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ABSTRACT

Operation Whole Numbers (OWN), a computer assisted instructional approach to the four arithmetic operations (addition, subtraction, multiplication, and division), was used in nine elementary schools from January 1975 through June 1976. This report contains a brief description of the OWN program, a discussion of the work required to implement the program beyond the single-school pilot phase, and an evaluation of the effect of the program in the nine schools. The evaluation of the OWN program was conducted by comparing the performance of students from the nine schools using the OWN program to performance of students from four schools using a traditional approach. All students were given a pretest and posttest developed specifically for this investigation. The test results showed that in each grade (3-6), students using the OWN program made significantly greater improvements than did students in the traditional approach. Benefits of the program were substantial for third and fourth grade OWN students who had scored below average on the pretest; these students averaged from 3.6 to 4.2 months gain. When teachers' attitudes toward the OWN program were examined using a Likert-type questionnaire, 87% of the teachers expressed a favorable overall opinion of the OWN program and 90% responded that their students enjoyed working with the program. (DT)

MONTGOMERY COUNTY PUBLIC SCHOOLS
Rockville, Maryland

EVALUATION OF COMPUTER-ASSISTED INSTRUCTION 1975-76

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ABSTRACT

Operation Whole Numbers (OWN) ~~is a~~ computer-assisted instruction approach to the four arithmetic operations (+, -, X, ÷). The main CAI techniques employed in the OWN program are diagnostic testing, drill, and practice. These techniques, and others, are used as each student progresses through a controlled sequence of objectives in each operation on a computer terminal. As students complete segments of the OWN program, e.g., a drill, they receive "scoreboards" on the computer terminal. The scoreboards are records of individual performance which students copy on individual permanent record cards. The teacher uses the record cards to monitor student progress and identify individual student needs.

A considerable amount of time, effort, and planning was required to implement the OWN program in twelve elementary schools: teachers and students needed a formal orientation to the system, teachers' manuals and other materials had to be developed for the orientation and for the regular classroom implementation, equipment had to be installed in each school, and the OWN program had to be translated into a different computer language. These activities were conducted in the summer and fall of 1974 and the spring of 1975.

An evaluation of the OWN program was conducted in order to determine its relative effectiveness in the context of a large scale implementation. The major areas of interest in this evaluation were to compare CAI to traditional instruction and to examine teacher attitudes toward the program. In comparing CAI to traditional instruction, it was of particular interest to examine the effect of CAI on students with below average skills in arithmetic.

Selection of elementary schools to use CAI and to participate in the evaluation of OWN in 1975-76 was based on the number of fifth grade students in a school who had performed one or more years below grade level in mathematics as measured by the Problem Solving subtest of the Iowa Test of Basic Skills. The sixteen elementary schools with the largest number of these students were identified, twelve were selected as CAI schools, and four were to serve as comparison (control) schools for the evaluation. Although the CAI implementation began with twelve schools, three were eliminated because of budget constraints. Therefore, the evaluation was conducted in thirteen schools (nine CAI and four control) and involved students in grades 3 through 6. Students were given a pretest in mid-December, 1974, and a posttest in late May, 1976. The tests used for the evaluation were developed specifically for this purpose; they were pilot-tested in a school not in the study and appropriate revisions were made.

The test results show that CAI students in each grade (3,4,5 and 6) made statistically significant greater improvements than did the students in the control schools. In different grades, CAI students averaged from 1.1 to 3.6 months greater gain in mathematics achievement than the control students over fourteen months of school. Furthermore, the test results show that the benefits of the program were substantial for third and fourth grade CAI students who had scored below average on the pretest; these students

averaged from 3.6 to 4.2 months gain.

The opinion of teachers using CAI were very positive toward all aspects of the OWN program (over 82 per cent of the teachers had positive attitudes for each aspect of the program studies). These opinions were reflected in such areas as using the program to help individualize instruction, using diagnostic information from the program, expressing a desire to continue using the program, and reflecting on student enjoyment of the program.

In addition to the evaluation of student achievement, teachers' attitudes toward the CAI program were examined using a Likert type questionnaire. Eighty-seven percent of the teachers expressed a favorable overall opinion of the program, and 90 percent responded that their students enjoyed working with the CAI program.

INTRODUCTION

This is an evaluation of an MCPS computer-assisted instruction program called Operation Whole Numbers (OWN). OWN is a computer-assisted instruction (CAI) approach to the four arithmetic operations (addition, subtraction, multiplication, and division) which was used in nine elementary schools from January, 1975, through June, 1976. This report contains a brief description of the OWN program, the work which was required to implement the program beyond the single school pilot phase, and an evaluation of the effect of the program in these nine schools.

An extensive research and development effort preceded the implementation of CAI and is documented in two MCPS reports. The first report, Computer Assisted-Instruction Project, covers the period July 1, 1969, through June 30, 1971, and the second report, Computer-Assisted Instruction Program, covers the period from July 1, 1971, to June 30, 1974. These reports discuss the history of CAI in the county and outline the research conducted during these periods which supported the implementation of the OWN program on a large scale.

A. THE OWN PROGRAM

OPERATION WHOLE NUMBERS (OWN) combines the CAI techniques of diagnostic testing, drill and practice in a program designed to strengthen a student's computational skills in each of the four basic operations on whole numbers. The program was designed for intermediate and upper elementary students but has also proved useful with students in special education, adult basic education, and tenth grade mathematics.

At a cathode ray tube (CRT) computer terminal, the student progresses through the program in a controlled sequence to attain the four terminal objectives:

1. Given an addition problem with 3 three-place numerals presented vertically, the student constructs the sum; regrouping from ones, tens, and hundreds places is required.

