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CALCULATOR USE AND INCORPORATION IN THE MATHEMATICS CLASSROOM

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Calculator Use and Incorporation in the Mathematics Classroom

Over the last few decades the mathematics curriculum in the United States has undergone some extreme swings in emphasis. Following Sputnik U. S. math educators tried "New Math" in the 1960's--an effort, according to Adler, to teach students the broadest possible concepts of mathematics, such as number theory and set theory, and to help them to gradually derive arithmetic principles from those concepts (16). It was hoped that as the students saw the "big picture" of math, they could more easily understand and learn the basic facts; it didn't work. Then came the counter reform "Back to Basics" movement. Adler comments that it reacted to the lack of rigor in "New Math" and emphasized drill to acquire the basic mathematical skills (16).

Developing around the same time period, however, was the calculator--technology which would call for yet another shift of emphasis in mathematics. As the National Research Council (NRC) has so aptly stated,

Ten years ago arithmetic fell to the power of inexpensive hand calculators; five years ago, scientific calculators offered at the touch of a button more sophisticated numerical mathematics than most students knew anything about. Today's calculators can do a large fraction of all techniques taught in the first two years of college mathematics. Tomorrow's calculators will do what computers do today (Everybody Counts (EC) 63).

Yet despite the global transition to a technological society permeated with mathematics the NRC observes that U. S. mathematical achievement scores are nowhere near the level needed

to continue to be a world leader in technology; it feels that our math curriculum conforms to the past, unaware of the future (EC 1). Instead of taking advantage of the potential for mathematical enrichment, enlightenment and expansion which the technology of calculators--and computers--offer (EC 74), the NRC charges that our math curriculum is a spiral of almost constant radius, with so much review being done yearly that little new learning occurs (EC 45).

Need for Revitalization in Mathematics Instruction

The need for a revitalization and revision of the U. S. math curriculum was made painfully clear in 1982, with the Second International Mathematics Study. According to McKnight, students 13 years old and/or in the eighth grade and students in advanced college preparatory courses at the end of secondary school and/or twelfth grade from 20 different countries, including the U. S., were tested on topics which represented an international consensus of what was important (v). While U. S. eighth graders scored well above the international average in computational arithmetic, they scored far below in non-computational arithmetic (e. g. problem solving) (McKnight vi). The twelfth grade calculus students--the U. S.'s best math students--scored average while precalculus students scored substantially lower than the international average; sometimes the United States ranked lowest of the industrialized countries participating in the study (McKnight vii). Adler, referring to the same study, stated that U. S. seniors ranked 14th out of 15 nations (16).

Certainly one reason for the low scores in problem solving, precalculus and calculus is the primary emphasis on arithmetic given in U. S. elementary classrooms. McKnight comments that the study discovered the eighth grade curriculum to be characterized by much repetition, review and topic coverage with little intensity. He says it tends to be arithmetic-driven, therefore more of an end to elementary level math instead of a beginning to high school math (ix). This emphasis seems to have narrowed students' opinions about what math is and how important it is. McKnight reports that in a survey taken during the International Study over three fourths of the eighth and twelfth grade U. S. students felt that memorizing rules and formulae is an important part of math, but fewer than 50% thought it easy and less than one fourth liked it (42).¹

This attitude of math as mostly "a collection of concepts and skills to be mastered" is too narrow, according to the National Council of Teachers of Mathematics (NCTM) (Curriculum Standards (CS) 5). In this technological world where situations change so quickly, the NCTM states that mathematics "includes methods of investigating and reasoning, means of communication, and notions of context" (CS 5); therefore problem solving "must be central to schooling so that students can explore, create, accomodate to changed conditions, and actively create new knowledge over the course of their lives" (CS 4).

Developing these abilities of reasoning, problem solving and communicating occur only by active and frequent practice, says

the Mathematical Association of America (MAA). It also observes that the way math is taught influences a student's view of math either as an integrated whole or as simply a collection of different topics (preface). Calculators and other technology are just the thing to help students learn about these broader, deeper, more important aspects of math, the NCTM feels (CS 128), and they have made several recommendations on how school systems can incorporate calculators to facilitate better learning for our country's future citizens and leaders.

