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first-grade students multidigit addition and subtraction**

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San Jose State University, 1992

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A COMPARISON OF TWO COMPUTER-ASSISTED METHODS FOR
TEACHING FIRST GRADE STUDENTS MULTIDIGIT
ADDITION AND SUBTRACTION

A Thesis
Presented to
The Faculty of the College of Education
San Jose State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts

By
Diane Dinardi Besterman
December, 1992

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ABSTRACT

A COMPARISON OF TWO COMPUTER-ASSISTED METHODS FOR TEACHING FIRST GRADE STUDENTS MULTIDIGIT ADDITION AND SUBTRACTION

by Diane Dinardi Besterman

Forty-eight first grade students were the subjects for this 6 week study. One group of students used computers and exponential blocks to solve computer-generated, multidigit addition and subtraction examples with regrouping. Another group of first grade students, which served as the control group, used computers and pencil and paper to solve computer-generated, multidigit addition and subtraction examples with regrouping. It was hypothesized that if subjects physically constructed computer-generated addition and subtraction examples with Base 10 Blocks they would show a greater gain in achievement and a greater gain in place value. Results indicated that at the end of the treatment period all subjects showed a gain in achievement. All subjects, except for two in the control group, showed an increase in place value. The gain for achievement and place value was greater for the experimental group; however, the gain proved not to be statistically significant.

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Chapter 1

INTRODUCTION

The Mathematics Framework for California Public Schools (1985) states, "The use of computers, including microcomputers is now pervasive in business and industry. In the schools, however, although microcomputers are common, they are used in mathematics education to only a limited degree" (p. 5). The National Council of Teachers of Mathematics (NCTM) in Goals, Leaders, and Positions (1991-1992) states that, "Teachers should use computers as tools to assist students with the exploration and discovery of concepts, and with the transition from concrete experiences to abstract mathematical ideas" (p. 20).

Research on computer use in the classroom is inconclusive. Guidelines on how to use computers effectively with young children have not been clearly established (Berlin & White, 1986; Lepper & Gurtner, 1989; Swick, 1989). Some local school districts have implemented district computer technology programs to help prepare students for the 21st century. Santa Clara County districts such as Cambrian, Cupertino, Los Gatos, Loma Prieta, and Sunnyvale are experimenting with technology programs that include the use of computers in mathematics.

Seymour Papert (1980), a pioneer in computer research states, "The computer is used not only as a way of introducing children to technology and preparing them for the future, but it is a means of stimulating their inventiveness and encouraging them to explore new ways of thinking" (p. 5). Other researchers agree that students are receptive to using computers (Anselmo & Zinck, 1987; Lepper & Gurtner, 1989; Swick, 1989). Computers are personal (Bove & Rhodes, 1981), interactive, non-punitive, and controllable (Watt & Wrege, 1982). They provide immediate responses and feedback. Students can proceed at their own pace; the computer remains patient, nonjudgmental, and supportive (Lepper & Gurtner, 1989). Lepper and Gurtner state:

Because the computer permits children to work at their own pace, individually and privately, it may prove a special boon to students who do not normally succeed in today's schools. Because the computer is always fair and impartial, it may minimize the pernicious effects of teacher prejudices or favoritism (p. 171).

A review of the literature on the effectiveness of computer use indicates that there has been little systematic research (Campbell, Horn, & Leigh, 1987; Swick, 1989; White, 1983). In the early use of computer technology, teachers used computers as a way for students to practice specific mathematical skills. The term used for this approach was Computer Aided Instruction (CAI) (Carrier, Post, & Heck, 1982). CAI was pioneered by Patrick Suppes at The Institute

for Mathematical Studies in the Social Sciences at Stanford University. CAI was designed as a supplement or substitute for standard textbook approaches to mathematics (Suppes, Jerman, & Brian, 1968). The curriculum in CAI was limited to tutorial programs that allowed students repeated practice of arithmetic "facts" for addition, subtraction, multiplication, and division drills.

CAI was viewed as a way to provide more individualized instruction (Burns & Bozeman, 1981) and possibly increase the effectiveness of instruction (Lepper & Gurtner, 1989). Burns and Bozeman (1981) reported the results of a meta-analysis of 40 studies that used Computer Aided Instruction (CAI). All of the studies used CAI as a supplement to regular mathematics instruction. The studies were conducted in elementary and secondary schools and each study had a treatment and a control group. All of the studies measured student achievement. Students who used CAI showed increased achievement over students who did not use the computer treatments. Other studies measuring the effectiveness of CAI have shown inconclusive results (Avner, Moor, & Smith, 1980).

A 14 week study conducted by Carrier, Post, and Heck (1982) investigated the effectiveness of using CAI to reinforce arithmetic skills with fourth grade students. One group of students used a variety of 40 computer drill

programs to practice multiplication and division. Another group used paper worksheets that included examples from the computer programs. At the conclusion of the study, the computer group showed higher achievement and retention of basic multiplication facts and higher achievement of division facts than the worksheet group. No differences were found between the groups in their ability to retain division facts or in their retention of symbolic algorithms for multiplication or division.

In another study, Campbell, Horn, and Leigh (1987) compared the mathematics achievement of two groups of third-grade students who used different methods of practicing division of whole numbers. One group of students used printed worksheets to solve division examples. The second group used only computers. The study lasted 5 weeks and at the end of each week a progress test was administered to both groups. Treatment effectiveness was measured by the scores on weekly progress tests. Only one significant finding occurred. The first progress test administered showed a significant difference ($p < .01$) in favor of the non-computer group. The researchers concluded, that the computer group may have scored lower on the first progress test, because they did not have much previous computer experience and were not familiar with the software used in the study. When posttest scores between the two groups were

compared the study found no other significant differences between the performance of the two groups.

