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The effects of microcomputers on the mathematical skills of low-achieving students

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THE EFFECTS OF MICROCOMPUTERS ON THE MATHEMATICAL SKILLS OF LOW ACHIEVING STUDENTS

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by

Charlotte Evans Copley

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THE EFFECTS OF MICROCOMPUTERS ON
THE MATHEMATICAL SKILLS
OF LOW ACHIEVING STUDENTS

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Approved December 1990 by

James M. Yankovich, Ed.D.
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Thomas J. Ward, Ph.D.

To my husband

H. Otis Copley

To my son

Thomas C. Speight

To my daughter

Mary Charlotte Cashion

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Acknowledgments

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Thanks and appreciation are offered to my parents who set the example and always had high expectations. I regret that they were not around to experience the completion of the project.

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THE EFFECTS OF MICROCOMPUTERS ON THE MATHEMATICAL SKILLS OF LOW ACHIEVING STUDENTS

ABSTRACT

The purpose of this study was to determine the effectiveness of using the microcomputer to improve mathematics achievement for those students who did not pass the mathematics section of the State Literacy Passport Test in Grade 6.

The sample consisted of nine classes of seventh grade students who had not passed the LPT and whose parent(s) committed to the five week summer program. Students were assigned randomly to the nine teachers. The teachers were then assigned randomly to either the microcomputer or non microcomputer group with five being assigned to the microcomputer group. To control for teacher variability staff development and a detailed teacher's guide were provided. The topics covered in both groups were those which are addressed on the State LPT: numbers and numeration; relations and functions; computation with whole numbers, decimals, and fractions; measurement and geometry; and applications. The lessons for both groups included identical teacher directed activities. Students in the microcomputer group were assigned in pairs to a microcomputer and spent approximately 20% of the time using the microcomputer for follow-up activities whereas the students in the non microcomputer group worked on more conventional follow-up activities such as games and puzzles. The students attended classes for two and one-half hours, four days a week for five weeks.

A literacy passport test developed by the project director which was previously examined for content and concurrent validity and reliability was the posttest assessment. The pretest assessment was the State LPT.

The major findings of the study were:

1. Students in the microcomputer group scored significantly higher on the posttest for the total test and for the subtests of--computation with decimals, computations with fractions, and measurement and geometry.

2. Students in the microcomputer group experienced significant posttest gains on the subtest on computation with whole numbers but the posttest differences were not significant ($p < .05$). This was due to the significant differences in pretest scores in favor of the non microcomputer group.

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THE EFFECTS OF MICROCOMPUTERS ON THE MATHEMATICAL SKILLS OF LOW ACHIEVING STUDENTS

Chapter 1

The Problem

Need

The Standards of Quality for Public Schools in Virginia, July 1990, reflect some of the recommendations made by the Governor's Commission on Excellence. Section 22.1-253.13:4 states that the General Assembly and the State Board of Education recognize "the need to reduce the illiteracy rate in the Commonwealth and the need to prescribe requirements for completion of high school programs and, to this end, establish the requirements for a Literacy Passport for all students prior to grade nine." The responsibility of the State Board of Education is to prescribe and develop "literacy tests in reading, writing, and mathematics for students in grade 6, and for students in grades 7 and 8 who have not successfully passed the tests." It is the responsibility of the local school division to administer the tests and "to require students who do not pass the state's literacy tests to take special remedial programs which may include attendance in a public summer session." A Literacy Passport is required of students who were sixth graders in 1989-90 or later for classification as a Grade 9 student beginning in the 1991-92 school year. Only handicapped students who progress according to the objectives of their IEP's are exempted.