NCTM Recommended Standards

Stating that calculator use at school would help students match math with everyday situations, develop reasoning capabilities and promote understanding and application in mathematics, the NCTM recommends calculator integration with mathematics curricula at every grade level for daily work in class and at home and for tests. This recommendation is in an NCTM position statement, February 1991. Along with it are suggestions for student calculator use, for teacher promotion of calculators and for other ways to facilitate calculator integration. See Attachment 1 for the full statement.

Opposition to Calculator Use

Despite the advancements of technology and recommendations from such organizations as the NCTM, many people still feel uncomfortable with the idea of allowing students--especially on the elementary level--to use calculators in school. The NRC

states that many people feel that calculator use in a classroom is bad (Willoughby says they think it constitutes cheating (61)), but that using a computer is okay, since it is a necessary tool in our society (EC 61). According to Willoughby, this attitude comes from a fear that calculators will prevent mastery of basic skills or will cause dependency to the point that one cannot function mathematically without a calculator (62). The NRC comments that some people fear the calculator will be to math what the television has been to reading (Reshaping School Math. (RSM) 17), that it will stifle or stunt growth in skills.

Other arguments against calculator use that Willoughby names include the charge that rich children will have better calculators than poor children or that administrative care and maintenance of calculators is too burdensome (62). Those arguments are hardly valid anymore, since both four function and scientific calculators are quite inexpensive and since, as both Willoughby (63) and Taylor (143) point out, administrative care for calculators is not any more difficult than for other school materials.

Taylor cites resistance to change as another factor inhibiting calculator use (143). According to Williams, parents seem to have the attitude that their children should learn exactly what and how they themselves did (9). Also, people who view mathematical achievement as a filter for entrance to professional and educational programs feel the calculator hinders the process, says the NRC (RSM 17).

Teachers too resist changes, but not necessarily because they think change is bad. Cornelius observes that changes in technology occur about every six months, whereas educators need about 10 years to assess the implications of a change in education (32). He says that teachers want to find out if a student's future education will be harmfully affected by the change--and they usually can't determine good or bad results for several years. Educators hesitate also, he continues, because they are unsure of the best way to use calculators, particularly in the elementary grades (33). The discrepancy between technology's and education's timetables makes teachers appear opposed to change.

Saxon, math textbook publisher, is an excellent example of one opposed to calculator use in elementary school. In an advertisement for his series of textbooks (elementary and high school) Saxon cites a 1985 report that the top five percent of American students scored similarly to Japan's 25th percentile students, and he blames this poor achievement on two factors: lack of emphasis on fundamental concepts "whose use can be automated by students," and American teachers' efforts to teach advanced concepts too soon (20). He specifically notes that Japan does not allow calculator use in the elementary schools and concentrates on fundamentals (20). Saxon fears that calculators in the elementary schools will make students think they are magic boxes to substitute for understanding and make them unwilling to put forth the mental effort required to develop a feel for

numbers and estimating. Concluding his advertisement, Saxon makes the appeal that if only five to ten percent of children are hurt by early calculator use, it should not be allowed(21). Thus he ardently represents those who fear calculators will prevent mastery of the basics and cultivate dependency on them.

Defense and Advantages of Calculator Use

Those who defend and advocate the use of calculators in the classroom don't share these fears. On the contrary numerous proponents cite evidence that calculator use does not hurt--and might even improve--skill acquirement.

Researchers Hembree and Dessart conducted a meta-analysis of 79 calculator studies. They concluded, according to the NRC, that calculator use combined with traditional instruction apparently does not harm a student's retention of paper-and-pencil skills and can actually improve those skills (RSM 22). Only one exception was found. Willoughby states that one study gave evidence that calculator use at the fourth grade level "may interfere with the acquisition of certain numerical skills usually tested at the end of grade four" (62), but did not name those skills. Taylor writes that Suydam summarized information from nearly 100 studies in the 1970's and concluded that using a calculator for instruction (not on tests) gave students the same or higher scores as those not using a calculator (134). In its statement of a framework for mathematics education in California public schools, the California State Board of Education (BOE) wrote that a "proper use of the calculator requires a knowledge

of basic facts and strengthens number skills" (excerpt in Arithmetic Teacher 64). Suydam writes, ". . . (W)aiting until after the facts are fully mastered before using calculators does not appear to be necessary" (22), firmly refuting Saxon's arguments against calculator use.

Besides reinforcing and strengthening computational skills, calculators help to improve problem solving skills as well. Rather than having to concentrate on computing the problem correctly, students who use calculators seem better able to focus on a correct analysis of the problem, according to the NRC (RSM 23). Carter and Leinwand say the calculator allows students to do twice as many problems, giving twice as much reinforcement on the problem solving sequence (56).