Research has not clearly supported that computers, by themselves, help children learn and understand mathematical concepts (Berlin & White, 1986; Campbell, Horn, & Leigh, 1987). Campbell and Campbell (1982) state:

A computer is simply a device which may or may not add utility. Where they fit the problems, computers can be extremely powerful educational tools. Misapplied, they can, at best, make no difference in meeting educational objectives (p. 2).

Most computer programs require young children to think symbolically or even abstractly (Lepper & Luc Gurtner, 1989). According to Piaget (1970), children who are pre-operational (approximately 2 to 7 years) would be capable of working with abstract ideas when the activity involves the use of concrete objects. For Piaget (1968), knowledge is not received passively but is constructed through action on objects. In Genetic Epistemology (1970), Piaget discusses two types of logical structures that children develop in order to gain knowledge. He calls these two functions figurative and operative. According to Piaget (1970), "figurative functions are perception, imitation and mental imagery, which is in fact interiorized imitation" (p. 14). The figurative function allows children to form ideas from the qualities or properties of objects. Piaget states:

A child, for instance, can heft objects in his hands and realize that they have different weights--that usually big things weigh more than little ones, but that sometimes little things weigh more than big ones. All this he finds out experientially, and his knowledge is abstracted from the objects themselves (p. 16).

The second aspect of logical structure discussed by Piaget (1970) is the operative function. This occurs as a result of actions upon objects. Piaget states:

The operative aspect of thought deals not with states but with transformations from one state to another. For instance, it includes actions themselves, which transform objects or states (p. 14).

In Genetic Epistemology (1970), Piaget gives the following example:

Consider a child who counts ten pebbles and finds they always make ten. In this case he is really not experimenting with pebbles, but with his own activities or arranging and enumerating, varying the order at will and observing that no matter what combination of activities he employs, whether he numbers from left to right or from right to left, he always arrives at the same result (p. 4).

It is the action on objects and the internalization of this action that develops cognitive structures and the ability to perform mental transformations (Piaget, 1970). In mathematics, concrete materials enable children to explore abstract ideas before they are fully ready to understand concepts. Elizabeth Fennema (1972), a mathematics educator states,

As children enter elementary school, the learning of most mathematical ideas will need to be facilitated through concrete representation both because the developmental level of the children indicates that this

is the appropriate learning style and because the experiential background of the children is meager (p. 638).

The National Council of Teachers of Mathematics (NCTM) Curriculum and Evaluation Standards for School Mathematics (1989) encourages teachers to establish varied classroom environments that encourage the use of concrete materials to assist students in learning mathematical skills. The Mathematics Framework for California Public Schools (1985) advocates the use of concrete materials in the classroom to help students learn mathematical concepts and to make the transition from concrete experiences to symbolic representation of ideas.

Exponential blocks in 1's, 10's, 100's, and 1,000's are concrete materials that are used to teach number systems.

Children can handle the blocks, pick them up, turn them around, and arrange them in groups. Handling and manipulating objects helps children build understanding of abstract operations (Copeland, 1982; Elkind, 1976; Piaget, 1968). By using blocks to count and solve computation

examples, operations are less abstract for children who are pre-operational (2 to 7 years). Exponential blocks permit students to see when regrouping is appropriate in addition and subtraction.

Sowell (1989) reported the results of a meta-analysis of 60 studies that investigated the effectiveness of mathematics instruction when combined with concrete materials. The studies covered a variety of mathematics topics. Subjects' ages ranged from kindergarten to college, however, 71% of the subjects were kindergarten through fourth grade students. Results indicated that when concrete materials were used, students' mathematics achievement level increased over the entire mathematics curriculum for grade levels 1, 2, and 6 ($p < .05$). There was, however, a time factor involved. When concrete materials were used over long periods of time, 1 year or more, students' achievement level increased, however, treatments of shorter duration did not produce statistically significant results.

Fuson (1986) and Fuson and Briars (1990) studied the effectiveness of using exponential blocks for teaching first- and second-grade students place value and multidigit addition and subtraction. They concluded that multidigit addition and subtraction was well within the capacity of most second-grade students and high-ability first-grade students, if they were done with the support of concrete

materials. First-grade students were able to perform multidigit operations and solve three and four digit examples. According to Fuson and Briars (1990), in typical first-grade programs students work on sums and differences to 18 and they are not introduced to multidigit examples with re-grouping until second grade. The researchers suggested that the use of concrete materials enables children to start exploring new concepts earlier.

Berlin and White (1986) investigated the effects of combining concrete objects and microcomputers. One hundred-thirteen second and fourth grade children were the subjects for this study. Three treatments were administered: concrete-only activities, concrete activities followed by computer activities, and computer-only activities. While their study used spatial ability tasks and not mathematical operations, the researchers concluded that the treatment may have been more effective if the concrete activities had been more integrated with the computer activities.

Research has been limited on ways to combine concrete materials and computer activities. There is a growing need to investigate how to integrate the computer with concrete materials in order to understand if this mixed approach will facilitate mathematics achievement and enable students to

eventually think abstractly (Berlin & White, 1986; Perl, 1990).

Statement of the Purpose

The purpose of this study was to compare two computer-assisted methods for introducing first grade students to multidigit addition and subtraction. One group of students used exponential blocks to construct computer-generated, multidigit addition and subtraction examples and then recorded their answers on computers. The second group of students solved the computer-generated, multidigit addition and subtraction examples using paper and pencil and then recorded their answers on computers.