In order for the students who are unsuccessful on the mathematics section of the Literacy Passport Test to experience success, new approaches to teaching mathematics skills appear to be needed as the curriculum and instruction of the past are no longer adequate to prepare students of today for the new millennium with its shift to an information and service workforce where technology plays a major role. The Literacy Passport Test addresses the State Standards of Learning for grades 4-6. Since each school division in the state of Virginia must include these objectives in their local curriculum objectives, there is a match between the expectations of the Literacy Passport Test and those of the local educational systems in Virginia. Since, therefore, the content is fixed, changes are not needed in it but rather in the delivery of instruction. A Nation at Risk and Educating Americans for the 21st Century (NCEE, NSF, 1983) called for reform in the teaching and learning of mathematics. The Second International Mathematics Study (SIMS, 1986) revealed that eighth grade students in the United States were slightly above the international average in computation, but well below the average in non-computation. The results from the Fourth Mathematics Assessment of the National

Assessment of Educational Progress conducted in 1986 (Silver & Carpenter, 1988) indicate that students at grades 3, 7, and 11 appear to reason better on questions involving familiar settings than on those questions which involve abstract contexts. Students at all three grade levels performed poorly on multi-step problems. Everybody Counts: A Report to the Nation on the Future of Mathematics Education (NRC, 1989) paints a gloomy picture of the nations schools where underachievement and low expectations are the norm in mathematics education, and students lose their enthusiasm for mathematics due to rigid systems of rules that emphasize accuracy, speed, and rote memorization. Mathematics, though, is "a science of pattern and order" whose domain is "numbers, chance, form, algorithms, and change" (NRC, 1989). The five broad goals of the National Council of Teachers of Mathematics Curriculum and Evaluation Standards for School Mathematics are: (a) learning to value mathematics, (b) learning to reason mathematically, (c) learning to communicate mathematics, (d) becoming confident of one's own ability, and (e) becoming a mathematical problem solver (NCTM, 1989). In the position paper entitled Essential Mathematics for the Twenty-first Century the National Council of Supervisors of Mathematics lists the following as the essential components of a mathematics program: problem solving, communicating mathematical ideas, geometry, measurement, mathematical reasoning, applying mathematics to everyday situations, estimation, appropriate computational skills, and alertness to the reasonableness of results (NCSM, 1989). Both documents emphasize the utilization of the power of technology.

From a review of research it appears that the use of microcomputers may enhance a student's learning of mathematics. Pogrow's Higher Order Thinking Skills (HOTS) program has proved successful with Chapter 1 students in providing gains in both thinking and basic skills (1987). Clements (1987) reported on research supporting that primary school children using CAI made dramatic gains in mathematics when using the microcomputer daily for 10-20 minutes. Becker (1987), after surveying teachers nationwide, concluded that lower ability students using CAI gained in self-confidence, motivation, and basic skills in mathematics whereas the use of computers promoted problem-solving skills in higher ability students.

Jan Davidson was quoted in the Curriculum Product News as believing that computers can be used effectively across all parts of the curriculum to help students develop higher order as well as lower order thinking skills. The lower order thinking skills provide the foundation by presenting and reinforcing the facts and other basic information needed for the mastery of a skill. The computer also allows students to progress at their own pace and to achieve success through its endless patience (1990).

Kulik, Bangert, and Williams (1983) in their meta-analysis of 51 independent evaluations of computer-based teaching in grades 6-12 found that using computer-based teaching was especially effective in raising student achievement in elementary school. Several of the studies also supported that computer-based teaching when used as a supplement to regular instruction in the elementary grades and particularly for disadvantaged students raised their achievement levels. Samson, Niemiac, Weinstein, and Walberg (1986) examined the effects of computer-based instruction on achievement and found that the effects of drill and practice with computers on student achievement was relatively small when compared to computer-based tutoring. Foley (1984) for her doctoral dissertation compared the mathematics achievement and attitudes of 33 general mathematics students where one group used personal computers and one group was taught using traditional methods. She found that the group using the computer improved significantly over the control group in mathematics achievement, but she found no significant differences between the groups in terms of attitudes toward mathematics and computers.