   EXAMPLE:
   $$\begin{array}{r} 986 \\ 747 \\ \underline{+568} \end{array}$$

2. Given a subtraction problem presented vertically, the student subtracts a four-place numeral from a four-place numeral; regrouping in hundreds, tens, and ones is required.

   EXAMPLE:
   $$\begin{array}{r} 9{,}284 \\ \underline{-7{,}995} \end{array}$$

3. Given a multiplication problem presented vertically, the student constructs the product when one factor is a three-place numeral and the other factor is a two-place numeral but not a multiple of ten; regrouping is required.

   EXAMPLE:
   $$\begin{array}{r} 763 \\ \underline{X\ 25} \end{array}$$

4. Given a division problem with a four-place dividend and a two-place divisor not a multiple of ten, the student constructs the two-place quotient with or without remainder. Estimation does not always provide the correct answer.

   EXAMPLE: $83\overline{)\ 6742}$

The content of OWN is divided into four sections: addition, subtraction, multiplication, and division. Each section has three components: a pretest, a sequence of drills, and several review tests. A posttest on all four sections completes the program.

A.1. Pretest

A pretest consists of a survey test on the terminal objective of the program section and a network of diagnostic tests at specific drill levels to place the student at the appropriate level for computer-assisted drill or teacher instruction. The addition and multiplication pretests also include basic fact tests.

In all survey, diagnostic, and basic fact tests, the student receives an immediate response to his answer. A correct answer will be reinforced with a comment such as "Correct," "Good," "Excellent," or "Fabulous." The student who answers a survey or diagnostic problem incorrectly will be given a comment such as "Not quite. Let's try another problem." or "Your answer is incorrect. Let's try a different problem." The wrong answer response in the basic fact tests is "Incorrect."

For each pretest problem, the student is given a total predetermined time in which to type and enter the answer. If a student takes too long to type and enter his answer, he is given a comment such as "Your answer is correct, but you have taken too long to work the problem. Let's try another problem." or "You were too slow in answering. Let's try another problem." A problem which is timed-out is scored wrong.

If the student finds a survey or diagnostic test problem too difficult, he is allowed to type and enter an "X" as the answer. An "X" is scored as a wrong answer.

Survey Test -- addition, subtraction, and multiplication. To demonstrate proficiency in the terminal objective of the operation and pass the survey test, the student must answer four problems correctly. A maximum of five problems is presented. If the first survey test (addition) is passed, the student proceeds to the next survey test (subtraction). However, as soon as he misses two problems in a survey test, he is branched to the basic fact tests in addition and multiplication or to the first diagnostic test in subtraction.

Basic fact test -- addition and multiplication. These tests include the 100 basic facts in each operation grouped in four sections according to difficulty. Student performance determines which of two possible paths the student takes: through section 3 and 4 to the diagnostic network or through sections 3, 1, and 2 to the drill sequence. Regardless of path, the student progresses through the section by studying and learning facts missed and by being retested until he achieves 100 per cent.

Diagnostic test -- addition, subtraction, and multiplication. To pass a diagnostic test, the student must answer three problems correctly. A maximum of four problems is presented. If the student passes, the computer program will branch him to a diagnostic test of greater difficulty or to a drill at a higher level. If, however, the student answers only two of the four problems correctly, he is put in a drill at that level. If he answers less than two problems correctly, he is further diagnosed with problems of lesser difficulty or is branched to his teacher for instruction.

Division pretest. In the division pretest, the student begins with a diagnostic test at level 13 in one-place divisors. If he passes with three correct answers, he proceeds to diagnostic tests at levels 18 and 19. If he does not pass diagnostic 13 (or 18 or 19), he is further diagnosed and placed in the appropriate drill or branched to his teacher for instruction.

The student who successfully completes the one-place divisors pretest proceeds to division Survey Test I, which contains problems from levels 28 and 29. If he passes Survey I with four correct answers, he is given Survey Test II with problems from level 34, the terminal objective. The student who does not pass Survey 1 is further diagnosed and placed in a drill.

Before typing any quotient in the division diagnostic and survey tests, the student must select the place position for the first digit (i.e. hundreds, tens, or ones) of his answer. If the student selects the wrong place position, the problem is counted wrong.

A.2. Drills

In each section, a sequence of drills is designed so that each drill provides practice in a computational skill based on a specific mathematical concept. There are 25 drill levels in addition, 21 in subtraction, 19 in multiplication, and 34 in division. The first 19 drills in division are one-place divisors; drills 20-34 have two-place divisors. At each of the 99 drill levels, there are 2 ten-problem drills: an original drill and an alternate drill.

In each drill problem, the student is given two attempts to type and enter the correct answer before the problem is scored wrong. If his first answer is incorrect, the comment "No, try again." appears. If his second answer is incorrect, he is given the correct answer, is allowed time to compare his answer with the correct answer, and must type and enter the correct answer before the next problem is presented.

Addition, subtraction, and multiplication drills. To pass a drill, the student must answer correctly nine or ten of the ten problems. When a student in an original drill misses the first three problems or when his incorrect answers total five, he is immediately branched to his teacher for instruction. After instruction, he reenters the original drill. When a student fails the original drill with a score of six, seven, or eight correct, he is given more practice with the alternate form of the drill. In the alternate drill, the student must complete all ten problems. If he answers correctly less than nine problems, he is branched to his teacher for instruction. After instruction, he enters the original drill again.

In each addition, subtraction, and multiplication drill problem, the student is given a total predetermined time in which to type and enter the answer. A student who times out with a correct answer is told "Your answer is correct, but you need to work faster." and is given the next problem. The timed-out problem is scored wrong. A student who times out with a wrong answer is told "No, try again." and is given the problem again. A second time-out on the problem scores the problem wrong.