Definition of Terms

Exponential Blocks. Exponential blocks are designed to be used as physical representations of the base ten counting system. The blocks are sized to represent the ones, tens, hundreds, and thousands in the base ten number system. The unit cubes represent the "ones." The ten blocks are equivalent to 10 ones in a single row. The hundred blocks are equivalent to 10 tens or a ten by ten array of units. The thousands cubes are equivalent to 10 hundreds. Some commercial names for exponential blocks are Base 10 Blocks, Number-Blox, and Dienes Blocks (Thomas, 1991).

Concrete Materials. Concrete materials are physical objects that can be picked up and handled. In mathematics, manipulative materials such as Base 10 Blocks, Unifix Cubes, Pattern Blocks, and Attribute Blocks are examples of commercially available concrete materials (Thomas, 1991).

Noncanonical Representation. In a noncanonical representation, ten blocks are used in conjunction with more than 9 unit blocks. For example, to construct the number 42, 3 tens blocks and 12 units (ones) blocks are used.

Chapter 2

LITERATURE REVIEW

As computers become more available in classrooms, educators are trying to determine how they can be used to develop and expand their students' exposure to mathematics and introduce them to alternative ways of experiencing it. Although NCTM (National Council of Teachers of Mathematics) (1991-1992) supports the use of computers as essential instructional tools that should be used to help students solve, investigate, and explore mathematical ideas, effective methods of using computers with children have not been clearly established or supported by research (NCTM, 1991). Along with NCTM the Mathematics Framework for California Public Schools (1985) stresses the importance of finding ways that students will be able to interact with computer programs to explore mathematical concepts.

Previously, most teachers used computers to provide individualized instruction in the form of tutorials. This computer assisted instruction (CAI) originated in the computer industry and was used to train employees (Burns & Bozeman, 1981). In the early 1960's Patrick Suppes of Stanford University originated the first CAI project for public education. The project focused on mathematics and language arts instruction for culturally disadvantaged

students. The research regarding the effects of CAI on mathematics achievement has been mixed. Some studies have shown that computers raise students' performance (Burns & Bozeman, 1981; Harthey, 1977, 1978).

Burns and Bozeman (1981) used a meta-analysis technique developed by Glass (1976) and by McGaw and Glass (1980) to analyze and synthesize the research findings of 40 studies. According to Burns and Bozeman:

The study was specifically aimed toward the analysis and integration of research findings relative to the pedagogical effectiveness of computer-assisted mathematics instruction (CAI). Student achievement served as the outcome criterion (p. 36).

Each study that was included in the meta-analysis had to meet the following criteria:

1. The study used CAI along with mathematics instruction.
2. CAI was a supplement to classroom instruction.
3. The study was conducted at the elementary (29 studies) or secondary (11 studies) school level.
4. Performances between a treatment and control group were compared.
5. The outcome variable was a measure of student achievement.

The outcome of the study showed that students who used CAI showed greater increased mathematical achievement (significant at the .01 level) than students who did not use computers. CAI programs were significantly more effective in promoting increased student achievement at both the

the elementary and secondary levels and among highly achieving and disadvantaged students.

Carrier, Post, and Heck (1982) conducted a study which used computers with fourth grade students to reinforce arithmetic skills. Three arithmetic topics were taught:

1. The development of symbolic algorithms for multiplication and division.
2. The development and maintenance of multiplication facts.
3. The development and maintenance of division facts.

Each topic was part of the standard fourth-grade mathematics curriculum in the schools that the subjects attended.

The subjects were 144 students from 6 fourth-grade classrooms in a metropolitan school district. The Iowa Test of Basic Skills was administered to all subjects and the test scores were used to rank students from high to low. Students were paired so that the students with ranks 1 and 2 formed the first pair; 3 and 4, the second pair; and so on (Carrier, Post, & Heck, 1982). Two types of treatment were administered; the computer treatment and the worksheet treatment. One member of each pair was randomly assigned to the computer treatment and the other to the worksheet treatment.

In the computer treatment, a total of 40 computer programs were used. Three different types of computer programs were used:

1. Programs that used graphics to motivate or enhance student interest.
2. Programs that used graphics or other capabilities to highlight the structural properties of the ideas in question (such as objects graphically displayed in arrays).
3. Programs that were electronic worksheets.

The worksheet treatment included examples that were selected directly from the computer programs. The study included 14 weeks of instruction. Paper and pencil pretests, posttests, and retention tests were administered to all subjects.

Students in the computer treatment group showed greater achievement and retention of multiplication facts, and somewhat higher achievement but no higher retention of division facts. The computer treatment group did not show any gain in the development of symbolic algorithms for multiplication and division.

The researchers concluded that the computer group participants may have shown more improvement in some areas because they were able to complete more problems on the computer (even though the instruction time was the same for both groups), and the computer programs provided immediate feedback to the students.

A study by Campbell, Horn, and Leigh (1987) investigated the effectiveness of using computers to practice the division of whole numbers. Forty-eight third

grade students from an affluent suburban school in Alabama participated in the study.

The students were divided into two groups, the computer group and the worksheet group. The computer group used the division portion of the Milliken Publishing Company Math Sequence package software and computers. The worksheet group used only printed worksheets. The examples on the worksheets were the same as the computer generated examples. both treatments were administered daily for 20 minutes. Progress tests were administered at the end of each week to both groups.

The study lasted for 5 weeks. The effectiveness of the program was determined by scores on the weekly progress tests. The researchers looked at the number of students who reached 90% mastery level on the weekly progress tests and the posttest. The study revealed only one significant finding. The scores from the first progress test showed a significant difference ($p < .01$) in the student performance between the two groups. The researchers attributed the lower score by the computer group to a lack of computer experience. The study found no other significant differences in performance between the two groups.

