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An overview of possible applications and the status of calculators in the public schools

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Abstract

The purpose of this paper ls to look at one of the most researched and controversial topics concerning the teaching of mathematics today. Should calculators be used in the teaching of mathematics at the elementary level? In the process of examining this question, five areas will be addressed: (a). A Historical Perspective of Calculators, (b). The Calculator's Role ln Page 4 Developing Student/a Attitude Toward Mathematics, (c). The Calculator/a Role in Problem Solving, Cd). Parent/a Viewpoint on Calculator Usage in the Classroom, and (e). Implications of Calculator Assisted Standardized Testing.

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An Overview of Possible Applications and the Status of Calculators in the Public Schools

It is important to note, at the beginning of this paper, that calculator usage is not intended to replace traditional paper-and-pencil computation and the drill and practice usually associated with mathematics in the early years of education. The purpose of using a calculator in the classroom is to complement and expand on what is already in the curriculum. A calculator can be used to facilitate the development of basic skills and promote more thoughtful problem solving practices.

The purpose of this paper is to look at one of the most researched and controversial topics concerning the teaching of mathematics today. Should calculators be used in the teaching of mathematics at the elementary level? In the process of examining this question, five areas will be addressed: (a). A Historical Perspective of Calculators, (b). The Calculator's Role in

Developing Student's Attitude Toward Mathematics, (c). The Calculator's Role in Problem Solving, (d). Parent's Viewpoint on Calculator Usage in the Classroom, and (e). Implications of Calculator Assisted Standardized Testing.

Many studies have been done concerning calculators and their place in the elementary classroom. Calculators, their effects, positive, negative and lack of effect, have been debated and studied in many different forums. To fully understand this controversy, it is necessary to look at a brief historical perspective of calculators, their rise, fall, rebirth.

Historical Perspective of Calculators

In 1975, the National Advisory Committee on Mathematical Education (NACME), took the following position: "...beginning no later than the end of eighth grade, a calculator should be made available for each student during each mathematics class" (NACME, 1975, p. 26). Needless to say, this initiated considerable discussion in the

field of mathematics. Probably the most serious doubt raised was whether or not the students would still learn their basic facts and computation skills. This is a very real concern when considering the use of a device that could displace attention currently devoted to paper-and-pencil skills. The National Council for Teachers of Mathematics (NCTM) added fuel to this fire in 1980 when they issued a position statement that read in part, "...mathematics programs should take full advantage of the power of calculators and computers at all levels" (NCTM, 1980, p.1). NCTM went even further in 1986 with, "...publishers, authors, and test writers should integrate the use of calculators in their mathematical materials at all levels" (NCTM, 1986, p. 19). Clearly the bulk of professional organizations have supported the use of calculators in the classroom for quite some time.

With the support of the major professional organizations, it would seem that calculators should have had an unfettered path to the

classroom. This is not necessarily so; early calculators were bulky, expensive, and often not even battery-powered. Parents and teachers questioned the calculator's practicality and reliability. Questions such as the following resounded throughout education: "What if students can't afford one?" "What if the batteries run down?" "What if it gets lost?" and inevitably, "What if the students aren't really learning their basic mathematics skills, and are just blindly pushing buttons on a seemingly magic box?" Most of these questions have been effectively answered with the development of the inexpensive, solar-powered, pocket calculator. Today, most students have calculators or have access to them in their home. This has come as a welcome relief to budget-minded teachers, administrators, and parents.

Unfortunately, the problem of getting calculators into classrooms wasn't yet solved. The early 1980's brought the personal computer to the forefront. Computers were eagerly embraced by

administrators, parents, and teachers. The calculator frequently ended up in a box, forgotten.

The functions of a computer and a calculator were all too often confused. As an example; it is much more efficient to have a student use a calculator to solve, "What number, times itself is equal to 25?" than it is to use a computer for the same operation. Computers serve many valuable functions, but the duplication of operations that can much more easily be accomplished with a calculator is not one of them.