Division drills. All division drills contain a maximum of ten problems. To pass a drill, the student must answer correctly nine or ten out of ten or the first five problems. If he correctly answers the first five problems, he does not have to work all ten problems. Strategy for repeating a drill, branching for teacher instruction, and answer evaluation are the same as in the other three operations. However, in those division drills which require the student to work out on the terminal each step involved in reaching the quotient (see below), each step is evaluated separately. Any two errors in a given problem (e. g., two "No, try again's") result in the problem's being scored wrong although the student must complete it to the quotient.

If the student selects the wrong place position for the first digit of a quotient for a drill problem, he is given the correct place position. The computer records these errors in place position, but they are not counted as wrong answers. In division drills, the student receives a total predetermined time in which to complete the drill. Problems are not timed individually.

When the student is first branched into a division drill, he is required to watch the computer work a sample problem on the terminal screen. Then he must work out, with the computer on the terminal screen, each step involved in reaching the quotient for each drill problem. After successfully completing his first division drill, the student is given a choice in each succeeding drill of working the problems out with the computer <u>or</u> working the problems on paper and typing and entering only the quotient. If he chooses to work the problems with the computer, he is given a choice of watching or not watching the computer work a sample problem. However, if the student fails an original division drill, he must work out the problems of the alternate drill with the computer.

A.3. Review Tests

In a review test, problems from the preceding drill sequence are randomly presented. There are 23 review tests placed at plateau points in the developmental sequence of skills throughout the program. Addition, subtraction, and division review tests contain 20 problems; the 6 multiplication review tests contain 10 problems. The student is given only one attempt to answer a problem correctly. For each answer, he is told "Correct" or "Incorrect."

To pass a review test, the student must answer correctly 18, 19, or 20 out of the 20 (or 9 or 10 out of 10) problems. If his score is 16 or 17 (or 8 out of 10), he is asked to try to correct the problems he missed. The computer recalls those 3 or 4 (or 2) problems and evaluates a second time for a passing score.

If the student does not obtain a passing score after trying to correct the three or four (or two) problems or if he misses more than four (or more than two out of ten) problems on his first time through a review test, he is branched to the lowest drill level from which he missed a problem. He repeats the drill(s) from which he missed problems, and then he repeats the review test. If he fails the review test on his second attempt, he is branched for teacher instruction on the objective presented in the lowest drill level in that drill sequence. When he returns for work on the terminal, he enters the drill sequence at that level.

In the multiplication and division review tests, problems are worked on paper and only final answers are typed and entered. If a student selects the wrong place position for the first digit of a quotient, the problem is counted wrong.

In each review test, the student receives a total predetermined time in which to complete the entire test. If he times out on his first attempt, he is branched to the lowest drill level from which he missed a problem; and he repeats all the drill from which he missed problems. He then repeats the review test. If he times out on his second attempt in the review test, he is branched for teacher instruction. After instruction, the student re-enters the drill sequence at the lowest level drill, repeating all the drills and then the review test.

A.4. Posttest

At the end of the program, the student is presented a posttest which measures attainment of the terminal objectives. Twelve problems, three from each operation, are randomly presented. The student is given only one attempt to answer correctly. Wrong answers are indicated with a comment such as "Your answer is incorrect. Let's try a different problem." The multiplication and division problems are worked on paper; only final answers are typed and entered. Selecting the wrong place position for the first digit of a quotient counts as a wrong answer. The student is given a total predetermined time in which to type and enter each answer. A time-out is scored as a wrong answer.

To this point, the description of the OWN program has been isolated to its internal structure. The rest of this section will describe how the program, as outlined above, functions in the classroom.

Upon completion of a survey test, a drill (or an alternate drill), or a review test, a "scoreboard" is presented on the screen of the computer terminal. A "scoreboard" is a representation of the student's performance and contains several elements: the student's name; a symbol indicating the level of the program the student was working, the number of problems the student attempted, how many problems the student answered correctly, and a comment for the teacher. The student must take a moment to record the scoreboard information on his or her own personal record card. A record card is a permanent record of the student's progress through the OWN program. An example of a scoreboard and a record card are presented in Figures 1 and 2 respectively.

FIGURE I

Example of a
Scoreboard from the CAI-OWN Program
As Presented on a Computer Terminal

Student:	Leslie Foster
Level	A17
Total Problems:	10
Score:	9
Comment:	Pass

FIGURE 2

Example of a Student Record Card
For Use in the CAI-OWN Program

Name Leslie Foster Student Number S123456/Arith

Date	9/11	9/14	9/19	9/23	9/27	10/3	10/7	10/14	
Level	A13	A14	A14A	A15	A16	A17	A17	A17A	
Total Problems	10	10	10	10	10	3	10	10	
Score	10	6	9	9	10	0	8	9	
Comment	Pass	Practice	Pass	Pass	Pass	Help	Practice	Pass	
Date									
Level									
Total Problems									
Score									
Comment									

The student record card provides the teacher with a view of the student's current performance and a history of the student's progress to that point. Figure 2 is the front side of a record card, the reverse side contains the same matrix format, thereby allowing 36 entries on a single card. When a student is finished working on the computer terminal, the record card is placed in a central location (e.g., a box on the teacher's desk) where cards for all the students are kept. The teacher then has quick and easy access to the performance of each student.

In addition to providing an up-to-date record of student progress, the record card has the most current level attempted by the student and a comment to the teacher concerning the student's work. The comment is a note to the teacher indicating how the student performed and what action the teacher should take in light of this performance.