Two hypotheses were tested in the Campbell, Horn, and Leigh study (1987). The first hypothesis stated that there would be no significant difference in the performance of the

two groups of students. This hypothesis was supported by the study, except for the results of the first progress test. The second hypothesis stated that at least 80% of all students in both groups, regardless of the treatment, would reach 90% mastery on a 50-item division test by the end of 5 weeks. This hypothesis was rejected, since more students using the worksheets reached mastery level by the end of the study.

The researchers found practical advantages and disadvantages to both treatments. The computer group received immediate feedback from the computer program while the worksheet students had to wait for the teacher to grade the papers. The question of immediate feedback from the computer vs. delayed feedback from the teacher was suggested as an issue that needed further investigation.

Although the results of computer research in mathematics has been mixed, the Mathematics Framework for California Public Schools (1985) and NCTM support classroom environments that include both computers and concrete materials. Concrete materials give children a chance to handle and manipulate objects while computer programs give children the chance to explore concepts using symbolic representations. Fennema (1972) states, "Most children in the elementary school years often require the use of

concrete materials to make symbolic ideas meaningful" (p. 636).

As children explore situations, understanding takes place as they organize and reorganize information. In Six Psychological Studies (1968), Piaget calls this complementary process of organizing and reorganizing information, assimilation and accommodation.

According to Elkind (1976), Piaget defines assimilation as changing the environment to fit the action. Children mentally take in information and relate what is new and to be learned to something they already know. At the same time that the process of assimilation is taking place, accommodation occurs. Assimilation is continuously balanced by accommodation.

Accommodation is the process of mentally adjusting to new and changing conditions in the environment (Pulaski, 1971). It is an internal adaptation to external reality (Beilin, 1985). Children take new information and make it their own. Papert (1980) states, "They make something with it, play with it" (p. 120). The use of concrete materials enables children to assimilate and accommodate information at a physical level and later internalize their actions and develop mental structures or schemas (Fennema, 1972).

In discussing how children develop mathematical concepts, Copeland (1982) writes:

Children must explore situations themselves to understand the necessary concept. To understand addition, for example, children should put sets of objects together, noting their number before and after they are put together. They should separate and reassemble the objects (p. 11).

Barr (1978) conducted a study comparing three methods of introducing two-digit numeration using concrete materials. He investigated differences between the treatments with respect to achievement in numeration skills and understanding number. The subjects consisted of 11 kindergarten classes from three school districts in central Illinois. Kindergarten students were chosen because they had not previously been introduced to two-digit numeration. Pretests were administered to all subjects and each class was divided into three homogeneous groups.

Three treatments were administered; Treatment A, Treatment B, and Treatment C. Each treatment consisted of ten 20-minute lessons. Following the ten lessons and testing, three maintenance lessons were given, 1 week apart. The subjects in the Treatment A group counted sets of objects with more than 10 members. After counting the objects they learned the symbol to go with the number name. This group only counted by ones.

For example, after counting out 35 counters and writing the numeral '35' the counters were grouped into three groups of ten and five groups of ones to give meaning to the "3" and "5" (Barr, 1978, p. 35).

The subjects in the Treatment B group never counted past ten. They grouped objects into tens and ones, learned to say how many tens and ones were in each group, and then they wrote the numeral associated with each group. Finally they learned the number name (16, 30) associated with the sets of tens and ones.

The subjects in the Treatment C group counted objects with more than 10 members, and learned the symbols to go with the number name. They grouped objects in sets of tens and counted by tens.

For example, a group of thirty-six counters was placed in three groups of ten and counted 10, 20, 30, 31, 32, 33, 34, 35, 36 (Barr, 1978, p. 35).

The differences in achievement and understanding were examined twice, once upon completion of the treatment and once 4 weeks after the treatment to test for retention. At the completion of the treatment, the Skills Achievement Test (S.A.T.) and Application Test were administered as posttests to all subjects. Upon completion of the posttests, three maintenance lessons were given, 1 week apart. Tests for retention were administered 4 weeks after the posttests.

Upon completion of the posttest, no significant differences in achievement were found between the three treatments. Upon completion of the tests for retention, there was a significant difference in the mean score for Treatment C ($p < .05$).

Hiebert (1984) reviewed research on beginning addition and subtraction skills to find out why some children have difficulty learning mathematics. Hiebert divides mathematical understanding into two categories, form and understanding. Form includes symbols for numerals (8, 2.1, $1/2$), symbols for operations (+, =), and knowledge about rules, procedures, and algorithms. Understanding includes ideas and intuitions children have about how mathematics works. Hiebert (1984) states,

Many children do not connect the mathematical concepts and skills they possess with the symbols and rules they are taught in school. It is the absence of these connections that induces the shift from intuitive and meaningful problem-solving approaches to mechanical and meaningless ones (p. 498).

As children are introduced to multidigit addition and subtraction with regrouping, concrete materials such as exponential blocks have been recommended to help students make the connections between the algorithmic procedures and understanding (Bell, Fuson, & Lesh, 1976; Resnick, 1987). Hiebert (1984) further states,

In order for students to make the link between physical and symbolic representations they must record information immediately after the objects have been manipulated. It is not just the use of concrete materials that improves mathematical understanding, but rather the construction of links between understood actions on the objects and related symbol procedures (p. 509).

Adding to the research regarding students making connections between physical and symbolic representations,

Fuson and Briars (1990) conducted a study with first and second grade students who used Base 10 Blocks to learn multidigit addition and subtraction.

Students from two schools in a small city in northern Chicago were the subjects for the research. The subjects were divided into two groups, addition instruction (N=169) and subtraction instruction (N=75). Subjects in the addition group received instruction just in addition. Subjects in the subtraction group had already learned addition with blocks and received instruction in subtraction. The teachers from the two schools provided the instruction for both groups.