Roblyer, Castine, and King (1988) in their review of recent research on the impact of computer-based instruction expanded on the research of Kulik and others. They noted that previously the meta-analyses had looked at few microcomputer studies. These researchers set up criteria and then examined studies since 1980 which met this criteria. Contrary to other meta-analysis studies they found that the effect size of studies at the elementary level was in the medium range of .29, at the middle/secondary it was much lower at .19, but at the college/adult level the effect size was high at .66. The effect size for studies involving mathematics was again within the medium range of .37. Only studies involving science had a larger effect size (.64), but there were only three studies examined in science whereas there were 36 studies in mathematics. Effect size for studies with low achievers was medium at .36 and for regular students was lower at .22 but somewhat significant. It was found that effect size was about the same for computation (.24) as for concepts/problem solving (.26). Tutorial studies had an effect size of .30 but drill/practice had a lower effect size of .20. Since all effect sizes were in the medium range, the results do appear to be significant.

Suydam in an overview of research on the use of computers in mathematics education found in most studies that used CAI that higher achievement gains were produced. In drill and practice research studies generally, she found that computers were no more effective than other means of delivery. She found that mathematical games were reinforcing and motivating. In one study the computer game group responded correctly to twice as many items on a speed test of basic facts in addition than the non-game group. It was also shown that using the computer games as a reward, setting time limits, and playing with a peer could be used as extrinsic rewards (1986). Since no information was given in the overview about the treatment of the control groups in the individual programs mentioned, it is suspect that the Hawthorne effect may have been the cause of the gains in student achievement. Longitudal studies could have determined the long range effectiveness of the programs.

In the May/June issue of Electronic Learning for the cover story 16 leading educators, politicians, and "technology watchers" were asked about the role of technology in the schools of the 1990's. The consensus was that educational technology works best when educators plan for it. Seymour Papert hopes that there will be a diversity of use by school systems and that children during the 1990's will have free access to technology. Alfred Bork is concerned that during the 1990's the software will not improve, schools will continue to deteriorate, and in some schools the computer "will be a contributing factor" as teachers will use the computer in game playing and as a reward for good behavior. Gilbert Valdez, Minnesota Department of Education, though, has a positive view saying that there will be more integration of the computer into the curriculum as teachers are becoming more familiar with the basic uses of the computer and are beginning to use content applications (Reed & Sauter, 1987).

Unfortunately, Computer Competence: The First National Assessment reports that computers are little used by many students, that use at the middle and high school level is limited to programming, and that many teachers do not feel comfortable enough to use computers effectively (Bracey, 1989). Holden (1989) believes that expanding the use of computers in classrooms is slow. She does, though, believe that computers will eventually become an integral part of pre-college education, but she is unable to predict how, when, and whether computers will be used to their fullest potential.

Results from The National Alliance of Business Survey conducted in 1990 found that 72% of the executives polled think that the mathematics skills of new employees have declined in the last five years. President Kolberg in a recent interview stated that the millions of students not planning to attend college have been abandoned and that respect for the skills needed for employees working in factories and service industries has been lost (Daily Press, July 16, 1990).

In 1988 an Industry Task Force was formed on the Virginia Peninsula to examine future workforce requirements in technical fields. The members of the task force are local high technology employees and faculty members from a local community college. As a result of the study it was projected that in order to have qualified workers in the mid 1990's and beyond, students must remain in school and must receive a firm foundation in the fundamental skills and be capable of adapting to the continuous changes in the workplace. This includes being able to learn the job requirements of tomorrow quickly. The task force feels that the solution to the future problem of lack of adequate manpower lies in students developing the basic mathematics skills along with their ability to apply these skills in problem solving. The task force recommends summer experiences which build self confidence and abilities in science, mathematics, written and oral communication, and the use of computers for middle school students (Templin, 1989).

Purpose

A change is needed in the way we teach mathematics to children. We are living in a technological world where knowledge changes daily. In order to prepare students for the 21st century, we must find ways to incorporate technology into education and additional ways to assist students to develop skills in mathematics. What better way than to incorporate the use of microcomputers with the development of students' ability to learn and apply mathematics.

The purpose of the study, therefore, is to determine the effectiveness of using the microcomputer to improve student achievement for those students who did not pass the mathematics section of the State Literacy Passport Test in Grade 6.