There are several types of comments a teacher may see on a record card: Pass, Practice, Help, Practice-Time, and Help-Time. The Pass comment indicates the student has correctly answered a percentage of problems which reflects mastery of a skill; 90 per cent correct or better is considered mastery in the OWN program. A Practice comment is received when either 6, 7, or 8 problems are passed in a drill; a teacher knows from this comment that the student will receive the alternate drill at the same level as a subsequent practice exercise. The teacher may decide to work with the student on the skill in which a Practice comment was given before the student attempts the alternate drill. A Help comment indicates the student is having difficulty; this type of comment is given if a student misses the first three problems in a drill, as soon as five problems are missed in a drill, or if a child misses two or more problems in an alternate drill. Obviously, at this point the student needs individualized instruction from the teacher. The Practice-Time and Help-Time comments are presented under the same circumstances as the Practice and Help messages respectively; however, with these comments the problems which were missed in the drill were counted as wrong because the student used too much time to work the problem.

The teacher's role in the OWN program is to introduce appropriate instruction whenever necessary. As students progress through the levels of the OWN program, the teacher can see from the student record cards which children require assistance and the specific skill in which each child needs instruction. A Practice comment might prompt a teacher to provide additional problems in this skill or allow the student to receive additional practice problems on the terminal. A Help comment directs the teacher to provide instruction for the student at the appropriate level.

B. IMPLEMENTATION OF OWN

The OWN program was originally pilot tested in one elementary school; and expanding from one to twelve schools required a considerable amount of time, effort, and planning. Teachers and students needed to be oriented to the system, manuals and materials needed to be developed for orientation and for the regular classroom implementation, equipment had to be installed in the schools, and the OWN program had to be translated into a different computer language. These activities were conducted during the summer and fall of 1974 and the spring of 1975.

B.1. Orientation for Students and Teachers

Prior to the implementation of the OWN program, students and teachers were oriented to the program and to the computer equipment. Students needed to learn how to operate an IBM 3277 cathode ray terminal; and teachers needed to learn how the system was developed, how students would progress through the curriculum, and how to interpret feedback on student performance.

Teachers who began using the CAI system in the spring of 1975 participated in an orientation workshop. The workshop was for three days which were about one month apart, spanning September to December, 1974. Teachers had an opportunity to spend time on a terminal as students, they learned how the OWN program was developed and how the levels of each operation (+, -, x, ÷) build in a logical sequence toward the terminal objective, and they learned about the kind of student information they would receive about student performance. In addition, practical aspects of using the system were presented in the orientation sessions, including scheduling students for their time on the terminal, keeping records, and learning how to recognize and correct certain equipment malfunctions. The format of the orientation was condensed into a single day for teachers who began using the program in the fall of 1975.

Everything presented to the teachers in the orientation was contained in a manual given to them to serve as a reference in the classroom. This was a loose-leaf notebook with sections on all aspects of implementing the CAI program, including information as diverse as how to keep student records, scheduling students for the terminal, procedures to check the terminal for malfunctions (and how to proceed if a malfunction occurs), a vocabulary list of all words a student might encounter during the course of the OWN program, and much more. However, the heart of the teachers' manual was the detailed description of the OWN program which occupied about three-fourths of the manual. This section provided a verbal description and a numeric example for each of the 99 levels of the OWN course of study. So, if a student's record card indicated he needed help on "M12" (multiplication, level 12), the teacher could flip to the multiplication section of the manual, find M12, and learn precisely the type of skill the student needed to be taught. A page of the manual is reproduced in Figure 3. For illustration, the page selected contains Level M12. Level M12 is clearly defined, and an example is provided of the type of problem which meets the requirements of this definition.

The students in each class participating in the program were given an orientation to the computer and the computer terminal. The student orientation consisted of a lecture-slide presentation to the class and an orientation for each child individually on the operation of an IBM 3277 cathode ray terminal. The lecture-slide presentation required approximately 30 minutes, and the individual orientation to the computer terminal required about 15 minutes per student.

FIGURE 3

A Page From The
Teacher's Manual

Level	Sample Problems		Behavioral Objective
M11	37 X 8	49 X 5	Given a multiplication problem presented vertically, the student constructs the product, regrouping from ones and tens, when one factor is a two-place numeral and the other factor is a one-place numeral.
M12	154 X 5	167 X 2	Given a multiplication problem presented vertically, the student constructs the product, regrouping from ones and tens, when one factor is a three-place numeral and the other factor is a one-place numeral
M13	293 X 6	425 X 7	Given a multiplication problem presented vertically, the student constructs the product, regrouping from ones, tens, and hundreds, when one factor is a three-place numeral and the other factor is a one-place numeral.

Following the student and teacher orientations, the OWN program became a regular part of the classroom activities. There were different approaches to using the CAI system among the schools. For example, in some schools the terminals were located in a math lab; in other schools the terminals were in the classroom. In either situation the student/terminal ratio was designed to provide each student an average of approximately 20 to 30 minutes per week on the computer terminal. This time, 20 to 30 minutes, allows a student to sign on the terminal, proceed through his or her exercises, record the appropriate scoreboard information on the record card, and sign off the terminal.

B.2. Equipment

The equipment required for the operation of the OWN program consists of several components: a cathode ray tube terminal which is located in the classroom or in a math lab, a modem and a control unit located in the school office, and the computer at the Educational Services Center in Rockville. The modems were from Bell Telephone, and the control units were model IBM 3271. The function of the modem and control units was to translate messages from the terminal to the computer and vice versa over telephone lines. The central computer with which the students were interacting was an IBM model 370/158.

The OWN program was originally written in Coursewriter II, a programming language for instructional material. This language was inappropriate for the new system (IBM 370/158), and the OWN program had to be translated into a new language called Coursewriter III. This was a considerable task in terms of work hours. In addition to the translation, a complete debugging of the OWN program in the new language was essential to ensure quality performance of the program.