All subjects learned to find sums and differences to 18 by counting on and counting up with one-handed finger patterns. For sums and differences greater than 18, the subjects used Base 10 Blocks for counting, building numbers, and trading. Addition and subtraction examples were constructed with the blocks on large paper calculation sheets. Students practiced trading blocks (ones for tens, tens for ones) in both addition and subtraction. The subjects recorded all number constructions and example solutions with paper and pencil. The students used blocks to practice multidigit examples from five to eight places after they could successfully add or subtract smaller examples without using blocks.

Three tests were administered as pre- and posttests to the addition group: a Timed Addition Test, an Untimed Addition Minitest, and a Ten-Digit Addition Test. Three subtraction tests were administered as pre- and posttests to the subtraction group: an Untimed Subtraction Minitest, a Timed Subtraction Test, and a Ten-Digit Subtraction Test.

On the pretest, only 9 of the 169 children in the addition group showed any indication of correct trading. On the posttest, 160 children could trade correctly ($p < .0001$) revealing a large statistically significant change. Of the 160 subjects, 156 correctly traded a four-digit or larger problem.

In the subtraction group, only 2 of the 75 students showed some evidence of trading on the pretest, while on the posttests, 72 of the 75 students could trade correctly. The difference between the pretest and the posttest scores showed a statistically significant change ($p < .0001$).

Some research has been conducted using computers along with concrete materials. Most of the research has not been very well documented. Perl (1990) cites a study conducted by Bieck and Wilson in 1988 which involved third and fourth grade students at Park Dale Lane Elementary School in Encinitas, California. The students were divided into two groups. One group used the computer software Puzzle Tanks to solve problems. The second group used water and

containers to solve the same problems as the first group. The authors of the study concluded that the students who poured real water gained a better understanding of the step-by-step procedures involved through enforced record keeping, while the students who used software concentrated on finding ways to solve the problems and solved the problems faster.

Berlin and White (1986) combined concrete activities and computer simulations to study the effects on the development of abstract thinking. The study was designed to assess student performance in three areas:

1. The recognition and duplication of designs.
2. The recognition and extension of patterns through seriation.
3. Spatial orientation and discrimination tasks.

The subjects were 113 second and fourth grade children. They were divided into three groups:

Concrete Activity Group

Subjects used only concrete materials which included pegs and pegboards, six by six grid cards, and colored cubes to duplicate and extend patterns.

Combination Activity Group

Subjects used concrete materials and computers. Their materials included pegboards, grid cards, and a computer simulation of the pegboard, and colored cubes. They completed five activities using concrete materials followed by five computer activities.

Computer Group

Subjects used only computer simulation activities of the pegboard and colored cubes.

At the conclusion of a 3 week treatment period, two pencil and paper tests were administered to all subjects. One instrument tested for design recognition and one instrument tested for pattern extension and spatial orientation. The results of the study were mixed. Some children scored higher when they only used concrete activities and some children scored higher when they only used the computer. None of the comparisons between the treatments showed any significant differences. Berlin and White (1986) concluded that the treatment for the integrated group (concrete materials and computer simulation) may have been more effective if the concrete and computer activities had been more integrated.

Summary

Although research clearly supports the effectiveness of using concrete materials to help children learn new concepts, research on using computers is limited. Studies on computer use with children have not revealed effective ways to use computers in the classroom. In this study, students used computers and concrete materials together to build and solve multidigit addition and subtraction examples. The research question for this thesis was, "Is

there a difference in student achievement between first grade students who use exponential blocks to solve computer-generated multidigit addition and subtraction examples and first grade students who solve computer-generated examples using pencil and paper?"

Chapter 3

METHODOLOGY

Purpose

The purpose of this study was to determine whether students who physically constructed computer-generated multidigit addition and subtraction examples with exponential blocks and recorded their responses on computers would achieve higher scores on an achievement test than students who solved computer-generated multidigit addition and subtraction examples using only pencil and paper. The research was conducted over a 6 week period between April and June.

Subjects

The sample for this study consisted of 48 first grade students from two first grade classes. This grade level was chosen because the students had not been introduced to multidigit addition and subtraction with regrouping. The students attended Loma Prieta School, a small rural district in the Santa Cruz mountains of approximately 450 students. The district has a broad socio-economic base consisting of children who spend their summers abroad to children who have no electricity in their homes. Loma Prieta Joint Union School District consists of two schools, Loma Prieta Elementary School and C. T. English Middle School.

Each class was divided into two groups, a control group and an experimental group. Students were placed in either the control or experimental group at random. At the beginning of the study, each group had 25 subjects. During the study, two subjects in the experimental group moved. As a result, the experimental group consisted of 23 subjects.

Previous to the study, all students had used a variety of concrete materials in the first grade mathematics program, including exponential blocks. All students were given time to practice counting, building numbers, and trading with the blocks as a review before the study began.

During the school year, the students had attended weekly classes at the Computer Lab and were familiar with using computers. Before the study began, students were given two 30 minute sessions to practice using the mathematics program used in the study.

Pretest

All subjects were given two pretests, an Achievement Test and a Place Value Understanding Test. A pilot study was conducted for the Achievement Test. The purpose of the pilot study was to determine the appropriate difficulty level of the examples and the appropriate number of examples. Four first grade students participated in the pilot study. These students were not members of either the

control or the experimental group and did not participate in the study.

The Achievement Test was a pencil and paper test that consisted of 10 addition and subtraction examples. The examples were written in vertical form. Subjects were tested in groups of 6 and manipulatives were not available for the children to use. The same test was used for both the pretest and the posttest. Each correct answer was worth 1 point (see Appendix A for test sample).

To determine whether the subjects showed any understanding of place value, a Place Value Understanding Test (Appendix B) was administered as both a pretest and a posttest. The test consisted of 3 problems taken from a study conducted by Muira and Okamoto in 1989. The researcher tested each subject individually.