General Research Hypotheses

Hypothesis H:1 states that students using the microcomputer will show significantly greater gains on the literacy passport mathematics test developed by the project director than students not using the microcomputer.

Hypothesis H:2 states that students using the microcomputer will show significantly greater gains on the subtest on numbers and numeration than students not using the microcomputer.

Hypothesis H:3 states that students using the microcomputer will show significantly greater gains on the subtest on relations and functions than those students not using the microcomputer.

Hypothesis H:4 states that students using the microcomputer will show significantly greater gains on the subtest on computation of whole numbers than those students not using the microcomputer.

Hypothesis H:5 states that students using the microcomputer will show significantly greater gains on the subtest on computation with decimals than those students not using the microcomputer.

Hypothesis H:6 states that students using the microcomputer will show significantly greater gains on the subtest on computation with fractions than those students not using the microcomputer.

Hypothesis H:7 states that students using the microcomputer will show significantly greater gains on the subtest on measurement and geometry than those students not using the microcomputer.

Hypothesis H:8 states that students using the microcomputer will show significantly greater gains on the subtest on applications than those students not using the microcomputer.

Definition of Terms

Standards of Learning (SOL). Those objectives which the State Department of Education has identified as providing a framework for students at given grade levels and courses in Virginia.

Literacy Passport Test (LPT). The test developed in Virginia by the State Department of Education to determine whether students have the requisite skills in reading, writing, and mathematics to enter senior high school.

Computer Assisted Instruction (CAI). The use of the computer as a teacher. It involves the interaction between a computer system and students and is used to aid students in learning new material or in improving their knowledge of materials presented earlier. The primary modes of presentation are: drill and practice, tutorial, and simulations.

Simulation. The representation of physical systems and phenomena by computers, models, or other equipment.

Software. The programs and routines which are used to increase the capabilities of the computer.

Programming. The process of planning the procedure for solving a problem and translating it into a language that the computer can understand and obey.

Logo. An easy to learn language even for very young children which features "turtle graphics", a system of built in commands, that allow users to create from simple to complex designs soon after they start programming.

Limitations of the Study

The sample of students selected for this study were rising seventh grade students who did not pass the mathematics section of the State Literacy Passport Test administered in the spring of 1990. Although all of these students were encouraged to participate, some parents did not elect to have their children in the program.

Hampton tested 1,512 students in the spring and 81.7% passed the mathematics section. The State had similar results with 81.5% passing. It appears that suburban school systems which are similar in size, socioeconomic features, and geography had comparable results. Four of these school systems in the surrounding area with characteristics similar to Hampton's had passing percents ranging from 81.9% to 86.8% whereas other school divisions in southeast Virginia which were different had the percent of their students' passing to range from 56.4% to 98.9%. Even with the differences in failure rates and demographics between the school divisions in Virginia, it would appear that students who do fail are similar to adolescents throughout the United States as described by the Carnegie Council on Adolescent Development (1989) in that many have low self-esteem and low expectations. Many have become bored with school as a result of too many routine worksheets, as a result of the teacher "telling" instead of engaging them and as a result of required rote memorization (Baroody & Ginsburg, 1990). Therefore, because of the probable similarities among failing students, the differences in demographics would not appear to result in a limitation thus enabling findings of the study to be generalized to other school divisions in Virginia.

A limitation of the study, though, concerns the assessment instrument itself. Because it addresses the Standards of Learning for Mathematics, grades 4-6 in Virginia, no attempt will be made to generalize the findings to other mathematics competencies.

Overview

The rationale for the study is presented in Chapter 2. This is followed by a review of literature on research on utilizing the computer in the development of skills, emphasizing research related to the computer and mathematics. Summary conclusions and implications of the research constitute the last section of the chapter. In Chapter 3 procedures used for the experiment are explained in detail. In Chapter 4 findings are presented, and in

Chapter 5 these findings are interpreted with conclusions stated, implications discussed, and recommendations for future research suggested.