Calculators for problem solving are urged in the specific areas of standardized tests and remediation. As Reys and Reys point out, standardized tests measure not only computational skills, but also a student's grasp of concepts, applications and problem solving skills. They urge teachers to equalize students with differing computational skills by having students use calculators on sections that test noncomputational skills (13). Posamentier and Stepelman feel that if calculators are used to improve problem solving skills of a remedial student, the student may be encouraged enough by that success to return to his deficiencies in computational skills and overcome them as well (119). The NRC uses a very interesting analogy to explain calculator advantages for weaker students: Calculators can make

higher math more accessible to those weak in algebraic (or arithmetic) skills much as spell checkers help a writer who has deficient spelling ability (EC 62).

The main reason to learn math at all is that it helps people to make sense of their world, according to Adler (i.e., insurance companies' statistics, probability for astrology, large numbers of children per million kidnapped each year, etc.) (18). Mathematics in the classroom should reflect the situations and numbers people will come in daily contact with at the office or the store or in the world of science. Willoughby states that a strong reason for teaching calculator use is that students notice people outside of school using calculators and they need to identify the fact that school math and outside math are connected (63). Calculators remove the computational barriers which real number situations erect and allow experience and math to meet, as Yvon puts it (16, 17). Comstock and Demana agree that calculators used with problem solving help students to understand math better and to prepare them for life in their high-tech society (51).

Calculator proponents add other advantages to the list. They feel that calculators promote more positive attitudes toward math, keep interest in math high, and encourage exploration and creativity which promote better understanding of mathematical concepts. As the NRC says, calculators allow math learning to be more active and dynamic because the burden of computation is relieved (EC 62). Reys and Reys feel a calculator encourages a

student to be more persistent at solving problems and more willing to explore alternate methods of solution (12). Yvon adds that it encourages more creative ways of checking problems (17). Finally, Reys and Reys state that exploration with a calculator exposes students to new and more advanced domains of math; for example, a first grader playing with the calculator notices that $7 - 12$ does not equal $12 - 7$ or a third grader sees that $9 \div 3$ is not the same as $3 \div 9$. These discoveries are opportunities for the teacher to help students gain fresh insights about numbers (13). Thus the calculator can help students realize that mathematics is the study of patterns and not merely a calculation craft, says the NRC (RSM 14).

Even calculator advocates realize, however, that the calculator is not a panacea that will make all paper-and-pencil or mental computations unnecessary. As cited earlier, the Hembree and Dessart meta-analysis stated that calculator use along with traditional instruction was good, and the California BOE said that a knowledge of basic facts was required in order to use the calculator properly. Taylor recommends calculators be available to all students with the "possible exception of the earliest elementary grades" and states that, of course, they should not be allowed for tests of computational skills (152). Sometimes a person's mind or memory is more efficient for certain mathematical tasks, and Willoughby reminds teachers that they need to teach students how to intelligently use the calculator and when it is not the best tool (63). Reys and Reys feel that

as students use the calculator they will realize its limitations (12), and the NCTM is confident that students will be able to choose the best method, knowing the demands of the problem they need to solve and the capabilities of the different methods of solution they have available (CS 8).

Suggestions for Curriculum Changes

Bringing calculators into the classroom necessitates change in the mathematics curriculum. As Willoughby says,

Never before has a change in technology made knowledge and understanding of mathematics so important to so many people. Never before has a change in technology made the kind of mathematics most people have been learning so obsolete (2).

Surely he refers to the fact cited by the NRC that nearly all math techniques taught through the first two years of college can be done on hand held calculators, requiring adjustments in the balance and approach to nearly every school math topic (RSM 2). More emphasis needs to be placed on certain areas and less on others. Some concepts need to be introduced earlier in the educational sequence. Others may not need to be dealt with at all. The NRC recommends that however the calculator (and computer) is used, it needs to reflect and anticipate the continuing rapid developments of technology (EC 84).

As cited above, Willoughby believes teachers need to teach intelligent use of the calculator--when and when not to use it, etc. This can be done by modeling more effectively than by pure instruction. The teacher who models a natural and routine use of technology in the processes of learning, teaching and doing

mathematics meets the NCTM ideals for math teachers of the 1990's, according to the MAA (intro.).