Problem 1:

Subjects were shown a card with the written numeral, 32, and asked to point first to the numeral in the ones position and then to the numeral in the tens position. Subjects were asked to use the exponential blocks to construct the 3 and the 2. Subjects were given one point for each correct answer, for a total of four points.

Problem 2:

The experimenter presented the subjects with a construction of the number 44 using 4 ten and 4 unit blocks.

The interviewer asked, "What number do the blocks make?"

The subjects were shown the written numeral 44 and were asked which set of 4 blocks represented the 4 in the tens position and which set showed the 4 in the ones position. Then the subjects were asked to explain how they knew which 4 was which. One point was given for each correct answer, for a total of 4 points.

Problem 3:

The subjects were shown a non-canonical construction (3 ten blocks and 12 unit blocks) and asked to write the number the blocks made.

If the subjects wrote the number 42, they were asked if the 4 or the 2 had anything to do with how many blocks there were. If the subjects wrote another number other than 42,

they were also asked if the number they wrote had anything to do with how many blocks there were. Students were given 2 points for each correct answer, for a total of 4 points.

Procedure

The procedure for both the control (N=25) and the experimental group (N=23) lasted for 6 weeks. Subjects worked individually at their own computer stations once a week for 30 minutes. In order to avoid any influence of one treatment over another, the control and experimental subjects did not work in the Computer Lab at the same time. The experimenter administered both treatments. All subjects began at level one of the computer program. Subjects in the control group were allowed the flexibility to complete computations mentally instead of using pencil and paper. Subjects in the experimental group were allowed the option of not using blocks to build examples which they could easily solve mentally.

The control group subjects used Apple IIe computers and pencil and paper to solve addition and subtraction examples. They followed these steps:

1. When the addition or subtraction example appeared on the computer screen, subjects copied the example onto paper (students were given the flexibility of completing computations mentally).
2. Subjects used pencil and paper to solve the example.
3. Students entered answer on computer.

4. If answer was correct, student proceeded to another example.
5. If answer was incorrect, student tried to solve example again or asked for help.

The subjects in the experimental group used Apple IIe computers, Number-Blox (Neufeld & Lucas, 1976), pencil, and paper. They completed the following steps:

1. When the addition or subtraction example appeared on the computer screen, subjects used blocks to build the top number.

2. For addition examples:

Subjects used blocks to build the bottom number.

Subjects combined blocks that represented top and bottom numbers and regrouped (traded ones for tens, tens for hundreds where appropriate).

For subtraction examples:

Subjects regrouped top number (traded hundreds for tens, tens for ones where appropriate).

Subjects removed number of blocks indicated by bottom number.

4. Subjects counted remaining blocks.
5. Some subjects recorded their answer on scrap paper before they entered their answer on the computer.
6. Subjects entered answer on computer.
7. If answer was correct, subject proceeded to another example.
8. If answer was incorrect, subject tried to solve example again or asked for help.

Computer Program

All subjects in both the control and the experimental groups used a computer program that generated addition and subtraction examples at five difficulty levels. The computer program was written for this study and is not commercially available.

Example Levels

Level 1 = Only single digit numerals, with some regrouping

$$\begin{array}{r} 8 \\ +2 \\ \hline \end{array} \qquad \begin{array}{r} 7 \\ -3 \\ \hline \end{array}$$

Level 2 = Level 1 examples plus double digit numerals with regrouping

$$\begin{array}{r} 12 \\ +9 \\ \hline \end{array} \qquad \begin{array}{r} 20 \\ -8 \\ \hline \end{array}$$

Level 3 = Level 1-2 examples plus double digit numerals, with regrouping

$$\begin{array}{r} 24 \\ +48 \\ \hline \end{array} \qquad \begin{array}{r} 37 \\ -19 \\ \hline \end{array}$$

Level 4 = Level 1-3 examples, plus double and multidigit numerals, with regrouping

$$\begin{array}{r} 678 \\ +99 \\ \hline \end{array} \qquad \begin{array}{r} 222 \\ -55 \\ \hline \end{array} \qquad \begin{array}{r} 338 \\ + 8 \\ \hline \end{array}$$

Level 5 = Level 1-4 examples, plus multidigit numerals with regrouping

$$\begin{array}{r} 146 \\ +175 \\ \hline \end{array} \qquad \begin{array}{r} 423 \\ -157 \\ \hline \end{array}$$

The program generated a response such as "good job" for correct answers and "try again" for incorrect answers. The subjects could continue to try to solve examples until they

obtained the correct answers. No limit was set for the number of attempts by students.

Posttest

After the 6 week program, two posttests were administered to both the experimental and control groups. The instruments used were the same as the pretest. All subjects were tested in the Computer Lab. The pencil and paper Achievement Test was administered to groups of 6 subjects. Subjects were tested individually for the Place Value Understanding Test.

Statistical Procedure

Pretest and posttest data were analyzed using independent samples t -tests. Pretest mean scores for the experimental and control groups were compared to look for significant differences between the groups before the treatment. Differences in posttest mean scores for the experimental and control groups were statistically compared to assess the treatment effects.

Chapter 4

ANALYSIS OF DATA

Introduction

The purpose of this study was to determine if constructing computer-generated multidigit addition and subtraction examples with exponential blocks and recording answers on computers would increase students' achievement level. The subjects for this study were 48 first grade students. The children were divided into two groups: an experimental group and a control group. The experimental group used exponential blocks to build and solve computer-generated addition and subtraction examples. The control group used pencil and paper to solve computer-generated addition and subtraction examples. The data for this study consisted of pretest and posttest scores for achievement and pretest and posttest scores for place value understanding.