Chapter 2

Review of the Literature

Rationale

National and international studies of public education (NAEP, 1988: SIMS, 1985, AAS, 1989) have cited a need to improve the mathematical skills and the problem posing and solving abilities of the young people in the United States. The National Research Council, the National Council Teachers of Mathematics, and the National Council of Supervisors of Mathematics all support the broad student goals of developing mathematical power, valuing mathematics, developing confidence in one's ability to solve problems, and using technology appropriately as a tool to help expand and develop an understanding of mathematics (NRC, 1989; NCTM, 1989; NCSM, 1989). One of the key educational goals as an outcome of the summit meeting of President Bush and the nation's governors in Charlottesville was to improve student achievement, particularly, in mathematics and problem solving, and to increase the conceptual understanding of students (Miller, 1989).

The computer has great potential as an interactive instrument. By using appropriate software it is possible to match the learning environment to the learning styles of individuals. The computer also can support many different exploratory activities in mathematics and science (Weir, 1989). More and more it appears that computers are: (a) being placed in the hands of middle and upper class rather than poor children, (b) being used for rote drill and practice primarily when placed in schools for the poor, and (c) being used less with female students then male (Middleton & others, 1989). It is the intent of this study to determine the effectiveness of software used in conjunction with instruction by the teacher in the development of those mathematics skills which are tested on the Virginia Literacy Passport Test for those students who previously did not pass the Literacy Test.

Research on Using the Computer in Skill Development

Roger Johnson, David Johnson, and Mary Beth Stanne (1986) in a research study of 74 Grade 8 students from a midwestern, suburban, middle class school system compared the effectiveness of computer-assisted cooperative, computer-assisted competitive, and computer-assisted individualistic learning. The students were randomly selected for each of the three groups, stratifying for sex, handicap, and ability. The instructional unit, Geography Search, was composed of 10 days of instruction for 45 minutes each. The three certified teachers were not only given 90 hours of instruction which included each of the conditions, but they read from a prepared script. In order to control further for teacher variability the teachers rotated spending approximately one third of the time working with each group. The teacher presentation each day included explaining the assignment, distributing the materials, and reviewing the goal structure for each condition. Each group was assigned a separate classroom which contained six computers. The computer time for each group was the same.

For this study the independent variables were: (a) cooperative vs. competitive vs. individualistic approaches to teaching and (b) male vs. female. The dependent variables were verbal interaction, attitudes, and achievement. The computer simulation selected for the unit was a modification of Geography Search. The instruments used to determine the level of achievement were worksheets, a test, and amount of gold accumulated. Three trained research assistants rotated among the groups to measure oral interaction by observing students at work, in social interactions, and in task management. The interrater reliability of the three observers had previously been checked at 80% agreement. The instrument used to measure students' attitudes toward computers was composed of three scales each with alpha coefficients greater than .70. The attitude scales for cooperative, competitive, and individualistic had alpha coefficients greater than .80. Students' perceptions of each other were measured using a sociometric nomination instrument. A 3 x 2 ANOVA was used to analyze the data.

Significant findings from the study showed that the computer-assisted cooperative group: (a) exhibited higher quality and quantity of daily achievement, (b) exhibited the greatest ability to apply facts for those test items requiring higher level reasoning and problem solving ability, (c) had more success in complex problem-solving situations involving mapping and navigation, and (d) addressed more statements to each other. Males perceived computers as being more of their domain than did females. The results also imply that, if teachers wish to measure achievement on computer-assisted learning tasks, they should consider structuring lessons cooperatively, rather than competitively or individualisticly. This study has a great deal of merit, for it adds to the research on both cooperative learning and computer-assisted learning. Another strength of the study is the strict controls for teacher variability, observer bias, and delivery of instruction. The extensive training for the teachers and the relatively high interrater reliability add to the credibility of results. Unfortunately, a serious limitation is the use of the instruments designed by the teachers to measure student achievement. No reliability or validity information was given for these tests. The weakness of these instruments could affect internal validity.

The question investigated by Woodward, Carnine, and Gersten (1988) was, "What is the effectiveness of a computer simulation in enhancing student learning, both factual level knowledge and higher cognitive skills in a unit on health?" From the reviewed literature the researchers concluded that previous simulation research had been "characterized" by weaknesses in research design. These weaknesses included the fact that some interventions had been too brief; the assignment of students had been by intact classes on a non-random basis; the hypotheses considering the intent of the simulation games had been poorly formulated; the criterion measurement instruments were generally developed by the experimenters and had not been checked for validity or reliability; and the simulations used in the research had not been field tested. The researchers in the present study set about to remedy the problems.

The subjects selected were 30 learning disabled high school students who scored at the sixth grade or higher level on the Metropolitan Achievement Test in reading. These students were randomly assigned to either the conventional or the simulation group. Both groups received instruction for 40 minutes each day for 12 days. During the first 20 minutes, each group received direct instruction from the teacher. After twenty minutes, the students were divided into the two groups. The experimental group worked with the computer simulation, while the other group worked on traditional application activities. The teachers rotated between the groups. The simulation Health Ways had been previously field tested in several junior high classes with students of varied abilities. Both measurement instruments were tested for reliability. The Nutrition and Disease Test has a .84 alpha coefficient for internal consistency and the Health Diagnosis Test has test/retest reliability of .81, thus placing them in the moderate category for reliability. Students in each group were tested one day, two days, and two weeks after instruction. Means, medians, and standard deviations were computed from the Nutrition Disease Test results. The means immediately after instruction were 73.3% for the simulation group and 59.7% for the conventional group. After two weeks the means were 66.5% and 51.6% respectively. Both results were significant at the .03 level of confidence.

The *t*-test was used to analyze the problem solving skills data for the Diagnosis Test. Results were significant at the .001 level, showing that the simulation group members were better problem solvers. The results indicate that the combination of structured teacher presentation and computer simulation for the health unit was effective in teaching both factual level knowledge and higher cognitive skills. The implications are that simulations combined with instruction in strategies for successful use of the simulation can contribute to a student's learning of factual information as well as acquisition of problem solving skills. The results, though, say nothing about use of computer simulations as "stand alone" activities. The researchers took great pains in the design of this study. The intervention of 12 days allowed ample time for the unit. By rotating the teachers they were able to control for teacher effects.

The simulation Health Ways had been field tested, and a written curriculum to accompany the instruction had been rewritten to control for vocabulary and new information. Both measurement instruments had reliability greater than .80 which is at the high/medium level. The conventional instruction was delivered to the groups using the principles of effective teaching. Students were not only assessed immediately after the instruction, but also two weeks later to determine the level of maintenance. These retestings could cause statistical regression, but it would affect both experimental and control groups equally. The researchers list as a strength the fact that the only problem solving skills which were tested were those taught in the simulation. This, though, would limit the generalization that could be made from the study.

The effects of two types of problem solving computer software on students critical and creative thinking were examined by Bonk (1988). He assumed that problem solving software could be categorized as either divergent or convergent and that the cooperative learning style is equally beneficial for learning that involves convergent and divergent thinking. The subjects in this correlational study were forty grade 4-6 children who had volunteered for a summer program. They were randomly assigned to either the convergent thinking or the divergent thinking group. The students worked for 25 hours in pairs using the software. Divergent software was defined as that related to brainstorming, designing patterns, drawing and animating pictures, and writing poems, stories, and music. Convergent thinking packages required the students to look for bias in statements, to look for supporting evidence, to formulate and select hypotheses, and to make conclusions. The measurement instruments used were Schaefer's Creativity Attitude Survey to assess creative attitude or disposition, the Torrence Test of Creative Thinking, and the Cornell Critical

Thinking (x) which had been reworked to assess critical thinking, inductive and deductive reasoning, and credibility of sources and assumptions. The test/retest reliability of each was between .61 and .90. After the intervention the mean test scores for each group were compared using the *t*-test.