Although Cornelius quotes Margaret Brown as saying that calculator availability should shift emphasis from "algorithm learning to understanding the structure of the operations themselves and how and when they should be applied" (201), the NCTM states that students need to learn algorithms and be able to do paper-and-pencil computations with at least some proficiency (CS 8). And while the NRC speaks of reduced emphasis on manual skills so all students can achieve some level of mathematical achievement (RSM 20), Willoughby balances the calculator advocates' position by saying that knowing how to manipulate symbols and perform rote tasks efficiently aids in doing higher order tasks such as mental calculations and estimations (60). Wiebe feels that instruction on paper-and-pencil computations should be limited to two or three digits and suggests that some more difficult algorithms, such as long division, could be replaced by easier ones, such as a subtraction and addition combination of finding a quotient (59). Reys and Reys comment, "If a computation takes longer than a minute to do with paper and pencil, then a calculator should be used" (14). About the memorization of addition, subtraction, multiplication and division facts, Willoughby states that they are as important as ever (2), although Wiebe specifies emphasis on recall of single digit sums and products, etc., only (58). This is important not only for paper-and-pencil work but also for mental computations,

which Wiebe says need equal instructional emphasis today (58). These suggested curriculum changes seem to try to balance the "New Math" and "Back to Basics" premises about math instruction as it changes to accomodate technology (see Adler 16). As Willoughby says, instead of teaching students all the skills and knowledge believed to be useful in the past, teachers must choose which abilities are necessary for the future and which are not (61). Adler observes that it seems the emphasis is shifting from skills for their own sake to the use of math as an adjunct to logic (18, 19).

Since, as Willoughby points out, higher order thinking skills are still uniquely learnable by humans (4), the mathematics curriculum needs to put more emphasis on those skills than on the lower order thinking skills with which the calculator can assist. Williams names two of those as a firm sense of numeracy and estimation skills and says they are vitally important to calculator use (9). A sense of numeracy will help a student decide what method of solution (calculator, paper-and-pencil, mental computation or estimation) is appropriate for particular problems. Development of this good number sense should be the main objective of elementary mathematics, according to the NRC (EC 46). Wiebe says that the ability to estimate and other mental arithmetic skills is even more important with the existence of the calculator because its user must be able to check the accuracy of the calculator answer and to detect errors of entry (57).

Wiebe suggests two other curriculum changes to incorporate higher order thinking and calculator use. The first is front-end and left-to-right computational strategies (58, 59). This will help to strengthen mental calculation and estimation skills. It seems that Wiebe feels this should replace conventional methods of computation or at least receive more emphasis. His second suggestion was that the hierarchy of operations and use of parentheses need to be taught (59). Thus a student can intelligently rearrange elements of a problem in preparation for doing the computation by calculator.

As stated earlier, the calculator allows word problems to utilize numbers from real experiences. Students need to see that the method of solving word problems they learn in school can be used outside of school to solve their own mathematical problems. Thus teachers and/or textbook publishers should be sure word problems are more realistic and pertinent to their students.

Yvon urges teachers to allow students more time for personal exploration with the calculator (18)--yet another emphasis on the development of higher order thinking skills. The NCTM feels that this exploration will help students see the patterns, concepts and number ideas forming the framework behind all the specific and seemingly disjoint parts of mathematics (CS 19).

Earlier introduction or emphasis on negative numbers and decimals is suggested. Since negatives can be used to solve such problems as $35 - (2 \times 1.75)$, Wiebe feels they should be introduced much sooner (59). He says that the meaning of

negatives should be taught in third or fourth grade while operation instruction could still wait until sixth or seventh grade (60). Willoughby (64), Wiebe (58, 59), Taylor (141) and the NRC (EC 48) all mention the need to introduce decimals earlier and to emphasize them more than fractions. Wiebe and Willoughby suggest second grade as a good time to introduce them. Willoughby feels decimals and fractions should be taught independently until grade five or until students are able to convert fractions to decimals on a calculator and can understand their connections, while Wiebe states, "A decision that educators in the United States need to face in the future is whether we should attempt to teach operations on fractions at all" (58). He suggests that operations on fractions be taught only after mastery of decimal numeration. However, despite the strong statement quoted above, Wiebe admits that more fraction instruction is handy in algebra to simplify equations, and he feels it would at least be good to memorize common fractions as decimal equivalents. Taylor feels students still need to be able to work with fractions as long as repetitive work with burdensome computations is avoided. Obviously, something different needs to be done about fractions and decimals, but even the experts disagree on exactly what that should be.