Pretest Results

A pretest was administered to determine if there was a statistically significant difference in achievement levels between the control and the experimental groups. Frequency distributions for pretest raw scores for the control and the experimental group are presented in histograms, in order to show a pictorial display of the scores. The maximum

possible score for the pretest was 10. Figure 1 shows the range of pretest scores in achievement for the control group. Scores ranged from 0 to +9 with a median score of 3 and a mode of 4.

Figure 1. Control Group Pretest Scores for Achievement.

Figure 2 shows the range of pretest scores in achievement for the experimental group. Scores ranged from 0 to +8 with a median score of 3 and a mode of 2.

Figure 2. Experimental Group Pretest Scores for Achievement.

The means, standard deviation, and t -test for independent samples were calculated. Table 1 shows the results of the pretest for achievement. The control group had a mean score of 3.08 on the pretest. The experimental group had a mean score of 3.04 on the pretest. The difference in the means was 0.04. This difference produced a t value of 0.04, a non-significant difference.

Table 1

Means, Standard Deviations, and t-test Results for
Achievement on the Pretest

	Experimental (N=23)	Control (N=25)	t
Mean	3.04	3.08	
Standard Deviation	(1.79)	(1.99)	0.04

A pretest was administered to determine if place value understanding was similar between the control and the experimental groups. The maximum possible score was 12. Figures 3 and 4 show the range of pretest scores for place value understanding. Scores for the control group ranged from +4 to +12 with a median score of 6 and bimodal scores of 5 and 7. Scores for the experimental group ranged from +2 to +12 with a median score of 5 and a mode of 5.

Figure 3. Control Group Pretest Scores for Place Value Understanding.

Figure 4. Experimental Group Pretest Scores for Place Value Understanding.

The means, standard deviation, and t -test for independent samples were calculated. Table 2 shows the results of the pretest for place value understanding. The control group had a mean score of 6.84 on the pretest. The experimental group had a mean score of 5.52 on the pretest. The difference in the means was 1.32. This difference produced a t value of 0.67 which was non-significant.

Table 2

Means, Standard Deviations, and t-test Results for Place Value Understanding on the Pretest

	Experimental (N=23)	Control (N=25)	<u>t</u>
Mean	5.52	6.84	
Standard Deviation	(2.12)	(2.59)	0.67

Posttest Results

After a 6 week treatment period in which the experimental group used exponential blocks to build and solve computer-generated multidigit addition and subtraction examples, two posttests were administered to both the control and experimental groups. Posttest frequency distributions for achievement are displayed in Figures 5 and 6. The maximum possible score was 10. The control group had posttest scores that ranged from +1 to +7 with a median score of 3 and a mode of 3. The experimental group posttest scores for achievement ranged from +1 to +8 with a median of 5 and a mode of 5.

Figure 5. Control Group Posttest Scores for Achievement.

Figure 6. Experimental Group Posttest Scores for Achievement.

The means, standard deviation, and t -test for independent samples were calculated. Table 3 shows the results of the posttest for achievement. The control group scored a mean of 3.36 on the posttest. The experimental group scored a mean of 4.91 on the posttest. The difference in means was 1.55. This difference produced a t -value of 1.18 which was not statistically significant.

Table 3

Means, Standard Deviations, and t-test Results for
Achievement on the Posttest

	Experimental (N=23)	Control (N=25)	<u>t</u>
Mean	4.91	3.36	
Standard Deviation	(1.76)	(1.47)	1.18

Posttest frequency distributions for place value understanding are displayed in Figures 7 and 8. The maximum possible score was 12. Scores in place value understanding for the control group ranged from +2 to +12 with a median of 10 and a mode of 12. The experimental group had scores ranging from +6 to +12 with a median of 12 and a mode of 12.

Figure 7. Control Group Posttest Scores for Place Value Understanding.

Figure 8. Experimental Group Posttest Scores for Place Value Understanding.

The means, standard deviation, and t -test results for place value understanding are shown in Table 4. The control group scored a mean of 9.04 on the posttest. The experimental group scored a mean of 10.78 on the posttest. The difference in mean scores between the control and experimental groups was 1.74. This difference produced a t -value of 0.58 which was not statistically significant.

Table 4

Means, Standard Deviations, and t-test Results for Place Value Understanding on the Posttest

	Experimental (N=23)	Control (N=25)	<u>t</u>
Mean	10.78	9.04	
Standard Deviation	(1.69)	(2.79)	0.58

Summary of Results

The results of this study indicated that at the time of the pretest subjects in the control and the experimental groups were comparable in their performance on measures of achievement level and their understanding of place value. On the posttest, the control and experimental groups proved to be comparable in their performance on measures of achievement level and understanding of place value, although subjects in the experimental group had higher raw scores on both measures.

Chapter 5

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine if first grade students who used computers and exponential blocks to solve computer-generated addition and subtraction examples over a 6 week period would score higher than a control group which used only computers.

As computers have been integrated into the mathematics curriculum their role has been limited and has not been clearly defined (Berlin & White, 1986; Lepper & Gurtner, 1989). Early studies tested the effectiveness of computers used as tutorials (CAI). Computer Aided Instruction (CAI) was developed as an alternative approach to standard textbook mathematics instruction. Educators saw CAI as a way to provide more individualized instruction for students and possibly raise achievement levels. The results of CAI studies were mixed and did not clearly show a gain in student achievement (Avner, Moor, & Smith, 1980; Burns & Bozeman, 1981).

Further research on computer use indicated that the animation, graphics, and the instant feedback that computers provide, held the students' attention and interest more than worksheets, but a review of the research did not show that computers alone helped children learn and understand

mathematical concepts (Berlin & White, 1986; Campbell, Horn, & Leigh, 1987; Carrier, Heck, & Post, 1982).