On the attitudinal test the convergent group scored higher but not significantly. The divergent group scored higher on all 14 components of the Torrence tests with larger differences on the figural than the verbal, but the only comparison that was significant was figural fluency. Unexpectedly the divergent group scored much higher on the assumption identification subtest of the Cornell, but since Hypothesis 2 was stated in the opposite direction, this was not considered significant. Conclusions supported by the study are that there was a significant difference in the figural fluency of the divergent group, but that there existed no significant differences on the attitudinal. Critical thinking was not significantly affected by the convergent treatment. The results suggest that intensive exposure to certain types of educational software may promote critical thinking, but additional research is needed to determine whether the effects will be more significant if students are exposed for a longer period of time. Unfortunately, because the study used only volunteers, it lacks external validity. Due to the small sample size, subdividing the group into the three grade levels resulted in finding no significance. In addition, the Cornell Critical Thinking test was probably not appropriate for use with children in grades 4-6 since its range was listed as grades 4-12.

Another research study examining the effects of different educational computing environments on student learning is one undertaken by Clements and Nastasi (1988). In this naturalistic observational study the social and cognitive interactions with Logo and CAI environments were compared. Twenty-four first-graders and 24 third-graders who were part of a larger Logo project were randomly assigned either to the Logo or to the CAI group. Twenty-eight training sessions (45 minutes each, twice a week) constituted the treatment for each group, one working with Terrapin and the other drill and practice. Prior to the data collection for this investigation, one of the researchers had trained the other observer using the data collection instruments. The training continued until interrater reliability was 95% agreement. The observations consisted of ten minutes per child over 2-3 sessions. Each pair of children for each group was audio taped for 20-30 minutes during the two weeks following the social interaction observations. Children were asked to begin and to complete each task as much as possible. The tapes were later transcribed. The tapes which were intelligible and contained at least 80 statements were analyzed. Twenty from the Logo and 18 from the CAI groups met the criteria. The instrument used to assess social behaviors was one previously developed by one of the researchers and adapted for this study. Reliability of interrater agreement was established to be 98%. Interrater agreement for the instrument which measured the information processing and metacognition components was 87%.

New skills and concepts were taught to each group in five to 15 minute demonstrations which were followed by guided application of these new skills. In the Logo group, the children first planned what the turtle would draw, drew this on paper, and then decided in pairs how to program the turtle. In the CAI group, following the introduction to the new skills, students were allowed to choose from the computer programs which addressed these skills. Adults were available to answer questions in both groups, and the students were allowed to interact with other pairs. In both groups the students generally worked with their own partners. The sequence of lessons was matched to the school system's curriculum objectives in mathematics, language arts, and reading and was adjusted according to the achievement level of the students.

Data for percentage of occurrence of social behaviors was analyzed by grade and treatment. The differences in means and the standard deviations were computed. Results showed significant differences between the Logo and CAI groups at the .001 level of confidence for rule determination, at the .01 level for resolution of conflict, and at the .05 level for self-directed work. The same two-way analysis of variance was performed with the percentage of occurrence of information-processing components. The only significant differences were found in metacomponential processing in favor of the Logo group. Conclusions from the study were that students in both groups spent substantial time (60-70%) working cooperatively. The Logo group evidenced a higher percent of conflict resolution strategies, as well as a significantly higher percentage of behaviors associated with rule determination and self-directed work. The implications are that the Logo environment enhances effective motivation, which lends support to the hypothesis that the characteristics of a Logo environment support the development of higher forms of reasoning. Additional research is needed to determine whether students derive more pleasure working in a Logo environment or just in a computer environment. Additional research is also needed to determine whether the encouragement of social interaction facilitates metacognitive development.

This naturalistic experimental study provides additional insights concerning the effect of a Logo environment on the development of higher cognitive skills. Since the students in this investigation were essentially volunteers from a larger group who had been selected on the basis of parental forms returned, the lack of external validity affects the ability to generalize. In addition, no mention was made of the reliability and validity of the instruments themselves for measuring the constructs. The use of the cooperative learning situation, combined with the use of computers, was found by Johnson, