

The Calculator in the Elementary Classroom: Making a Useful Tool out of an Ineffective Crutch

Erin McCauliff

**Department of Education and Human Services
Villanova University**

Edited by Klaus Volpert

In the early 1980's the hand-held calculator began to appear in elementary classrooms, and with its introduction came controversy. Would the use of the calculator take away from students' ability to think and reason through problems? The purpose of this paper is to review research that addresses both the positive and negative effects of calculator use in the primary grades. The author will specifically address research findings that both support and challenge the use of calculators in primary grades. It is important to note that most research that supports the use of calculators, but also cautions that responsibility must lie with the teacher. One study showed a direct correlation between teacher training and calculator use. "Teachers who had received no training in the use of calculators were evenly divided between whether their students used calculators or did not. Teachers who had more training were likely to have students use calculators in their classroom." (Porter, 1990) This paper will also address teachers' attitudes toward calculator use, and will conclude with a summary of how the existence of calculators in the primary grades demands curriculum modification, and consequently, a reformation in teacher education.

In 1966, a development team at Texas Instruments invented a miniature calculator that would change the lives of many. One could use the device to perform simple mathematical computations more quickly and more precisely than with paper and pencil. This tool expanded the mathematical capabilities of everyone from high school students to businesspersons. Public interest in calculator use in schools has grown over the past twenty-five years, as they have become more affordable.

Until the hand-held calculator appeared, elementary school mathematics curricula stressed paper-and-pencil calculations out of necessity—it was the fastest way to find the answer to the problem. Today, however, the device can quickly do computations that used to take students many hours of instruction and practice to master. This poses an important question: How will the incorporation of this technological advance influence the development of students’ basic reasoning skills, specifically in the elementary class room? The National Council of Teachers of Mathematics (NCTM) made the following statement in 2000: “Technology should not be used as a replacement for basic understandings and intuitions; rather, it can and should be used to foster those understandings and intuitions.” This belief has not wavered much since 1974, when the NCTM issued a sweeping statement urging that calculators appear in school at all grade levels. They expected that the tool “would aid algorithmic instruction, support concept development, reduce demand for memorization, enlarge the scope of problem solving, provide motivation, and encourage discovery, exploration and creativity.” Yet, twelve years later, the calculator had been unsuccessful in redirecting the curriculum and had failed to enter most classrooms. (Hembree and Dessart, 1986) Today, the National Council of Teachers of Mathematics takes the position that calculators can and should be used in all mathematics classrooms, *as long as they are implemented properly*. “Appropriate instruction that includes calculators can extend students’ understanding of mathematics and will allow all students access to rich problem-solving experiences.” (NCTM, 2000) This qualification, appropriate instruction, is the reason for concern. In order for this technology to have a positive impact on students’ learning of mathematics, teachers must be educated as to how to put the calculator into practice. The calculator should be used as a supplement to learning, not as a replacement for learning computational algorithms.

Professional Mandates

Before addressing the research findings on the positive and negative effects of calculator use in the elementary classroom, it is necessary to state that professional mandates exist. The National Council of Teachers of Mathematics published a position statement that speaks to the use of calculators in the education of the nation’s children. “The NCTM recommends the integration of calculators into the school mathematics program at all grade levels.” The committee goes on to explain the rationale behind their position:

“Research and experience support the potential for appropriate use to enhance the learning and teaching of mathematics. Calculator use has been shown to enhance cognitive gains in areas that include number sense, conceptual development, and visualization.”

The committee recommends that all students should have access to calculators. They state that all mathematics teachers should promote the use of this technology and that they should keep up with new skills by participating in professional development activities that are encouraged by the school district.

In her doctoral dissertation in 1990, Porter quoted a Reys and Reys study from 1987 that concluded “every school should have a clear calculator policy; otherwise, teachers in the same school at the same grade level may employ different rules for calculator use.”

Some states also have mandates that support the use of calculators in at all grade levels. With such directives come a responsibility for all school districts, administrators, and teachers. The next two sections will address research that has highlighted both the positive and negative effects of calculator use in the elementary grades.