Number-related computer programs require young children to think symbolically or even abstractly. In examining how children learn, children at the pre-operational stage (approximately 2 to 7 years) may not be capable of thinking purely symbolically. They still need to use concrete materials to give meaning to concepts (Copeland, 1982; Elkind, 1976). Handling and manipulating objects helps children build understanding of abstract operations (Piaget, 1976). In mathematics, children can use concrete objects to explore abstract ideas before they are ready to understand concepts at the abstract level (Fennema, 1972).

Some studies have shown that concrete materials help children learn abstract concepts (Barr, 1978; Hiebert, 1984; Ross, 1989; Sowell, 1989). Fuson and Briars (1990) found that first and second grade students could learn multidigit addition and subtraction when they used concrete materials, such as Base 10 Blocks.

Little is known about the effects of combining concrete materials and computers together. Some research has been conducted, but it is not clear whether or not a mixed approach would increase children's mathematics achievement (Berlin & White, 1986; Perl, 1990). Berlin and White (1986) studied the effects of using concrete materials and computer

simulations. The subjects completed a series of activities using concrete materials followed by a series of activities using computer simulations. The study did not produce any statistically significant results. It was concluded, however, that the use of the computer may have been more effective if the computer activities had been more integrated with the concrete material activities.

Results

The present study was designed to compare two computer-assisted approaches of teaching first grade students multidigit addition and subtraction with regrouping. One approach used computer-generated examples and exponential blocks. The second approach used computer-generated examples and pencil and paper. Two classes of first grade students were the subjects for the 6 week research. One group participated in an experimental treatment in which they constructed and solved computer-generated multidigit addition and subtraction examples with blocks and entered their answers on computers. The other group, which served as the control group, solved computer-generated examples using paper and pencil and entered their answers on computers. Both groups were pre- and posttested for achievement level and place value understanding.

The mean scores for the pretests showed that the experimental and control groups were at approximately the same level for achievement and place value understanding at the beginning of the treatment. Posttest comparisons for achievement and place value understanding showed no statistically significant differences.

In comparing the pre- to posttest scores for achievement, both groups showed increases in mean scores. Raw scores indicated that the experimental showed a greater increase in mean scores for achievement than the control group. The experimental group mean scores increased 1.87, while the control group's mean scores increased 0.28. The increases, however, did not prove to be statistically significant.

Both groups showed an increase in mean scores from pre- to posttest in place value understanding. The experimental group showed a greater increase in mean scores than the control group. The experimental group's mean score increased 5.26 while the control group's mean score increased 2.20. The increases, however, were not statistically significant. The posttest frequency distributions of raw scores for both groups indicated that the difficulty level of the tests should have been greater.

Discussion

Research has not shown the most effective way to use computers in mathematics. Should computers be used alone or integrated with concrete materials? This study was designed to investigate whether students' achievement level would increase if they used exponential blocks to build and solve computer-generated addition and subtraction examples. While multidigit addition and subtraction with regrouping is usually introduced in second grade, the study showed that even first grade students are capable of solving multidigit addition and subtraction with regrouping.

The children in both groups were eager to use the computers, but because they only used the computer program once a week, they had difficulty remembering how to use the program. At the beginning of each session, the students needed a review of the program steps before they could begin solving the multidigit examples.

During the study, the experimental group continued to progress through the computer program levels, moving from single to triple digit examples. Although it took time for the experimental group to physically construct the examples with blocks, they were still able to correctly solve as many examples per session as the control group. Toward the end of the study, some students in the experimental group were able to correctly solve examples in Levels 3 and 4 without

using the blocks, while many students in the control group chose to return to the lower levels (Levels 1 and 2) of the computer program. On the posttest for achievement, the experimental group attempted to solve more of the examples while the subjects in the control group left more examples unanswered.

As the study progressed, it became evident that children in the control group became frustrated as they tried to solve the more difficult examples. Students began to use their fingers and tally marks for counting. They asked if they could use counters or blocks to help solve the examples. As students advanced through the levels, they complained that the examples were "too hard" and they started guessing at answers.

Recommendations

The following recommendations for future study should be considered.

1. This study should include a third group which would use a textbook approach.
2. The treatment should be administered more than once a week.
3. A computer simulation program should be considered.
4. A more appropriate pre- and posttest should be developed.
5. This study should be conducted with a larger group of students.

6. This study should be conducted over a longer period of time.

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APPENDIXES

APPENDIX A
Pre- and Posttest for Achievement

Appendix A
Pre- and Posttest for Achievement

6	10	14	153
<u>+8</u>	<u>-2</u>	<u>-8</u>	<u>+68</u>

12	31	15	146
<u>+9</u>	<u>-15</u>	<u>+18</u>	<u>- 9</u>

135	120
<u>+ 6</u>	<u>-11</u>

APPENDIX B

Pre- and Posttest for Place Value Understanding

1. Researcher: Show card with numeral 32

Point to the numeral in the ones position 3 2

Point to the numeral in the tens position 3 2

Use the Base 10 blocks to show the 3

Use the Base 10 blocks to show the 2

2. Researcher: Construct 44 using 4 ten blocks and 4 units

Ask subject:

What number do the blocks make?

Show subject the written numeral 44

Ask:

Which set of 4 blocks represents the 4 in the tens position?

Which set of 4 blocks represents the 4 in the ones position?

How do you know which 4 is which?

3. Researcher: Show construction of 42 with 3 ten blocks and 12 units

Ask subject to write the number you made with the blocks

If the subject writes 42 then ask:

Does the 4 and 2 have anything to do with how many blocks there were?

If subject does not write 42 ask for an explanation.