can eliminate tedious computations that often hinder pupil problem solving, and consequently allow more pupils to solve problems, appreciate the application aspects of school mathematics and engage in more challenging or more realistic tasks. Calculator use enhances problem solving skills (Hembree & Dessart, 1986, 1992). Campbell and Stewart (1993) reported that the use of calculators not only helped to strengthen understanding of arithmetic operations, but also stimulated problem solving thinking by widening children's number sense. As well, calculators enabled children to make and test conjectures and generalizations related to numbers and operations and hence be engaged in higher order thinking (Charles, 1999). With calculators, pupils can solve real-life problems involving realistic data. Such use of real data is motivational; it helps pupils make connections between the school mathematics and the mathematics used in the world.

4. Not all pupils can afford calculators.

The power of calculators is changing rapidly. Critics of calculator use are afraid that some pupils may be at a disadvantage because they cannot afford to buy a calculator or their calculators are not as powerful as their peers'. Such equity issues would probably not arise in Singapore. Once the Examination Branch at the Ministry of Education specifies the type of calculators to be permitted in the examination, the schools would purchase the appropriate calculators for class use or examination use. With the rapid drop in the price of calculator, no pupil would be denied the access to a calculator. In fact, it may not be an advantage to pupils to have a different type of calculator as they would not be familiar with the keys and functions of the calculator that is allowed in the examination hall. However, there is no reason to prohibit pupils to explore other more advanced calculators.

Calculators in primary mathematics

Calculators, like any other technology, cannot replace basic understanding and intuitions in mathematics. This point is stated clearly in the following NCTM position statement (2005) on the place of computation, calculator and common sense in the mathematics classrooms.

> *School mathematics programs should provide students with a range of knowledge, skills, and tools. Students need an understanding of number and operations, including the use of computational procedures, estimation, mental mathematics, and the appropriate use of the calculator. A balanced mathematics program develops students' confidence and understanding of when and how to use these skills and tools. Students need to develop their basic mathematical understandings to solve problems both in and out of school.*

Hence, to encourage the use of calculators in the primary mathematics classrooms, the mathematics curriculum has to be modified to integrate calculators in a meaningful way while promoting mental computation, basic computational skills, estimation and problem solving. In Singapore, educational policies and the curriculum framework are set up by the Ministry of Education. If calculators are to be used in the primary mathematics classrooms, curriculum guidelines must be sent to all primary school teachers, informing them of the relative emphasis of mental computation, written computation, estimation and calculator use in the mathematics curriculum. Teachers have a great influence on the calculator use in the classrooms. Unfortunately, many of them lack confidence in using calculators as a teaching aid and learning tool. They tend to have a limited view of the potential of calculators and believe that checking would be the main role of calculators.

It is advantageous to let pupils with low confidence or low ability in mathematics to use calculators to check their answers as the immediate feedback encourages them to check the accuracy of their computations frequently. The calculator provides a 'neutral' respond as it does not criticize. This is important to these pupils as they would not feel ridiculed and may be motivated to persevere. Moreover, they can practise aspects of calculation without constantly referring to their teachers to confirm their answers; the teachers will hence be able to focus their attention to selected small groups of pupils in the class.

However, getting the correct answer is not the key objective of mathematics education. At the centre of the pentagonal framework for mathematics curriculum in Singapore is *mathematical problem solving*. The attainment of the mathematical problem solving ability depends on the attainment of five interrelated components placed along the sides of the pentagonal framework. These five components are concepts, skills, attitudes, metacognition and processes. Calculators can be used as a means to help pupils develop a deep understanding of mathematical concepts and procedures, foster mathematical thinking and promote enthusiasm and confidence in pupils when solving problems. Examples of such activities are shown below.

In Activity 1 below, the concept of place value is reinforced. Pupils are asked to use a calculator to represent a given number in different ways. For pupils to obtain the sum in part a, they have to identify the place value of the digit 8 in 318 563 and rename 318 563, for example, as 317 563 + 1000 or 319 563 – 10 000, and so on. Compare this activity to the routine textbook exercise of getting the pupils to identify the value of the digit 8 in 318 563. Activity 1 is more challenging and engaging for pupils. Pupils can also investigate how to find the product / quotient with the broken calculator. They can make and test their conjectures, not hindered by cumbersome or tedious computations.

Activity 1: Broken Key (Primary 5)

Your calculator has a broken key. It is [8]

Explain how you would use your calculator to find

a) 318 563 + 21 479 = ___________

b) 800 000 – 13 456 = _________

c) 456 490 + 382 109 = __________

d) 605 793 – 308 267 = ___________

Different pupils are motivated by different learning activities. Routine practice exercises found in the textbooks would not stimulate pupils' interest in leaning. Activity 2 illustrates how calculators can be used to help pupils learn estimating skills in division in a fun way. The game can be extended to include more than one operation. The aim of the game is then to discover the mystery rule. When the first player enters the rule, he or she has to take note of the calculator logic used, keeping in mind that in a calculator that uses algebraic logic, the multiplication and division operations will take precedence over addition and subtraction.

Calculators can also be used in primary mathematics classrooms to help pupils see patterns and relationships in numbers and operations. In Activity 3, the number of multiplication to be done would dampen the interest of many pupils, particularly those with weak computational skills and hence prevent them from carrying out the investigation. With calculators, pupils of wider range of abilities can work on the same activity. They can make and test conjectures about the number relationships. Decimals are introduced in Primary 4. Some pupils may wonder whether the magic products can be extended to decimals. Consequently, a new problematic situation is created, leading to a meaningful mathematical activity.

Activity 2: What is my divisor?

A game for two players.
Any calculator with memory key. (e.g., TI30X)

Player A chooses a number between 10 and 50 and enters it into the calculator and challenge Player B to 'discover' the divisor by suggesting a number.

[2nd] [K] [÷] [43] [=]

Player B suggests a number that are recorded for all to see (e.g., 37)

Player A then presses [37] [=] out of sight of Player B and then records the quotient for all to see.

The play continues until Player B guesses correctly the mystery divisor.

For example,

Round 1

Player B's guesses	*The quotient*
37	*0.860465116*
38	*0.88372093*
44	*1.023255814*
43	*1*

Player B takes 4 steps to guess the mystery divisor.

Players switch roles.

The player who uses fewer steps to identify the mystery divisor wins the game.

Activity 3: Magic Products

1. Find the product of

(a) $63 \times 48 =$ ____ (b) $36 \times 42 =$ ____ (c) $46 \times 96 =$ ____

$36 \times 84 =$ ____ $63 \times 24 =$ ____ $64 \times 69 =$ ____

2. Find the product of

(a) $84 \times 63 =$ ____ (b) $18 \times 65 =$ ____ (c) $27 \times 51 =$ ____

$48 \times 36 =$ ____ $81 \times 56 =$ ____ $72 \times 15 =$ ____

3. Compare the products in Q1 and Q2. What do you notice?
Compare the factors. How are they similar? How are they different?

4. Which of the following multiplication sentences are correct?
24 x 84 = 42 x 48 31 x 39 = 13 x 93
46 x 31 = 64 x 13 64 x 53 = 46 x 35
Check your answer with a calculator.

5. State the rule you use.

Activity 4 is a problem in the real world. The two chocolate items mentioned cost $4.90 and $7.50 respectively in a supermarket in Singapore. Usually, primary school teachers would not give such tasks to their pupils as they are afraid that the unit price will involve quotients with too many decimal places. Instead of asking the pupils to find out the selling prices, the teachers would give 'nice' prices for the class to compute. Consequently, the problem statements are not as realistic. In this activity, a calculator would allow the pupils to use the real data and focus on the selection of the appropriate operation to find the unit prices and the comparison of the different unit prices.

These four activities illustrate how calculators enable primary school pupils to explore a greater variety of examples, practise skills in estimation, engage in the application of real and not oversimplified data, and focus on the problem-solving process rather than routine computation. Moreover, calculators, used wisely, can enhance number sense and open up new topics in primary mathematics as well as making the existing topics more accessible and exciting for all pupils. For example, concepts like square roots and cube roots can now be introduced earlier to pupils in the primary schools and realistic measures can be used in the word problems on measurement.

Activity 4: Rate (Primary 5)

You want to buy a box of chocolate for your mother.

Go to a supermarket nearest to your home.

Check out the selling price of the following:

- a packet of 16 Ferrero Rocher chocolate
- a packet of 24 Ferrero Rocher chocolate.

Which is the better buy? Explain.

Compare your findings with that of your friends.
Which shop would give the best buy?

Calculators do have a place in the primary mathematics curriculum. A thoughtful and creative use of calculators can help pupils see patterns and focus on reasoning and problem solving. Calculator use improves the attitudes of pupils towards mathematics, and increases their confidence and persistence in problem solving (Ellington, 2003). However, there are pupils who do not take easily to the calculator use. They often lack manual dexterity or might have acquired the negative attitudes from their parents who are critics of calculator use at school (Shuard, Walsh, Goodwin, & Worcester, 1991). Hence, a school mathematics programme that integrates calculators in a meaningful way should include as well a programme that educates parents on the role of calculators in primary mathematics.

Teaching the use of calculators in primary mathematics

Allowing pupils to use calculators does not lead to pupils learning the calculator skills. Pupils must be taught the calculators skills systematically so that they can enjoy the full benefits of calculators. The calculator skills at upper primary level include

- clear the display at the start of any calculation. This is to prevent pupils from making errors involving the answer from previous calculation or previous entry.

- use of various keys including the square key, the square-root and cube-root keys, the memory keys and clear entry key. For example, pupils must recognize the symbols on the key board and realize that the symbol √ or $^3\surd$ must be keyed in before the number to find the square root or cube root of a number. The process is different from the actual thought process when they identify the number and then find the square root or cube root of the number.
- recognize the two different types of calculator logic in common usage: arithmetic logic and algebraic logic. The calculator that uses arithmetic logic performs operations in the order in which they are entered while the calculator that uses algebraic logic performs operations following the order of operations.
- use different methods to enter fractions. For example, $^5/_8$ may be entered by the following key sequences using TI-30X

  [5] [$A^b/_c$] [8] [=] or [5] [÷] [8] [=]

  The final display is 5 / 8 and 0.625 respectively.
  Pupils need to recognize that the two displays are equivalent.
- enter and interpret calculations involving money and measures. Pupils need to know how to key in money and measures; e.g., lengths in metres and centimetres and recognize whether the answer is in metres or centimeters.
- recognize rounding errors. Pupils cannot just report the answer shown on their calculator. They have to make sense of the problem and realize that the answer has to be rounded. For example, an answer such as 5.9999999999 is likely equivalent to 6.
- recognize repeating decimals. They need to realize repeating decimals such as 0.66666667 as $^2/_3$.
- use estimation to check the answer. It is easy to press the wrong key. Pupils must have a feel of the size of an answer so that they can check the reasonableness of their calculations.
- select the number of figures displayed that is appropriate for the context of the problem statements. An incorrect selection of the number of figures displayed often leads to nonsensical answers.

Besides teaching these calculator skills, teachers also have to teach pupils when to use a calculator. Thompson and Sproule (2000) developed a framework to help middle school teachers decide wisely when to use calculators (Figure 1). Their framework shows clearly that the use of calculator is task specific. The instructional objectives of the task predetermine the calculator use. If the practice of computational skills in pupils is neither the main focus of the activity nor the major instructional objective of the teacher in using the activity, then calculator use is recommended as the pupils would then be able to focus on thinking mathematically, rather than spending their valuable time on tedious computation.

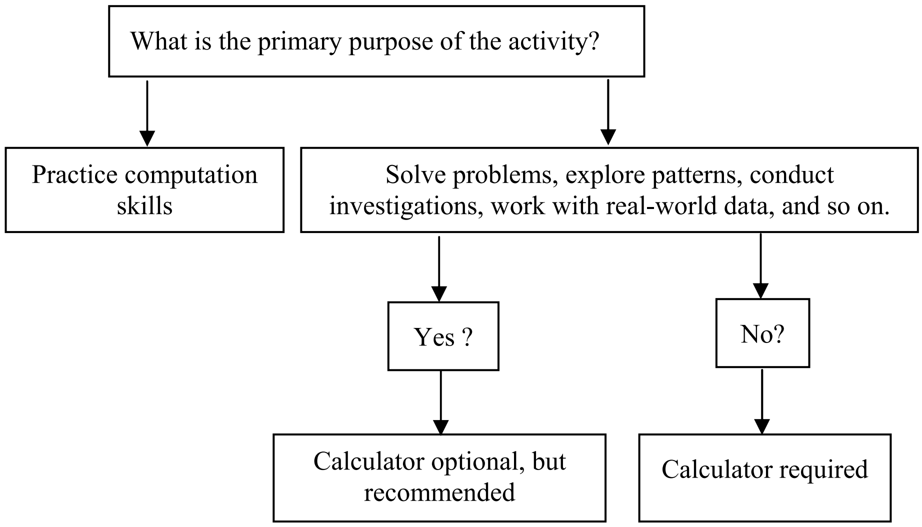

Figure 1. Calculator Decision Making Flow Chart

For example, both Activity 5 and Activity 6 concern the addition of two 3-digit numbers involving renaming. However, Activity 5 is a routine exercise that focuses on the recall of basic addition facts and procedural skills while Activity 6 is an open-ended task. It has more than one correct answer. Computation skills are needed but the focus is on problem solving. Teachers should exposure pupils to both activities, get them to compare the two activities and lead them to see how calculator can be used in the activities.

The focus in Activity 5 is to provide practice, so the use of the calculator to compute the sum should be discouraged. Generally, it is better not to ask pupils to use calculators to check their answers as they may wonder why they have to carry out the paper-and-pencil computations in the first place. However, it is appropriate to use calculators to check answers by using an inverse operation as in Activity 5 if the pupils have not been taught the subtraction of a 4-digit number by a 3-digit number and they are aware of the use of inverse operations to check their answer from their past dealings with smaller numbers.

Activity 5

Find the missing numbers in the boxes.

```
  5 6 7        □ 3 8
+ 8 4 3      + 8 4 □
-------      -------
□ □ □ □      1 □ □ 7
```

Activity 6: Find the sum

Use each of the 0 – 9 number cards.
Arrange the cards to make the answer correct.

```
   □ □ □
+  □ □ □
--------
 □ □ □ □
```

Find another way of using each card to make the correct answer.

```
   □ □ □
+  □ □ □
--------
 □ □ □ □
```

Pupils should also be taught to use other means, like estimation and approximation to check answers. This concept is important as it is very easy to press the incorrect keys or input the numbers in wrong order. Pupils must realize the importance of selecting the best calculation method (be it mental computation, paper and pencil or calculator) for a particular situation. Consider the following three textbook type problems.

> Example 1: *Ben and Joel were given $72 in the ratio 3:5. How much money did Joel receive?*
>
> Example 2: *Ben and Joel were given $1723.60 in the ratio 3:5. How much money did Joel receive?*
>
> Example 3: *How many 24-seater buses will be needed to carry 250 National Service men to the camp?*

The convenience of the numbers in Example 1 means that the calculation can be easily done mentally, while, in Example 2, a calculator would be helpful. As the context in Example 3 demands an answer to the nearest whole number, a mental method is more appropriate here. Think: *240 ÷ 24 = 10, there are 250 men, so 11 buses are needed*. If a calculator is used, 250 ÷ 24 = 10.416667, the quotient will have to be interpreted correctly.

In fact, there are many textbook questions that provide opportunities for teachers to teach pupils the uses of calculators and to appreciate the application aspect of mathematics that they are learning. Consider the following question on rate found in one of the primary mathematics textbooks.

> *Jackie exchanged 300 Hong Kong dollars for 66 Singapore dollars at the money-changer. At this rate, how many Singapore dollars could David exchange for 500 Hong Kong dollars?* (Shaping Maths 5B, p. 56)

This question is on rate. In the one-computer classroom, teachers can go beyond the textbook question and use the internet to show the current Hong Kong – Singapore exchange rate to the class, explain how it fluctuates and determines the amount of Singapore dollars received. The teachers can then let pupils pose real-world problems on exchange rate that are important to them. For example, a Primary 5 pupil may wish to compare the cost of a cheeseburger in different countries. The goal of the task is to make a decision involving computation and the use of calculator would be appropriate as it removes the tedious computation.

Hence, it is most important to teach pupils when to use a calculator, when to use paper-and-pencil, and when to use mental computation. To help pupils become discriminating in calculator use, teachers may need to have a mixture of problems including those that are easier to solve by mental computation or paper-and-pencil. The practice would help pupils “become fluent in making decisions about which approach to use for different situations and proficient in using their chosen method to solve a wide range of problems." (NCTM, 2005)

Conclusion

To function in this fast changing information and technology-based society, we need to put the technology in the hands of our pupils and teach them how to use it effectively and efficiently. In Singapore, restricted use of calculators may be allowed in the Primary School Leaving Examination (PSLE) mathematics paper in the near future. This is encouraging as it would prevent pupils from over-reliance on calculators and at the same time provide opportunities for more pupils with weak computation skills to display their problem-solving ability in this standardized test. At present, calculators are prohibited in PSLE and most teachers hesitate to allow calculators in school assessment. Consequently many pupils are being penalized for weak computation skills.

If and when the prohibition of calculator use in the primary classrooms is removed, teachers must realize that the calculator is just one of the calculating tools and should not be used indiscriminately in their classrooms. Teachers need to make rationale judgments in the calculator use in their classroom. They must take into consideration the needs and abilities of the pupils and their instructional objectives. Like other instructional technological tools, teachers have to consider whether or not calculator use would help their pupils develop deeper understanding of the concepts being presented, offer a unique way of learning about numbers and the number system, facilitate the problem solving process, and motivate and challenge their pupils. Further, as not all primary school teachers are calculator literate or effective users of calculators, there would be a need to provide professional development activities to facilitate and enhance the use of calculators in primary mathematics classrooms.

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