Examples of Change

Because of strong NCTM recommendations and the weight of evidence in favor of calculator advantage, teachers and school

systems seem to be slowly incorporating calculators in their mathematics curriculum. Three such examples include calculators in California public schools, on Connecticut's eighth grade mastery test and on Georgia's Basic Skills Test.

The NRC relates that teachers are beginning to adopt new approaches to instruction and to cover new subject matter that relates to future needs (EC 84). For example, the NCTM tells of a college teacher who encouraged students to explore and discover math rather than requiring them to listen to lectures and memorize formulae. She commented that there was plenty of time to cover all the subject matter mentioned in her syllabus and that the extra time taken to teach the use of graphic calculators and to allow students to discuss, discover and work actually allowed them to learn more than her former method had (Professional Standards 131).

Citing advantages of calculator use similar to those named in this paper, California's BOE wrote a Framework for public school mathematics instruction in 1985 (excerpt in Arithmetic Teacher 64). It advocated calculator use beginning in the primary grades for exploratory activities and recommended that before the end of sixth grade students should have calculators continually available for homework, tests, etc. The Framework cautioned against calculator use merely for drill or busy work or to check paper-and-pencil problems. Rather, it recommended that the calculator be used to lighten the computational burden and allow more time to think through problems. Probably seeking to

allay fears of teachers who feel as Saxon does, the BOE stated that "proper use of the calculator requires a knowledge of basic facts and strengthens number skills", but that its use "must not replace the development of the student's understanding of the meaning of arithmetic operations and the common algorithms used to perform those computations."

In 1986 Connecticut's BOE endorsed calculator use on parts of its state's eighth grade mastery test (Carter and Leinwand 55, 56). Reasoning that calculators are in widespread use in work and home environments and citing several of the advantages already discussed, the BOE allowed calculators for measurement-geometry and problem-solving applications sections of the test beginning October 1986. Interestingly, the BOE also stated that rote paper-and-pencil learning of algorithms repeated over and over with larger and larger numbers was a disturbing characteristic of elementary classroom mathematics.

The state of Georgia has also adopted the priority of teaching students "how to solve real-life problems, rather than simply compute answers," reports Pendered (A12). He tells how the old Georgia Basic Skills Test (BST) is being phased out and how a new one allowing students to use calculators during the test will be introduced in 1994. According to the math coordinator for Georgia's Department of Education, calculators on graduation tests are allowed in 13 states currently and will be allowed in four additional states in 1992 (Pendered A12).

Personal Interviews

In order to determine how teachers at the classroom level feel about calculator integration and what they are doing with calculators in their mathematics program, I interviewed or surveyed 16 area teachers. See Attachment 2 for their names, grade(s) taught and school name and location. Attachment 3 is a copy of the survey used.

Calculator Use Policy Responses to question three invariably indicated that the decision about calculator use was left to the individual teacher. However, the Standifer Gap SDA Elementary teachers stated that in Fall 1991 their school board members expressed concern over calculator use except under very controlled circumstances--not on a daily basis. One board member, also interviewed as a high school teacher (Greve), even said he wished calculators were not used in elementary school at all, because he later teaches students conditioned to use the calculator. Their computational skills and speed are slower than if they weren't so dependent on the calculator, he feels.

Grades K - 4 The grades K - 4 teachers were divided fairly evenly on calculator use for instruction or demonstration (five did not, four did). None of them allowed calculators for tests. The six teachers in this group who allowed calculators for assignments did so mainly for specific calculator activity sheets or pages in the textbook. Dearing and Duncan mentioned that they allowed their students to use calculators when adding or subtracting numbers above grade level. Corbin and Hochs said

they allowed students to check some problems with a calculator, and Hochs and Peak said they would allow their students to use calculators when solving word problems, since the emphasis there was on process, not answer.

Interestingly, Estep, who did not allow calculators on assignments and did not even assign textbook calculator activity pages (she said that in her multigrade environment there simply was not enough time for calculator instruction and other skill and concept instruction too) did help her students learn how to figure their grade percentages on a calculator. They had seen her figuring percentages for them and wanted to know how to do it themselves. Since the topic of percentages is taught later on and since the calculator makes the work so much faster and easier, Estep felt it was a good way to expose her students to something beyond their scope of study. She also suggested that a calculator could be used instead of flash cards for drilling multiplication or addition facts, since this would include both visual and tactile senses. Meadows did not allow calculators in her classroom at all and commented, ". . . not in my second grade. Children need to use their minds."

The question concerning ideal grade level for calculator introduction drew various responses. Estep thought the calculator could be introduced as early as kindergarten to give the children visual and tactile experiences with numbers and calculators. Five teachers, including the kindergarten and first grade teachers, felt first grade was a good time. Corbin picked

third grade, Meadows opted for junior high (because arithmetic skills should already be learned by then) and Hochs felt high school or college was soon enough.

Grades 5 - 8 The four teachers of grades 5 - 8 were divided two against two on whether they used calculators for instruction and demonstration. The two teachers who did not demonstrate calculator use also did not allow their use for homework or tests. They were very strongly against calculators for their students. Keasler said that while she did discuss keys and functions of a calculator during a textbook calculator unit, she wanted her students to know how to do the same operations themselves without the calculator. Christoph said he did not allow the calculator to be used in his classroom because he wanted to guard against the attitude, "Why should I learn basic math skills if I can use a calculator to do it for me?" He commented that if a student had not learned his basic skills before seventh grade, allowing him to use a calculator then would not cure his problem--the teacher needed to help the student build confidence in himself to learn those skills and help the student become manually proficient before he used a calculator. Christoph did say that he probably would allow his eighth grade students who were learning ninth grade algebra in a small "fast track" group to use calculators; he knew they had acquired their basic skills and the calculator would save them much time and effort which could then be devoted to algebra instead of arithmetic. When asked about another exception, Christoph agreed

that a severely handicapped child should be taught to use the calculator so that he could use that skill on the job.

The two teachers who allowed calculators for their students did so for different activities. DeLeon, a teacher of Chapter 1 students who are learning disabled and two years below their current grade level, allows only calculator checking for assignments, but she has learning centers set up for various calculator activities. These include learning about the keys and functions on a calculator and totalling sales receipts and figuring tax. She said she would also allow calculators for large division and multiplication problems, exponents, combined operations after they had been learned manually and word problems. Gass, an enthusiastic supporter of the NCTM, allows her students to use the calculator frequently on assignments and for the same types of problems on tests, although she did say that calculators were not usually allowed during the first nine weeks of school. That was set aside for mastery and/or review of basic number facts. She named several topics on which she allowed calculator use, including percent, area and perimeter, number theory, estimation and word problems. Gass commented that students saw math activities with a calculator as a game and were willing to try harder problems than if they had to use paper and pencil only. She also contradicted Christoph by saying that if students who had been drilled on multiplication facts since third grade had still not mastered them by eighth grade, they should be allowed to do math with a calculator. Possibly those students

are not capable of memorizing tables or have not matured enough mathematically, she feels, and they don't need to be further restricted from learning in other areas of math just because of that problem.

These teachers answered the question of grade level for calculator integration with the curriculum in a manner typical of their other responses. Christoph opted for high school level courses. Keasler felt it was okay to introduce the calculator during the primary grades, but it was not crucial to use until high school. DeLeon stated that middle school was a good time, since adding the calculator as a tool would keep students interested in math. Finally, Gass said it could be used from first grade to demonstrate higher level concepts (for example, demonstrating that multiplication is just a shortcut to addition), but that of course one method should not be used exclusively.

High School Grades Two out of the three high school teachers used the calculator for instruction/demonstration. Gordy even commented that he used his overhead calculators everyday. All three allowed, or at least did not forbid, use of a calculator for assignments--except Gordy for his remedial math students--and Gordy and Morford allowed them for certain parts of tests. Greve said he did not allow them for tests because he only asked questions requiring computations simple enough to do manually.

Each teacher had a different opinion on appropriate grade

level to introduce the calculator. Surprisingly, Gordy, who uses and allows the calculator so much, said it wasn't essential before high school level, while Greve, who felt that in his math classes the calculator could be used or omitted with little difference (and who made such strong statements at Standifer Gap board meeting--see above), stated that if done correctly it could be introduced at "the very beginning" or in fourth or fifth grade after the fundamentals were learned. He cautioned, however, that arithmetic needs to be done manually to learn the skills. Morford thought seventh and eighth grades were a good place to learn calculator use as a tool for doing math, as with the slide rule in times past.

Disadvantages of Calculator Use The disadvantages of using calculators in the classroom which were named can be summarized as follows: Students can come to depend on the calculator to remember the basic facts for them. Some might let the calculator replace their own thinking process and become lazy in math. However, as a few teachers pointed out, if a student doesn't use his own mind to do arithmetic at least periodically, his abilities will decrease, and one needs to remember the basic facts in order to judge the reasonableness of the answers from a calculator.

Do the disadvantages of calculator use outweigh the advantages? One teacher said yes for lower grades, four more gave a solid yes. Nine others, however, answered no, and while the remaining two did not give a solid yes or no answer, their

general attitude could be interpreted as no. Here are three notable quotes from teachers who answered no:

. . . (A) well integrated program that utilizes both aspects of the math curriculum (calculator use and skill practice) can be advantageous to the student (White).

(T)eachers know what their students need and are capable of determining use to students' advantage (Kennedy).

The calculator adds a whole (new) dimension to math. . . (It) is user friendly (Gass).

Conclusion

As one can readily see, not everyone agrees on how or when the calculator should become part of the mathematics curriculum. Certainly some things will always be true. As Willoughby says, students need a knowledge of basic facts to do mental arithmetic and estimation. They need good number sense and the ability to judge the reasonableness of an answer (65). Wiebe writes that paper-and-pencil work is not completely obsolete, since a calculator may not always be handy and some problems may be too hard to solve mentally. He adds that paper-and-pencil work helps to develop mental computational strategies (58).

Along with these skills, Willoughby feels,

Students should regularly use calculators in school, with appropriate instruction, so that they will learn to integrate their various skills to solve mathematical problems efficiently. To restrict calculators in school or to continue teaching the same topics in the same way (ignoring the technological changes taking place) would be an anti-intellectual, 'head-in-the-sand' way of failing to prepare our children to live in the 21st Century (66).

The NRC states that the basic skills for a 21st Century student

include the need to learn when to use math as well as how to use it (EC 63). With so many tools available--the mind, paper and pencil, calculators, etc.--a student will need to learn more, but it should also be easier to learn more.

Experts or researchers like the NCTM or NRC can say that the calculator should be around from day one, but individual teachers in specific situations may find or feel it necessary to teach otherwise. Perhaps in a few years the education community will have had enough time and experience with calculators to decide more firmly the place they should have in math education.

Notes

¹Similar to the opinions about the importance of memorizing rules and formulae, slightly more than 50% of the eighth graders and over 75% of the twelfth graders felt that using calculators was important. In contrast, however, all considered calculator use to be extremely easy and cited it as their best liked math activity (McKnight 43). The study also noted that calculator use was generally higher in Europe than in the U. S. (McKnight xii).

NCTM Position Statement**Calculators and the Education of Youth**

The following statement is an official NCTM position. Developed by the Instructional Advisory Committee, the statement was approved by the Board of Directors during their February 1991 meeting.

Calculators are widely used at home and in the workplace. Increased use of calculators in school will ensure that students' experiences in mathematics will match the realities of everyday life, develop their reasoning skills, and promote the understanding and application of mathematics. The National Council of Teachers of Mathematics therefore recommends the integration of the calculator into the school mathematics program at all grade levels in classwork, homework, and evaluation.

Instruction with calculators will extend the understanding of mathematics and will allow all students access to rich, problem-solving experiences. This instruction must develop students' ability to know how and when to use a calculator. Skill in estimation and the ability to decide if the solution to a problem is reasonable are essential adjuncts to the effective use of the calculators.

Evaluation must be in alignment with normal, everyday use of calculators in the classroom. Testing instruments that measure students' understanding of mathematics and its applications must include calculator use. As the availability of calculators increases and the technology improves, testing instruments and evaluation practices must be continually upgraded to reflect these changes.

The National Council of Teachers of Mathematics recommends that all students use calculators to—

- explore and experiment with mathematical ideas such as patterns, numerical and algebraic properties, and functions;
- develop and reinforce skills such as estimation, computation, graphing, and analyzing data;
- focus on problem-solving processes rather than the computations associated with problems;
- perform the tedious computations that often develop when working with real data in problem situations;
- gain access to mathematical ideas and experiences that go beyond those levels limited by traditional paper-and-pencil computation.

The National Council of Teachers of Mathematics also recommends that every mathematics teacher at every level promote the use of calculators to enhance mathematics instruction by—

- modeling the use of calculators in a variety of situations;
- using calculators in computation, problem solving, concept development, pattern recognition, data analysis, and graphing;
- incorporating the use of calculators in testing mathematical skills and concepts;
- keeping current with the state-of-the-art technology appropriate for the grade level being taught;
- exploring and developing new ways to use calculators to support instruction and assessment.

The National Council of Teachers of Mathematics further recommends that—

- school districts conduct staff development programs that enhance teachers' understanding of the use of appropriate state-of-the-art calculators in the classroom;
- teacher preparation institutions develop preservice and in-service programs that use a variety of calculators, including graphing calculators, at all levels of the curriculum;
- educators responsible for selecting curriculum materials make choices that reflect and support the use of calculators in the classroom;
- publishers, authors, and test and competition writers integrate the use of calculators at all levels of mathematics;
- mathematics educators inform students, parents, administrators, and school boards about the research that shows the advantages of including calculators as an everyday tool for the student of mathematics.

Research and experience have clearly demonstrated the potential of calculators to enhance students' learning in mathematics. The cognitive gain in number sense, conceptual development, and visualization can empower and motivate students to engage in true mathematical problem solving at a level previously denied to all but the most talented. The calculator is an essential tool for all students of mathematics. (February 1991)

Press Conference

Continued from page 1



Clifton R. Wharton, Jr., one of the speakers at the press conference.

director of the MAA; James R. C. Leitzel, visiting mathematician at the MAA; Paul H. O'Neill, chief executive officer of Alcoa and chair of President Bush's Education Policy Advisory Committee; Clifton R. Wharton, Jr., chair and chief executive officer of Teachers Insurance and Annuity Association of America and the College Retirement Equities Fund; and James D. Gates, executive director of NCTM.

New Position Opens at NCTM

A new position is being added to the headquarters staff—a field services coordinator. The coordinator will serve as liaison to the Regional Services Committee, plan and manage leadership conferences, and give general office support.

Candidates should have a bachelor's degree or higher in mathematics education or mathematics and at least eight years of successful work in education at the school or college level.

The deadline for application is 1 June. A decision should be made by 1 July 1991. The person selected should expect to serve in this position for at least two years, with the anticipation of continued employment. Resumes should be sent to Department E.

Attachment 2

Teachers Interviewed or Surveyed

<u>Name</u>	<u>Grade</u>	<u>School & Location</u>
Christoph, Richard	7 & 8	Spalding SDA Elem- Collegedale, TN
Corbin, Judy	3	Mtn. Oaks Elem- Ooltewah, TN
Dearing, Thelma	1	Mtn. Oaks Elem- Ooltewah, TN
DeLeon, Elsie	6 - 8	Ringgold Middle School- Ringgold, GA
Duncan, Nancy	1	Mtn. Oaks Elem- Ooltewah, TN
Estep, Abbe	2 - 4	Apison SDA Elem- Apison, TN
Gass, Debbie	7 & 8	Ooltewah Middle School- Ooltewah, TN
Gordy, Frank	9 - 12	Ringgold High School- Ringgold, GA
Greve, Bob	9 - 12	Collegedale Academy- Collegedale, TN
Keasler, Belinda	6 - 8	Standifer Gap SDA Elem- Chattanooga, TN
Hochs, Barbara	3 - 5	Standifer Gap SDA Elem- Chattanooga, TN
Kennedy, no name given	2 & 3	Mtn. Oaks Elem- Ooltewah, TN
Meadows, no name given	2	Mtn. Oaks Elem- Ooltewah, TN
Morford, Alvin	9 - 12	Collegedale Academy- Collegedale, TN
Peak, Ava	1 - 4	Ooltewah SDA Elem- Ooltewah, TN
White, Fran	K	Mtn. Oaks Elem- Ooltewah, TN

Attachment 3

Teacher name _____ Grade taught _____

School _____

Teacher Attitudes about Student Calculator Use

1. Do you currently use calculators in your classroom instruction (demonstrations, etc.)?
2. Do you allow students to use calculators for:
 assignments?
 tests?
 free time activities?
3. What is your school administration's policy on calculator use in the classroom?
4. For what types of activities do you or would you allow calculators to be used?
5. At what grade level do you think calculators can be effectively introduced into the math curriculum and why?
6. What are the disadvantages of calculator use in math classes?
7. Do these disadvantages outweigh the advantages?

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