Positive Effects

Research highlights both advantages and disadvantages of utilizing the calculator in elementary classrooms. However, most studies show no definite harmful effects from recommending a calculator for computation at an early age. It seems clear that if the calculator is used properly to enhance a curriculum, the students will reap many benefits. First, students can spend more time solving problems conceptually. “For example, a simple four-function calculator will allow students to use whatever operation is appropriate in a problem, regardless of whether they are confident of their own skill at carrying out that operation.” (Hembree & Dessart, 1986) Here, the students experience a computational advantage and become more secure in their abilities. Computation is important specifically because it is necessary to solve many mathematical problems. The particular method used, however, whether it involves mental math, paper and pencil, or a calculator, is just one part of the computation process. Students must also know what kind of computation to perform and be able to identify the appropriate numbers to use in computations. Hembree and Dessart (1986) assert “real mathematics means knowing a variety of strategies for solving problems and having the ability to apply them appropriately.” Using a calculator enables students to think more abstractly: It allows children to solve problems whose solutions are within theoretical, but not computational, grasp. Furthermore, “The use of realistic data is motivational and helps children see connections between school mathematics and the mathematics used in the real world.” (Charles, 1999)

Hembree and Dessart’s research in 1986 reported the findings of a meta-analysis of the effects of pre-college calculator use. They analyzed the results of seventy-nine research reports that focused on students’ achievement and attitude. Each study involved one group of students using calculators and another group

having no access to calculators. From their analysis, Hembree and Dessart concluded that the calculator “did not delay students’ acquisition of conceptual knowledge and that it significantly improved their attitude and self-concept concerning mathematics.” In this study, results show that “for problem solving with the calculator, the effects for low- and high-ability students were higher than the effect for average students. The calculator created not only a computational advantage but also a benefit in the selection of proper approaches to a solution.” It was also found that “in grades K-12 (except grade 4), students who use calculators in concert with traditional instruction maintain their paper-and-pencil skills without apparent harm.” Hembree and Dessart found that the use of calculators in testing produces much higher achievement scores than paper-and-pencil efforts, both in basic operations and in problem solving. This was true across all grades and abilities.

In general, these researchers found that students using calculators possessed a better attitude toward mathematics and more confidence than non-calculator students did. (1986) In fact, “The role of the calculator as a positive motivator for students has been documented in many studies. Several studies have reported increased confidence and improved attitudes toward mathematics as well as a greater persistence in problem solving when calculators are used.” (Porter, 1990; Driscoll, 1981) So not only will students be able to develop conceptual thinking skills with the use of a calculator, but they will also gain confidence in their mathematical abilities.

In 1997, Smith conducted a meta-analysis that extended the results of Hembree and Dessart. Smith analyzed twenty-four research studies conducted from 1984 through 1995, asking questions about attitude and achievement due to student use of calculators. As in the Hembree and Dessart study, test results of students using calculators were compared to those of students not using calculators. Smith’s study showed that the calculator had a positive effect on increasing conceptual knowledge. This effect was evident through all grades and statistically significant for students in third grade. Smith also found that calculator usage had a positive effect on students in both problem solving and computation and did not hinder the development of pencil-and-paper skills. (DeRidder, Dessart, Ellington, 1999; Smith 1997)

Dockweiler & Shielack found that conceptual development “was fostered by the calculator’s quick capability to display numbers. This is directly to students’ concrete experiences with the numbers by using the calculator to reinforce the patterns generated in base ten materials. A calculator provides support for recording the connections between the concrete material and their symbolic representation. For example, many young students have difficulty counting with the combination of hundreds, tens, and ones represented by the

pieces in the base ten materials. With the use of the calculator, students can explore the relationships between these place values.” (1992)

The proper use of calculators will also enhance number sense, conceptual development, and visualization. Number sense is a foundation for early success with mathematics. Calculators can help to develop the conceptual understandings and abilities that underlie strong number sense. Calculators are particularly powerful in enabling children to make and test conjectures and generalizations related to numbers and operations.

“Making and testing conjectures about counting patterns helps children understand number relationships, develops flexibility with numbers, and promotes the development of mental and paper-and-pencil computational strategies. For example, students can use a calculator to skip count by 5’s (press $0 + 5 =$, and so on). Students can try the same process with other numbers and try to figure out what patterns emerge, and make predictions. The counting capability of the calculator allows students to focus on patterns that result from adding the same number repeatedly.” (Charles, 1999)

This type of activity can aid students in future studying of multiplication and division. “In upper elementary grades, students can use the calculator to explore the relationships among various representations of rational numbers.” (Reys &Arbaugh, 2001)

Negative Effects

Unfortunately, most teachers do not know how to implement the calculator properly and hence, students are often at a disadvantage.

First, if students do not understand the basic skills necessary to move on, they may not have success in future classes. If the students are taught to rely on the calculator, even to only check answers, their confidence will suffer when the calculator is taken away. If one provides calculators at an early age, students may not learn computational algorithms.

Secondly, calculators also provide an illusion of progress; students may experience a false sense of confidence and consequently, their motivation decreases.

As mentioned earlier, Hembree and Dessart found positive results for calculator usage in all grades except grade four, “where paper-and-pencil skills were hampered by the calculator treatment. Throughout the analysis, it had appeared that the calculator usage served the low or high ability student less well than the average student. Sustained calculator use by average students in Grade 4 appears counterproductive with regard to basic skills.” (1986)

Danielle McNamara, at the University of Colorado, examined a specific laboratory finding called the generation effect, and applied it to the elementary classroom.

“The generation effect refers to the finding that having students generate to-be-learned information themselves, rather than simply copying or reading the information enhances both short-term (e.g., Slamecka & Graf, 1978) and long-term (e.g., Crutcher & Healy, 1989) retention of information in various situations. Elementary school children learned simple multiplication by generating (i.e., computing the answers) or reading (i.e., reading the answers from a calculator display). The children were given a pretest, read or generate training, posttest, and a retention test after 2 weeks. (The children did not use calculators on these tests). Read training involved approximately half as much training time compared with generate training and was moderately effective. In terms of test time, read children showed a loss of efficiency after the 2-week delay compared with the generate children who showed no loss.” (1995)

Earlier in 1995, McNamara and Alice Healy conducted a similar study of adults. While the findings of this study implied that the use calculators would be ineffective for children at this specific skill level, the second study did not positively support one learning method over the other. However, the study did imply that allowing elementary school children to use calculators to solve addition and multiplication problems before basic skills were acquired would be detrimental to the learning process. This means that children should not use calculators, but should perform the operations mentally when learning new types of problems.

“One goal of the experiment was to examine how elementary-school-age children learn new multiplication facts best, reading the answer from a calculator display versus generating the answer and thus solving the problem mentally. Children in both conditions used a calculator; however, the principal difference between the read and generate conditions was the point at which the answer was displayed on the calculator. In the read condition, it was before writing down an answer to a problem, and in the generate condition, it was afterward.” (1995)

The following is a table showing overall results.

Figure I (McNamara, 1995)

Overall Test Completion Time (in Seconds), Proportions of Correct Responses for Each Problem Type, and Mean Number of Errors for Each Error Type as a Function of Training Condition and Test

Test completion	Read				Generate			
	Pretest	Posttest	Retention	Across tests	Pretest	Posttest	Retention	Across tests
Test time	521.0	446.0	468.9	478.6	515.4	448.6	404.8	456.3
Accuracy: Problem type								
Trained	0.494	0.571	0.571	0.545	0.542	0.661	0.571	0.591
Reversals	0.414	0.493	0.543	0.483	0.407	0.457	0.507	0.457
Easy	0.875	0.899	0.917	0.897	0.966	0.958	0.965	0.963
All problems	0.605	0.664	0.685	0.651	0.651	0.706	0.691	0.683
Errors: Error type								
Operand cued	2.714	1.500	2.000	2.071	0.214	0.000	0.000	0.071
Table related	4.071	4.071	2.143	3.428	6.214	4.857	4.786	5.286
Addition	2.000	0.923	0.857	1.260	0.929	0.214	0.214	0.452
Close miss	1.929	2.286	2.357	2.191	2.071	2.143	3.071	2.428
Other	2.714	2.714	3.357	2.928	2.429	2.786	2.429	2.548

McNamara concluded that “calculators were neither good nor bad for elementary aged schoolchildren, but that their value depended on the use to which they are applied, the stage of development of the basic arithmetic skills, and the cost of using them relative to the possible benefits in a realistic classroom setting.” (1995)

International Approaches

Australia

“The Australian Association of Mathematical Teachers has a policy on school students’ use of calculators: It suggests that scientific calculators should be used by students in their early secondary schooling.

“The National Statement of Mathematics for Australian Schools (Australian Education Council, 1990) recommends that all students use calculators at all levels (K-12) and that calculators be used both as instructional aids and as learning tools. However, research has shown that, despite overwhelming support for the early introduction of calculators, a majority of infant teachers rarely or never use calculators in their classrooms.” The *Calculators in Primary Mathematics* project was based on the premise that the calculator, as well as acting as a computational device, is a highly adaptable teaching aid that has the potential to radically transform mathematics teaching by allowing children to experiment with numbers and construct their own meanings” (Groves, 1997).

A four-year research project investigated the effects of the introduction of calculators on the learning and teaching of primary mathematics in six Melbourne schools. Classroom observations confirmed that the use of calculators provided a rich mathematical environment for children to explore and promoted the development of number sense. “Despite fears expressed by some parents, there was no evidence that children became reliant on calculators at the expense of their ability to use other forms of computation. Extensive written testing and interview showed that children with long-term experience of calculators performed better

overall on a wide range of items, with no detrimental effects observed.” (Groves, 1997)

Japan

The current *Course of Study* in Japan does not permit the use of calculators until after grade 4. “Moreover, Japanese primary teachers generally agree that the calculator is not appropriate in grades 1-3 (Reys, 1996; Senuma, 1994). Although a calculator might be visible on a teacher’s desk, it would be for the teacher’s personal use rather than for instruction. Japanese teachers are currently debating whether students should continue to learn about and use the abacus for calculation.” (Reys, Reys, & Koyama, 1996)

In 2000, James Tarr and others produced a study that determined trends in calculator use among 13-year-olds in Japan, the United States, and Portugal. “Data from both student and teacher surveys confirm that calculator use in eighth-grade classrooms varies substantially across nations. Perhaps most intriguing is the virtual absence of calculator use in Japanese eighth-grade mathematics classrooms, particularly given Japan’s technologically advanced society and its tradition of excellence in mathematics education.” The study shows that only 0.37 percent of students in Japan used calculators during mathematics lessons, while 43.03 percent of the US students used calculators.

Figure II (Tarr et. al., 2000)

Country	Never		Once in a While		Pretty Often		Almost Always	
	Percent of Students	Mean Achievement						
Japan	74.7 (2.27)	607.24 (2.06)	20.8 (1.88)	603.04 (3.37)	3.46 (0.65)	575.35 (6.69)	0.37 (0.09)	524.37 (24.12)
US	9.88 (1.52)	463.87 (9.39)	19.62 (1.54)	498.28 (5.83)	24.86 (1.16)	501.22 (5.30)	43.03 (2.66)	510.63 (5.64)
Portugal	3.02 (0.61)	455.29 (7.32)	27.19 (1.59)	456.56 (3.10)	34.07 (1.19)	453.87 (3.50)	34.80 (1.45)	454.08 (2.83)

Note. Standard errors reported in parentheses.

Curriculum Change

“It no longer seems a question of *whether* calculators should be used along with basic skills instruction, but *how*.” (Hembree & Dessart, 1986) In 1990, Porter reminded us, “not only have calculators failed to enter most mathematics classrooms, but they have also failed to redirect the curriculum.” (Porter, 1990) “The goal is not to produce a calculator-driven curriculum, but one that integrates calculators in a meaningful way while promoting mental computation, estimation, problem solving and critical thinking skills.” (Reys & Reys, 1998)

In order for calculators to be a presence in the classroom, certain changes must take place in the curriculum. Teachers can encourage the use of calculator in elementary classrooms while promoting a positive attitude towards their use among parents and students. This may involve the use of calculators in estimation activities, problem solving experiences, and composition of word problems. However, programs must be in place to educate parents on the role of calculators in elementary mathematics teaching.

“Contrary to the fears of many, the availability of calculators and computers has expanded students’ capability of performing calculations. However, there is no evidence to suggest that the availability of calculators makes students dependent on them for simple calculations. Students should be able to decide when they need to calculate and whether they require an exact or approximate answer.” (Dresdeck, 1995)

Dresdeck asserts, “It is important to keep classroom calculators readily accessible to children. Their physical proximity and availability help to promote their use.” (1995)

“The NCTM encourages teachers to provide experiences that build the underlying concepts and argue that only after these ideas are carefully linked to paper-and-pencil procedures is it appropriate to devote time to developing proficiency.” (1989) Meanwhile, local school district and state curriculum guidelines may be sending a different message to teachers, requiring them to introduce and develop a mastery of standard computation algorithms by a certain grade level. Unlike many industrialized countries that have a clearly defined national curriculum specifying the content and placement of various mathematics topics, the US educational policy of control has contributed to uncertainty and bewilderment among some teachers about the relative emphasis of computation. Ultimately, without clear direction, teachers make their own decisions based on the mixed messages received from the collective forces of parents, fellow teachers, standardized assessments, curriculum materials, backgrounds that their students bring to the learning environment, and their own beliefs about how children learn. This situation creates significantly different approaches to computation within and across schools, districts, and states. Reys and Reys proposed a sequence of computation and curricular emphasis:

Figure III (Reys & Reys, 1998)

Computational Tool	Primary (Gr. K-2)	Intermediate (Gr. 3-5)	Middle Grades (Gr. 6-8)
Mental Computation (invented thinking)	Students are encouraged to develop and	Students are encouraged to use mental computation when efficient for whole number, fraction, and decimal	

strategies)	use invented computational strategies and to record work, as needed.	computation.	
Written Computation (efficient paper-and-pencil strategies, invented and standard)		Students develop efficient algorithms for whole number computation. Standard algorithms are introduced as one method.	Students develop efficient algorithms for fraction and decimal computation. Standard algorithms are introduced as one method.
Estimation	Students are encouraged to make sense of data and answers and to develop strategies for estimating in <i>measurement</i> settings.	Students develop and share a variety of strategies to produce <i>computational</i> estimates and to judge the reasonableness of answers.	
Calculator	Students use a calculator to explore patterns and relationships with numbers and operations <i>and</i> as an efficient tool to do complex computations associated with solving problems.		

Note: Examples of computational problems that are typically encountered and that need to be the focus at this level are included for illustrative purposes.

The Role of the Teacher

Though seldom heard, the views of primary teachers are important. These educators influence calculator use in the classroom. Rousham and Rowland (1996) suggest that the potential of the calculator in primary schools is largely unrealized. They report variable enthusiasm from teachers about calculator use and say the quality of calculator use is generally disappointing. In an early evaluation of the National Numeracy Strategy, many teachers were said to lack confidence in using calculators as a teaching aid. (Houssart, 1997; OFSTED, 2000)

In 1997, Jenny Houssart carried out interviews with twenty-six teachers from a wide range of primary schools in England. “The main purpose of the interviews was to see which issues teachers chose to raise and in how much detail. The teachers were shown separate classroom tasks, and then asked to respond. One such task included a fairly prominent picture of a calculator.” In response, one teacher stated outright that she did not allow calculator use and another expressed clear reservations, which he linked to his view of the importance of mental arithmetic. Only one teacher was openly positive about calculator use; others were apparently low users by default. One interesting reason that arose for the absence of calculators in the classroom was the lack of awareness of the teaching and learning potential of calculators. Only one teacher believed the calculator was a tool for exploring number operations. For the others, checking seemed to be the main role for calculators, with some attention also paid to calculator use for its own sake in order that children knew how to use them. This small-scale study, therefore, suggests that for a majority of teachers interviewed, low use of calculators exists alongside a limited view of the potential of calculators. (Houssart, 2000) Although this particular study was conducted abroad, it is quite possible that many teachers in the United States are in the same position.

In her 1990 dissertation, Priscilla porter reported on teacher attitude in the Irvine Unified School District in California.

“Teachers are mainly concerned about how calculators will affect students’ computational skills (Reys et al., 1980). The teacher factor remains the most important aspect of effective instruction (Vannatta & Hutton, 1980) A successful calculator program must include effective teaching materials correlated with the ongoing mathematical program. Teachers mention a need for workshops to develop and improve competence in the use of calculators. In 1987, Williams

suggested that an extensive training program was needed for elementary teachers to be calculator-literate and to be able to teach students to use calculators effectively to learn mathematics.” (Porter, 1990)

Without teacher commitment to the use of calculators, the policies of professional organizations and state curriculum departments toward calculator use will go unheard and the advantages for using calculators suggested by research will never occur. It is imperative that teachers be educated in the use of this technology so that it may be used in the most appropriate and effective manner.

References

- Charles, Randall I. (1999 May/June). Calculators at the Elementary School Level? Yes, It Just Makes Sense. *Mathematics Education Dialogues*, 8.
- Colman. (2003 March). Calculators. *Youth Studies Australia*, 22, 7.
- Dessart, D., DeRidder, C., & Ellington, A. (1999 May/June). The Research Backs Calculators. *Mathematics Education Dialogues*, 2, 8.
- Dresdeck, C. (1995 January). Promoting Calculator Use in Elementary Classrooms. *Teaching Children Mathematics*, 1, 300(6).
- Groves, S. (1997) The Effect of Long-Term Calculator Use on Children’s Understanding of Number: Results from the “Calculators in Primary Mathematics Project.” *Proceedings of the 16th Biennial Conference of the Australian Association of Mathematics Teachers*, 158.
- Hembree, R. & Dessart, D. (1986). Effects of Hand-Held Calculators in Pre-College Mathematics Education: A Meta-Analysis. *Journal for Research in Mathematics Education*, 17(2), 83-89.
- Houssart, J. (1997). I Haven’t Used Them Yet: Primary Teachers Talk About Calculators. *Micromath*, 14-17.
- Lehman, J. (1994 April). Technology Use in the Teaching of Mathematics and Science in Elementary Schools. *School Science and Mathematics*, 94, 194-201.
- McNamara, Danielle S. (1995). Effects of Prior Knowledge on the Generation Advantage: Calculators Versus Calculation to Learn Simple Multiplication. *Journal of Educational Psychology*, 87, 307-318.
- National Council of Teachers of Mathematics, NCTM Standards 2000: Principles and Standards for School Mathematics, April 2000.

- Porter, Priscilla H. (1990). Perceptions of Elementary School Teachers toward the Status of Calculator Use in the Irvine Unified School District.
- Reys, B. & Arbaugh, F. (2001 October). Clearing up the Confusion over Calculator Use in Grades K-5. *Teaching Children Mathematics*, 8(2), 90-94.
- Reys, B., Reys, R., Koyama, M. (1996). The Development of Computation in Three Japanese Primary-Grade Textbooks. *The Elementary School Journal*, 96(4).
- Reys, B. & Reys, R. (1998 December). Computation in the Elementary Curriculum: Shifting the Emphasis. *Teaching Children Mathematics*, 236-241.
- Schielack, J. & Dockweiler, C. (1992 November). Elementary Mathematics and Calculators: Let's Think About It. *School Science and Mathematics*, 92, 392-394.
- Tarr, J., Mittag, K., Uekawa, K., Lennex, L. (2000 March). A Comparison of Calculator Use in Eighth-Grade Mathematics Classrooms in the United States, Japan, and Portugal: Results from the Third International Mathematics and Science Study. *School Science and Mathematics*, 100(3), 139-150.