C. RESEARCH

An evaluation of the CAI-OWN program was conducted in order to determine the relative effectiveness of the program in the context of a large scale implementation. The primary component of this evaluation was student achievement, and there were three major questions of interest concerning this variable:

1. Does the use of CAI result in an increase in math achievement beyond what is achieved without CAI?
2. If CAI is beneficial, is it differentially beneficial for students above average in achievement versus students below average in achievement?
3. Do students below average in math perform better with CAI than without CAI?

A second component of the evaluation was teacher attitudes toward the program. Although specific qualitative questions were not raised concerning teacher attitudes, measures were taken to provide information on teachers' perceptions of the program.

C.1. Design of the Study

This study was designed to evaluate the effect of the CAI OWN program on student skills in arithmetic computation. In order to do this, nine schools using the CAI program were compared to four schools not using the program. Grades 3, 4, 5, and 6 were used to compare CAI with non-CAI performance from December, 1974, through May, 1976. Three parallel tests were developed and pilot tested to measure student progress. These tests were used for five test administrations during the course of the study. A pretest was administered in December, 1974. The second test, an end-of-year test, was administered in June, 1975. The third test was given in September, 1975 as a beginning-of-the-school-year test. A midyear test was administered in December, 1975; and the fifth test, a posttest, was conducted in May, 1976. In addition to student achievement, teacher attitudes were measured with a questionnaire using a Likert scale in June, 1975, and in May, 1976, to provide feedback from the teachers participating in the study.

C.1.a. Sample

The initial stage of the large scale implementation of CAI involved the selection of schools to use the program. Studies conducted during the pilot project indicated that CAI was beneficial for students with poor arithmetic skills. Based on this information, the criteria for selection was the number of disadvantaged students in a school; and schools with the greatest number of disadvantaged students were selected to participate in the program. "Disadvantaged" was defined as performing at or below one standard deviation below the mean on the Problem-Solving subtest of the Iowa Test of Basic Skills (ITBS). The ITBS was the only test available which provided data on mathematics achievement in all elementary schools in the county.

A list was compiled ranking all elementary schools in Montgomery County on the basis of the number of disadvantaged students. Of the 16 schools with the greatest number of disadvantaged students, 12 were selected to participate in the CAI program; and the remaining four schools served as control or non-CAI schools. Table 1 lists the schools in the study, the number of disadvantaged students in each school, and the treatment they received.

TABLE 1

Schools Participating in the Study

Rank in MCPS	Number of Disadvantaged	Treatment
1	100	CAI
2	99	Control
3	77	CAI
4	70	CAI
5	68	*
6	68	CAI
7	66	*
8	64	Control
9	58	CAI
10	57	Control
11	55	CAI
12	54	CAI
13	53	Control
14	52	*
15	51	CAI
16	48	CAI

*Indicates schools which were eliminated from the CAI program--see text

Three of the 12 schools originally selected to use the CAI program were eliminated from the study. Although 12 schools were planned to use the system, budget constraints required that some schools be eliminated for the 1975-1976 academic year, leaving 9 CAI schools and 4 control schools in the study. The schools eliminated from the study are indicated with an asterisks in Table 1.

Third, fourth, fifth, and sixth grade students were involved in the study. All third through sixth grade classes in each control school were used; however, this was not the case in CAI schools because of the availability of computer equipment. Four computer terminals were available in each CAI school to accommodate eight classes. (A few schools received additional terminals in January, 1976.) Four terminals could accomodate eight classes and still maintain the desired rate of 20 to 30 minutes per student per week as discussed earlier. Given that only eight classes could use the terminals, they were deployed differently in different schools; some schools used the program in third and fourth grades, some in fourth and fifth grades, some in fifth and sixth grades, and others in combination of three grade levels.

The student was used as the unit of analysis because of the impossibility of using the classroom as the unit of analysis. It is often desirable to use the classroom as the unit of analysis (with student nested within classroom) to eliminate the confounding of treatment and classroom effects or the confounding of treatment and teacher effects. However, a nested analysis was not used for several reasons. First, the study continued through two academic years; therefore, students were regrouped from one year to the next to form new class units. In addition, as these new and different units are formed, they have new teachers. The changes in class composition and teachers across academic years make it impossible to isolate nested groups. Second, a variety of approaches to instruction in mathematics was used in the CAI and control schools. Some schools had self-contained classrooms, some schools used math labs, and other schools regrouped students within and across grades by achievement level for math instruction. With some students going to math labs, some students going to different teachers for instruction, and some students staying in their own room, isolating nested groups became an intractable problem; and a nested design was not feasible.

Using the student as the unit of analysis, the sample size for each grade level is indicated in Table 2. These figures are based on the number of students with pretest (12/74) and posttest (5/76) scores. Therefore, the number of students used in the analysis is less than the number of students in the schools during the course of the study. Mortality, or loss of subjects, may have occurred for a number of reasons; students may have moved, they may have been absent for the pretest or the posttest, or they may have had an invalid test (there were three pages to each test, and some students skipped the second page).

TABLE 2

Number of Students Used in the Analysis for Each Grade

Treatment	Grade 3	Grade 3/4	Grade 4/5	Grade 5/6
CAI	146	159	408	515
Control	180	159	154	179
Total	326	318	562	694

The grade notation used in Table 2 is continued throughout the report, and a brief explanation is in order. Grades "3/4," "4/5," and "5/6" are used to indicate that students started in the CAI program in one grade in the spring of 1975 and continued in the program in the next grade for the 1975-1976 academic year. The students designated as grade "3" were only in the program for the 1975-1976 academic year.

C.1.b. Instrumentation

The dependent variable of interest was mathematics achievement which can be more specifically described as arithmetic computation (addition, subtraction, multiplication, division) with whole numbers. Different tests were developed for grades 3, 4, and 5. The sixth grade test was identical to the fifth grade test because the most advanced skills covered in the OWN program are ordinarily presented by the end of fifth grade. All tests contained four sections, one for each arithmetic operation; however, the number of problems in each section and the difficulty of the problems differed across grades. The number of problems in each section of the three tests is presented in Table 3.

TABLE 3

Dispersion of Problems
On the Different Tests

Test Section	Grade 3	Grade 4	Grade 5/6
Addition	11	7	4
Subtraction	9	7	5
Multiplication	5	9	9
Division	4	12	15
Total Problems	31	35	33

The precise specification of skills in the OWN program was ideal for the development of tests. The problems in each section of a test were chosen from levels of the OWN program in order to reflect the entire range of skills which are covered. The last problem in each section was the terminal objective for that operation. That is, the most difficult skills covered by the OWN program are included as the most difficult problems on the test. The only exception to this was for the multiplication and division sections of the third grade test where the last problems were levels M13 and D10, respectively, and the terminal objectives are M19 and D35, respectively. The problems on the tests were grouped by operation; and within each operation, the problems were arranged in ascending order by difficulty. The student was required to construct the answer to each problem (it was not multiple choice), and one point was given for each problem answered correctly.

The first form of the test for each grade was pilot tested at an elementary school not in the study. There were two classes available at each grade (3, 4, 5, and 6) for the pilot testing. The testing was conducted to evaluate the range of difficulty of the items, to detect problems in the administration procedures, and to see if 40 minutes was an adequate time allotment for students to complete the test (the test was intended to be nonspeeded). The items in the tests were satisfactory, minor revisions were made in the administration procedures, and the time limit was found to be adequate.

The test administrations of December, 1974, and December, 1975, were used to estimate the reliability of the tests. A nonrandom sample of tests were drawn from each grade in CAI and control schools. Reliability was estimated by using coefficient alpha[1] which was computed by using a Fortran IV program written by the author. The reliability estimates are presented in Table 4.

TABLE 4

Estimates of Test Reliability
For Each Grade

	Reliability	
Grade	12/74 (n)	12/75 (n)
3	.87 (119)	.89 (104)
4	.91 (79)	.90 (132)
5/6	.91 (108)	.92 (105)

The precise specifications of skills in the OWN program made the development of parallel forms of the tests straightforward. Three parallel forms were developed, and every item in each form had a parallel item in all other forms. The items were parallel in that they came from a specified level of the OWN program. Therefore, the seventh problem in the addition section of the third grade test was from level A18 (addition level 18); and all parallel forms of the third grade test have a problem from level A18 as the seventh problem in the addition section.

C.1.c. Data Collection

There were five test administrations in all, including the pretest and posttest which are the basis of the data used in this evaluation. Several weeks before testing, the schools were contacted by phone to ensure that the tentatively selected test date was satisfactory. If there was a conflict (i.e., field trip, school play, or other activities which would disrupt a testing environment), a testing date could be moved up or back a day or two. Once the test dates were established for each school, memoranda were forwarded to principles and teachers involved in the testing. The memo indicated the test date, the time of testing, and general testing procedures. Attached to the memo was a set of instructions

[1] Coefficient alpha (α) is an index of the reliability of a test which may be used with a single administration of a test.

for the teacher, part of which were read to the class. These attached instructions were complete, from handing out the tests through picking up the tests when the test administration was completed.

All classes in a school were tested on the same day. A CAI teacher specialist distributed a packet of tests to each classroom teacher at the start of school. The CAI teacher specialist remained in the school as a monitor during the test administration to provide assistance, if needed, or to provide extra copies of tests or instructions in case of a shortage. Teachers were allowed to begin the testing at their convenience any time before 10:00 a.m. After a class had completed the test, they were placed in the packet and returned to the CAI teacher specialist. There was one deviation from the single-day test administration in the 13 schools in the study. One school administered the tests in the school's math lab during each student's scheduled math lab period. In order to test all students in this manner, one full week was required to complete the test administration in this school.

There were five test administrations using three parallel forms of the tests for third, fourth, and fifth/sixth grades. Table 5 indicates test dates for the five administrations and the form of the test used in each.

TABLE 5

Test Dates and Forms

Administration	Date	Form
1	12/74	I
2	6/75	II
3	9/75	III
4	12/75	I
5	5/76	II

C.2. Results

The purpose of this study was to evaluate the achievement of students in schools using CAI where the achievement variable of interest is in arithmetic computation of whole numbers. The results presented below are directed toward answering several specific questions:

1. Does the use of CAI result in an increase in math achievement beyond what is achieved without CAI?

2. If CAI is beneficial, is it differentially beneficial for students above average in achievement versus students below average in achievement?

3. Do students below average in math perform better with CAI than without CAI?

These questions are not directly answerable as stated; each one must be studied at each grade level. In addition, as with all data in behavorial sciences, there is more than one way to approach the answer to each question; therefore, two approaches will be used here. The first approach will be the usual analysis of variance, which will provide statistical information about the differences which are observed between students who use the CAI program and those who do not use the CAI program. Statistically significant differences provide only limited information for decision making. For this reason, a second approach will be used to evaluate the program if significant differences are found. The second approach is a quantification of differences which expresses test performance in months, as opposed to points, thereby allowing a conceptualization of the magnitude of any statistically significant differences observed in the data.

In addition to examining student achievement, teachers' responses to questionanires given in June, 1975, and May, 1976, are discussed. The questionnaires were designed to provide information about teachers' perceptions of the CAI program.

C.2.a. Question 1. Does the use of CAI result in an increase in math achievement beyond what is achieved without CAI?

This question was answered by examining pretest and posttest scores between students in the CAI schools and students in the control schools, and it was answered affirmatively in each grade. Table 6 provides data on pretest (12/74) and posttest (5/76) performance for CAI and control students as well as data from the three intermediate test administrations. Analysis of Covariance (ANCOVA) was used to examine pretest and posttest performance for the existence of statistically significant differences; these results are presented in Table 7. Posttest performance was significantly different ($p < .05$) for each grade in favor of the CAI program.

A second approach can be used to study the observed difference in achievement between CAI and control schools. Beyond the claim that the differences are statistically significant, a useful interpretation can be achieved by translating the observed test point gains into months of gain. There are several ways this can be accomplished.

TABLE 6

Means and Standard Deviation for CAI and Control Schools

		12/74	6/75	9/75	12/75	5/76	Gain
Grade 3/4	CAI Mean	13.612	19.973	14.507	17.015	23.478	9.866
	S. D.	4.770	6.087	5.679	5.789	7.079	
	Control Mean	13.255	19.191	14.055	17.426	21.752	8.497
	S. D.	4.862	6.145	5.813	7.305	7.955	
Grade 4/5	CAI Mean	16.362	22.563	18.208	21.260	24.590	8.228
	S. D.	7.630	8.176	8.489	8.003	6.969	
	Control Mean	15.740	20.400	15.789	19.9701	23.367	7.627
	S. D.	5.585	6.888	6.668	7.388	6.433	
Grade 5/6	CAI Mean	17.905	22.647	21.887	24.421	27.126	9.221
	S. D.	7.597	7.428	7.697	7.212	6.289	
	Control Mean	20.561	22.392	23.232	26.179	27.750	7.189
	S. D.	7.144	7.219	6.841	5.428	5.362	
Grade 3	CAI Mean	*	*	11.507	*	22.582	11.075
	S. D.			4.878		6.441	
	Control Mean	*	*	10.352	*	19.094	8.742
	S. D.			3.547		5.713	

* test not administered - see text

TABLE 7

ANCOVA Tables for Posttest with Pretest as Covariate

Source	df	SS	MS	F
Grade 3/4 (12/74 - 5/76)				
Covariate	1	7,640.539	7,460.539	
Treatment	1	174.289	174.289	5.16*
Residual	315	10,639.781	33.777	
Total	317	18,274.609	57.649	
Grade 4/5 (12-74 - 5/76)				
Covariate	1	13,643.977	13,643.977	
Treatment	1	87.762	87.762	3.897*
Residual	559	12,590.871	22.524	
Total	561	26,322.609	46.921	
Grade 5/6 (12/74 - 5/76)				
Covariate	1	11,388.914	11,388.914	
Treatment	1	87.309	87.309	4.306*
Residual	691	14,009.001	20.274	
Total	693	25,485.230	36.775	
Grade 3 (9/75 - 5/76)				
Covariate	1	3,254.939	3,254.939	
Treatment	1	649.310	649.310	23.478*
Residual	323	8,932.855	27.656	
Total	325	12,838.105	39.499	

* ($p < .05$)

The approach chosen was to define the control schools as a standard and assume that during the 14 months of the study the performance of the control students represents 14 months of achievement. Based on this assumption, the ratio months/point was calculated for the control schools, where points are calculated as posttest minus pretest differences. This ratio was then multiplied by the difference between pretest and posttest performance in the CAI schools. This process had to be performed separately in each grade; for example, in the third/fourth grades, the control students gained 8.497 points in 14 months of school or 1.648 months per point. The CAI students gained 9.866 points during the same period; or assuming that one point represents 1.648 months, they gained 16.259 months during the same 14 months of school. This type of data is provided for each grade in Table 8.

TABLE 8

Performance of CAI and Control Students
Using Control Students as a standard

	Months Gain	
Grade	Control	CAI
3	10	12.669
3/4	14	16.259
4/5	14	15.103
5/6	14	17.597

C.2.b. Question 2. If CAI is beneficial, is it differentially beneficial for students above average in achievement versus students below average in achievement?

Although the first question was answered affirmatively, this could occur if CAI was beneficial for only a subgroup of the students in the study. It may be that CAI is effective for all students, only students with less than average skills, or only students with above average skills. The second question addresses this possibility. In order to perform this type of analysis, the overall mean on the pretest for CAI and control students was used to make a dichotomy of upper and lower groups in each grade. For each grade, there are four groups; CAI above average, CAI below average, control above average, and control below average. Results of the performance in these subgroups is given in Table 9.

TABLE 9

Analysis by Above and Below Mean Dichotomy

	Pretest	Posttest	Gain
Grade 3/4			
Above Mean			
CAI	16.709	26.819	10.110
Control	16.466	26.443	9.977
Below Mean			
CAI	9.603	19.724	10.121
Control	9.155	15.944	6.789
Grade 4/5			
Above Mean			
CAI	22.148	28.626	6.478
Control	20.992	27.013	6.021
Below Mean			
CAI	9.661	20.089	10.428
Control	10.558	19.553	8.995
Grade 5/6			
Above Mean			
CAI	24.006	30.611	6.605
Control	24.610	29.588	4.978
Below Mean			
CAI	11.518	23.758	12.240
Control	12.235	24.164	11.929
Grade 3			
Above Mean			
CAI	15.216	25.189	9.973
Control	13.970	22.448	8.478
Below Mean			
CAI	7.694	19.903	12.209
Control	8.239	17.106	8.867

The results from this breakdown of the data are not consistent across grades. Students in upper and lower groups in CAI schools outperform the control schools at each grade level. However, neither upper nor lower groups are consistently favored across grades. The below average students appear to benefit more in lower grades, whereas the above average students appear to benefit more in the upper grades.

There are two problems encountered in the interpretation of this information. First, the grade by level interaction cannot be tested for significance. Different tests were used in different grades, therefore the variables have been measured in such a way as to prohibit statistical analysis of this interaction. Second, the interpretation of this type of interaction would be speculative. If CAI were consistently better for one group of students across grades, the interpretation would be straightforward. However, this is not the case, and interpreting the interaction of grades with levels is not straightforward.

C.2.c. Question 3. Do students below average in math perform better with CAI then without CAI?

This question is logically contained within the preceding question. However, it is of interest to address this question specifically and separately because it was believed that CAI was beneficial for students achieving below average in arithmetic. Evidence of this nature was seen in studies conducted during the pilot phase of the OWN program.

Like the preceding questions, this question must be examined at each grade level. Differences in gain from pretest to posttest are given in Table 10 by grade for all students scoring below the overall mean on the pretest. Because this question is actually part of Question 2, it is not surprising that the data does not provide a straightforward interpretation here as well. By examining student performance within each grade, it is found that students below average in achievement are helped more in the lower grades (3,4) by CAI and that CAI is less beneficial, if at all, for these students in the upper grades (5,6).

TABLE 10

Performance of Students below Average
On the Pretest

Grade	Treatment	Gain (Posttest-Pretest)	Difference (CAI-Control)
3	CAI	12.209	3.324
	Control	8.867	
3/4	CAI	10.121	3.132
	Control	6.989	
4/5	CAI	10.428	1.433
	Control	8.995	
5/6	CAI	12.240	0.311
	Control	11.929	

The differences presented in Table 10 can be better understood by noting that at a minimum one test point indicates at least one month's gain in achievement. Therefore, the gains in the earlier grades are substantial. In addition, all the differences are statistically significant ($p < .05$), except in grade 5/6.

C.2.d. Teacher Attitudes

Likert attitude questionnaires were distributed in June, 1975, and in May, 1976, to teachers using the CAI program. These two instruments were given a year apart to see if teachers' attitudes changed after using the CAI system for an extended period of time. This was important because the initial novelty of the program could produce biased attitudes at the beginning of the program, whereas attitudes would stabalize after a longer period of using the program. By June, 1975, teachers had used CAI for about four months; and the first measurement of teachers' attitudes would reflect initial impressions. By May, 1976, teachers had used the system for about 14 months; and the second measurement reflects a more stable opinion.

As it turned out, the results of the two administrations of the attitude questionnaires were highly consistent. There were ten items common to both instruments, and the aggregate response of teachers to these items did not change markedly for any of these items. The results of the items which reflect teacher perceptions of the system are discussed in the paragraph which follows. The percentage figures reflect the combined results of the two administrations of the attitude inventory except where otherwise specified. For most of the items, the results of both administrations were so similar that a distinction between the results of the June, 1975, and the May, 1976, data is trivial. Therefore, unless otherwise indicated, the data reflects a combination of the two measurements for 80 teachers.

When asked if the CAI program was a useful resource, 89 per cent of the teachers indicated that it was useful, 3 per cent felt it was not a useful resource, and 8 per cent either marked neutral or did not respond to this item. One of the major functions of the CMN program is to diagnose areas in which individual students are having difficulty; 88 per cent of the teachers indicated that the diagnostic information they received was useful, 5 per cent did not feel this information was useful, and 7 per cent marked neutral or did not respond. The purpose of providing individual diagnostic information is to allow the teacher to provide individualized instruction to students. In May, 1976, 82 per cent of the teachers felt that the CAI program enabled them to individualize their math instruction; this is an increase from 68 per cent in June, 1975. By May, 1976, only 5 per cent of the teachers did not feel that CAI program enabled greater individualization. Eighty-seven per cent of the teachers indicated a favorable overall opinion of the program, and 82 per cent expressed a desire to continue using the program; 3 per cent indicated a negative overall opinion of the program, and 9 per cent indicated that they would prefer not to use the CAI program. Finally, in May, 1976, after using the program for 14 months, 90 per cent of the teachers felt that students enjoyed working on the computer terminal. This indicates that students did not seem to lose interest in doing arithmetic on the computer terminal over an extended time period.

D. CONCLUSION

It is evident from the answer to Question 1 that the OWN program enhances student achievement in arithmetic computation. Examination of the performance of all students in grades 3, 4, 5 and 6 show that OWN is beneficial in each grade from statistical and practical viewpoints. There was statistically significant improvement in achievement of CAI students when compared with students in traditional classroom settings. This improvement can be expressed in months gain to help clarify the magnitude of the effect of CAI. Students in grades 3 through 6 using the OWN program for fourteen months averaged from 1.1 to 3.6 months greater gain in arithmetic achievement than students not using this program. Third grade students who used the program for one academic year, 10 months, averaged approximately 2.7 months greater gain than control students. These findings establish the beneficial effects of the OWN program.

In an examination of the effects of CAI on students with above and below average skills in arithmetic, the findings were not consistent in different grades. The OWN program is most helpful for students in grades 3 and 4 with below average skills in arithmetic and for students in grades 5 and 6 with above average skills in arithmetic. However, the greatest benefit of the OWN program is for students in the middle elementary grades (3 and 4) with below average arithmetic skills; these students averaged from 3.6 to 4.2 months gain.

The opinions of teachers using CAI were very positive toward all aspects of the OWN program (over 82 per cent of the teachers had positive attitudes for each aspect of the program studied). These opinions were reflected in such areas as using the program to help individualize instruction, using diagnostic information from the program, expressing a desire to continue using the program, and reflecting on student enjoyment of the program.