Calculator proponents still needed to overcome their major detractor; the concern that the students would not be learning their basic number facts or mastering the computation skills necessary for success in any math area. As recently as 1986, this concern was being voiced loudly by textbook publisher, John Saxon. Saxon wrote an editorial for the Wall Street Journal (16 May 1986), stating in part:

> Common sense tells us that if calculators are approved and made available too early, many capable students will resist doing the arduous paper-and-pencil practice that is necessary to develop the mental skills of arithmetic. Then these students will be unable to do simple computation in their heads, and, worst of all, they will not be able to estimate. Calculators should not be permitted until the first or second year of high school mathematics, by which time the students will have completed their instruction in arithmetic.

The Association for Supervision and Curriculum Development (ASCD) promoted the use of calculators in their publication Content of the Curriculum in 1988 with their stance that mathematics programs take full advantage of the power of calculators at all grade levels. Moreover, they advocated that the priorities of curriculum be altered so the decimals, negative numbers, and scientific notation naturally

encountered with the use of calculators be accommodated earlier and given more prominent attention. The calculator provides an efficient method for obtaining solutions and causes no ill effects on computation skill involving basic facts (Campbell and Fey, 1988). "Calculators and computers for users of mathematics, like word processors for writers, are tools that simplify, but do not accomplish, the work at hand." National Council of Teachers of Mathematics (NCTM 1989, p.8).

The primary focus of calculator critics has always been: "Do calculators threaten the development of basic skills?" To date, this has been the main area probed by researchers. Suydam (1982) found positive effects or no effect at all on basic skill development, provided those basics are first developed with paper and pencil. This is attributed to the students not being concerned with the actual computation of the answer, but with what data is needed to solve the problem and

how to manipulate that information to solve the problem.

Most of the research on calculators has concentrated on whether or not acquisition of basic skills would be harmed through calculator usage. Very little effort has been devoted to how to use calculators to enhance mathematics instruction. The vast majority of research conducted on calculator usage was between 1976 through 1980, then attention seemed to be diverted to the microcomputer. Following that time great changes have been made in the calculator itself, as noted earlier, and it is appropriate that more research be devoted to <u>how</u> to best use calculators, instead of <u>whether or not</u> to use them. Considering the amount of research indicating calculators have no negative effect on basic skills but little or no positive effect either, many teachers ask themselves, "Why should I bother to use calculators if it's not going to make any difference?" The answer may lie not within the realm of mathematics skills, but in the

attitude students have about themselves in relation to mathematics itself.

The Calculator's Role in Developing Students' Attitude Toward Mathematics

If students are to be able to enjoy mathematics, appreciate its usefulness and applications, and truly understand its nature, education needs to refocus its goals. Helping students develop a positive attitude toward mathematics needs to become as much a goal of mathematics instruction as are the achievement related goals.

Very often students can become mired in the technicalities of mathematics. Of all academic subject areas, mathematics is probably best-suited for student frustration. In no other academic area can a student spend so much time on drill, memorization, and practice. When it finally comes time to apply those skills that have been drilled, memorized, and practiced, the whole process can frequently be thwarted by a simple mistake or a

missed step. The stage is well-set for frustration and the beginning of a bad attitude toward mathematics.

A bad attitude toward mathematics can be the most severe blockage that both teacher and student face. Frequently, a teacher's main task is to convince the student that they do have a potential for success in mathematics (Houlihan, 1981). Clearly it is much easier to prevent a negative attitude than it is to change a negative attitude. With this in mind, the need for early intervention becomes obvious.

Early intervention is a key part in the success of calculator usage in the classroom. The use of calculators in a first grade classroom frees the pupils to explore and expand their minds and, opens them to new ideas (Starkey, 1989). In a properly monitored classroom, students are not just idly pushing numbers, they are more likely to know what they are doing and why they are doing it. The teacher has the opportunity to observe and measure students' competency in calculator use

because the calculator allows the teacher extra time for monitoring student progress.

Calculators can help the students develop "number sense." The NCTM"s "Standards" state that students with "number sense" have (1) well understood number meanings, (2) developed multiple relationships among numbers, (3) recognize the relative magnitudes of numbers, (4) know the relative effect of operating on numbers, and (5) developed referents for measures of common objects and situations in their environments. (NCTM, 1989).

Students should be allowed, and encouraged, to use calculators in primary classrooms because it allows them the opportunity to "grow-up" with technology (Spiker and Kurtz, 1987).

It is to this end that the NCTM suggests the need for curricular reform in K-4 mathematics (NCTM, 1989). In traditional mathematics curriculums, pencil-and-paper computational skills have been the dominant force for instruction.

This type of curriculum does not encourage reasoning, foster insight, or problem solving. It reinforces and rewards rote learning. Students are passive rather than active in their learning.

The NCTM's 1989 "Standards" outline five general goals for K-12 students. Briefly they are that (1) students need to learn to value mathematics, (2) students become confident in their ability to do mathematics, (3) students become mathematical problem solvers, (4) students learn to communicate mathematically, and (5) students learn to reason mathematically (NCTM, 1989). Goals such as these imply that students be exposed to varied and familiar experiences that will encourage them to place value on mathematics and its place in their world.

The use of calculators in teaching can contribute to the attainment of these goals. A calculator can be used to remove the drudgery of drill and practice often associated with mathematics. A calculator would allow students to use mathematics facts, rather than just practicing

them; a considerable amount of time would then be made available for accomplishing the goal of learning the value of mathematics (Yvon, 1987).

Using calculators can also be effective in developing a higher level of self-confidence in students. If students are allowed to check their work with a calculator, they will receive immediate reinforcement for their efforts, as opposed to waiting until tomorrow or when the teacher has time. With a calculator, students can find their own errors and develop their ability to solve and create their own problems. This alone would decrease dependency on the teacher, minimize emphasis on only getting the correct answer, and facilitate an increase in self-sufficiency, and confidence. The calculator is a patient, reliable, ready source of ideas willing to help students at any hour of any day (Kansky, 1987).

Calculators can be a very powerful tool in developing a high enthusiasm and positive attitude toward mathematics. Any device which causes so

much pleasure to be associated with mathematics should be incorporated into the mathematics curriculum. Also to be noted is that the increased probability of appropriately chosen mathematics strategies for problem solving will decrease the customary dread with which students approach this task.

The Calculator's Role in Problem-Solving

Problem solving has a prominent role in the NCTM's "Standards". Problem solving goals in grades K-4 have five points, stating that mathematics curriculums need to emphasize problem solving so that students can:

1. use problem-solving approaches to investigate and understand mathematical content;
2. formulate problems from everyday mathematical situations;
3. develop and apply strategies to solve a wide variety of problems;

4. verify and interpret results with respect to the original problem;
5. acquire confidence in using mathematics meaningfully. (p.23)

Problem solving has always been a difficult skill for students to master. This has largely been attributed to the varying degrees of cognitive development demonstrated by students of even slightly varying age groups. Carpenter, Moser, and Bebout (1988) found vast differences in the way first and second graders interpret and solve word problems. As children become older, their problem solving capabilities become more sophisticated. These varying degrees of development cause problem solving skills to be an area that can be most effectively taught individually. If problem solving is to be taught individually, teachers must have the available time to assist students individually. Calculators allow the teacher more freedom for monitoring as students can correct their own work and verify answers.

When calculators are used, students are allowed greater individual growth in the development of their problem solving skills. Frequently, students are unable to progress in a given line of thinking because they can not complete a computation. As an example, students are naturally curious about averages, however the computations for problems such as; "How many beef cattle are necessary to supply a fast-food restaurant chain for a day, week, month, or year?" can be overwhelming to most students. They have the desire to explore the topic, but don't have the computational expertise to complete the task, therefore the topic is discouraging and not attempted. A calculator can be used to assist the student, but the student still must know the process and procedure. The calculator assists the students in their task, it does not complete their task for them.

The calculator can move the focus from the computational aspect and allow students to direct their energies toward analyzing what is necessary

to solve the problem. Szetela and Super (1987), found that 7th grade students taught problem solving with a calculator scored significantly better ($p < .05$) on an attitude-toward problem-solving test than the group taught problem-solving without calculators. Due to the improved success-rate in problem solving, the traditional negative feelings of students toward problem solving may be improved. As reinforcement for the use of calculators, the calculator group suffered no loss on a test of rational number skills and concepts. Szetela and Super (1987), suggest that the resistance to the use of calculators may be delaying opportunities to learn mathematics.

Problem solving is the main application of mathematics skills in adult life. Yet, only 20% of the elementary classrooms regularly use calculators in problem solving (Kouba and Swafford, 1989). The main reason for this low rate is the fear that computational skill development will be retarded by calculator usage.

Calculators were never intended to take the place of instruction in estimation and basic arithmetic skills. The calculator should be regarded as a powerful problem solving resource that will allow students to investigate relationships and patterns without the burden of tedious paper-and-pencil computation. (Dick, 1988).

The lack of concern about the actual computation in problem solving, when using a calculator, is supported by Hedren (1985) where a significant difference ($p < .05$) was noted between calculator and non-calculator groups. The calculator group also demonstrated a better quantitative understanding of numbers and the ability to make use of information in problems lacking one single answer. The same calculator group showed no significant difference from the non-calculator group in competency in mental arithmetic or calculations with simple algorithms.

Parents' Viewpoint On Calculator Usage in the Classroom

At the beginning of this project, it was anticipated that there would be a tremendous mass of writing that had been done in this area. This however, did not prove to be true. Actually, a very small amount of material was found on this subject. Parents seem to have been strangely mute on this topic.

It is difficult to ascertain why there is a virtual void in this area. Due to the absence of literature in this area, it is only possible to advance a theory as to why parents haven't become involved. A survey of 100 "random" occupations indicates that fully 98 percent of those occupations directly involve people using some sort of calculator for work-related tasks (Saunders, 1980). This high percentage of calculator-related jobs could indicate that so many people are already using calculators regularly that they are not intimidated by them and see the true value of calculators in real

life. These figures do not even touch on the number of people who have and use calculators in their day-to-day living for budgeting, shopping, and checkbook balancing.

As stated earlier, it is difficult to tell what a group's viewpoint is if they don't tell you anything. All that remains is to evaluate what that group does concerning an issue. In classrooms where calculators are used, but not supplied by the school, parents often send their children to class with an extra calculator, just in case another student may have forgotten to bring one (Starkey, 1989).

In 1988, the Chicago Public Schools began supplying calculators for all 200,000 students, grades 4-8. This program costs about $10.00 per student and insures equity between all income levels (NCTM, 1988). Due to the fact that students in all five grade levels will be evaluated quarterly, both with and without calculators, the school district is insuring parents and potential critics that the calculators

are not hindering student progress in development of computational skills. There has been no negative parental outcry to date.

A review of the available literature indicates the question that parents seem to raise most frequently is: "Will the children become dependent on calculators and not be able to do well on tests?" Research in this particular area indicates the answer is "No". In 1981, Shumway, White, Wheatley, Reys, Coburn and, Schoen reported:

> "Children grow significantly on basic fact and achievement tests taken without the use of calculators regardless of whether or not calculators were used during instruction. Children did not develop any of the feared debilitations when tested without calculators because of calculator use for instruction (p. 139).

Parents are being encouraged to work with their local schools and help those schools do

their own research comparing how students do on tests when allowed and when prevented from using calculators (Roberts, 1987). In an atmosphere of cooperation, it is possible that actions such as suggested here could produce the most significant data to date on this subject.

If the adage - "Actions speak louder than words" - is true, this is likely to be the place where it applies. Through their silence, parents seem to support the use of calculators in mathematics teaching. If parents don't support the teaching of mathematics with calculator-assistance, then they don't seem to object to it either.

Implications of Calculator Assisted Standardized Testing

How students perform on standardized mathematics tests is the usually the only indication that the public receives concerning the efficiency and the effectiveness of the mathematics curriculum. It has been public

higher test scores that has forced our mathematics curriculums to respond to the standardized tests. As more attention is focused on raising those test scores, more distortion is introduced into the curriculum and resultant instruction (Shepard 1989). This distortion causes mathematics curriculums to be arithmetic or computation driven, rather than focusing on realistic applications of mathematics and the associated skills that students will use as adults. A mathematics curriculum that emphasizes realistic mathematics applications is what the NCTM speaks to in their 1989 "Standards".

The NCTM's 1989 "Standards" directly address several topics relative to the use of calculators and computers. As the calculator is the area of focus in this paper, computers will not be discussed.

In the introduction to the 1989 "Standards," calculators are explicitly mentioned as being part of the reason for the societal shift from industrialization to information. The easy and

convenient availability of technology, such as the calculator, has impacted the way governments, business, industry, and academic disciplines interact. The traditionally slow means of communication, printed matter and voice are no longer sufficient unless supplemented by some sort of electronic communication (NCTM, 1989).

The first calling of the new standards is for "mathematically literate workers" (NCTM, 1989, p.3). Due to the increasing mathematical expectations that are being placed on workers, what has been thought of as basic mathematical competence simply is not sufficient. Employers no longer want workers with strong backs, and "shopkeeper" arithmetic skills. The employees that are in demand are those that can understand and use the technologies of communication, ask questions, assimilate unfamiliar information, and work cooperatively (NCTM, 1989).

The first standard in each of the three grade level areas; K-4, 5-8 and, 9-12, is Mathematics as Problem Solving. As discussed in the section on problem solving in this paper, the calculator can and should be used in the teaching of problem solving skills.

The bulk of most mathematics curriculums in place today are tremendously stable. The Mathematical Sciences Education Board (MSEB) observes that this stability is dependent on two outdated and unbending premises. They are that "(1) mathematics is a fixed and unchanging body of facts and procedures; and (2) to do mathematics is to calculate answers to set problems using a specific catalogue of rehearsed techniques." (MSEB, 1990, p. 4). The core of most mathematics curriculums - the arithmetic, geometry and, elementary algebra - differs very little from what was taught by tutors 500 years ago. Even calculus, as it is taught in most schools, is 300 years old. This type of curriculum is no longer adequate for the needs of today's students.

The standardized tests that are administered today echo a need for that stability. This has forced our mathematics curriculums to be arithmetic-driven, focusing on the past, not recognizing the development of time and effort-saving devices such as the calculator. Computation and the manipulation of symbols that could be much more efficiently be completed with a calculator are still the backbone of most mathematics curriculums. Those same test scores that are so highly thought of by the public serve to confirm what mathematics teachers already know: students are completing ten to eleven years of mathematics experiences with a curriculum that does not prepare them to apply mathematics sensibly to the world in which they must live (Held, 1988).

As the world makes the shift from an industrial and agrarian society to a modern informational society, that shift has changed the way in which mathematics should be approached by today's teachers and students. The procedures and

concepts that are mastered today are not what students need if they are to become productive, self-fulfilled citizens in the next century.

The make-up of the mathematics curriculum has responded to the mathematical demands of the standardized tests. Mathematics curriculums have not included calculator usage largely due to the fact that most standardized tests prohibit the use of calculators (Held, 1988). Simple logic tells teachers and curriculum authors that one should teach in the same method as the evaluation. It would be unfair to students to teach them mathematics with calculators and test them without the use of calculators.

The mathematics curriculum is a result of what is evaluated on standardized tests. If calculators are ever to become a meaningful and well-integrated part of mathematics curriculums, the tests themselves need to be modified so they require calculator instruction in preparation for the test. These tests need modification because it is the content of the tests that communicate to

students what is important to know and the content of the tests determine the content of the curriculum (NCTM, 1989).

In the spring of 1987, Missouri administered the Missouri Mastery and Achievement Tests (MMAT), calculators were allowed, but not required or supplied by the state or local school districts. The school districts decided independently whether or not to allow calculator usage and whether or not to supply calculators for the tests. If the district did not supply calculators the students were given the option to bring their own from home. Either the test proctor or the student indicated if the student used a calculator on the test. In an analysis-of-covariance, the calculator group performed significantly better ($p < 0.01$) than the no-calculator group on the total test, numbers cluster, computation cluster, and the interpretation-and-application cluster. There was no significant difference between groups on the geometry-and-measurement cluster. As the complexity of the problems increased, so did the

amount of difference in the scores (Long, Reys, and Osterlind, 1989).

In their summary, (Long, et al. 1989), bring out several points to support the use of calculators in testing:

1. Calculator use on mathematics tests designed to measure understanding of key mathematical concepts has afforded reviewers of test results a clear picture of students' deficiencies.

2. Calculator use on the state mathematics test has legitimized the use of calculators in mathematics classrooms, thereby promoting a shift in instructional emphasis in all grade levels and a shift in curricular emphasis at the junior high school and senior high school levels.

3. The logistical problem of furnishing and supervising calculators for a large scale assessment, often cited as an

> overriding deterrent by test publishers, has proved manageable in Missouri and has encouraged the use of the tool on other tests. For example, a test is currently being developed to assess the general knowledge of students entering teacher-education programs in Missouri. Calculators will be included as a tool for taking the test.
>
> 4. Administrators' reluctance to allow the use of calculators in testing and instruction is decreasing. Preliminary data indicate that 84 percent of eighth graders in the 1988 state sample, compared to 46 percent in the 1987 assessment, had access to calculators for the test. (p.324-325).

The tests that are in use today are flawed. Given the great amount of weight that is assigned test scores, teachers are often induced to teach to the test. Often the students are taught the skills needed without proper emphasis being placed

on the underlying concepts. Teaching isolated discreet skills is less efficient than teaching in an application situation. Teachers have reported giving up essay tests because they are not effective in preparing students for the multiple-choice format. This type format gives rise to seemingly endless drill and practice and decontextualized skills (Shepard, 1989).

There is a need to examine standardized testing as it is conducted today. Tests should measure the more challenging and complex mental processes, and more closely reflect the real learning that can take place if calculators are used in the teaching of mathematics.

It is only fair to students that they should be taught the material in a fashion that is in agreement with the method that will be used to evaluate them. If test publishers are not going to address the calculators, then the curriculum should not include them. Based on the study cited in this paper, (Long, et al. 1989),there seems to be no good reason that calculators should be used

on standardized tests. If history is to tell curriculum authors anything, it should be: "If you want it in the curriculum, then ask to have it measured on the standardized test."

Summary

Calculators have been researched as a potential aid to teaching and as possibly the biggest disaster to hit mathematics since "New Math."

Little data has been found, to date, to indicate that using a calculator does anything to harm the acquisition of basic skills or to cause a student to become overly dependent on a calculator.

Originally, calculators were thought of as too expensive, unreliable due to internal batteries, and impractical because of their size and limitations. These negative features of the calculator were easily forgotten when personal computers were introduced. Educators soon

recognized that the computer duplicated all the functions of the calculator and could do much more as well.

Eventually, discussion turned from whether or not to use calculators to how to use them most efficiently. In this area, attitude improvement and development of problem solving skills were examined.

No topic of this magnitude would be complete without considering the opinions of parents. Oddly enough, parents don't appear to have strong feelings in this area. By their actions, parents do indicate their acquiescence. The main concern that parents have is, "How will using a calculator affect standardized test scores?"

Standardized test scores have an increasing role in education today. Bond issues can succeed or fail based on how students score on their tests. Indeed, the public has a right to know how their children are doing when compared to other students of the same station in life, and how

efficiently their tax dollars are being spent. Everyone is best served if calculators are used on standardized tests. The tests themselves will be better and more reflective of a child's strengths and weaknesses, and requiring calculators to be used on tests will force their usage into the mathematics curriculum.

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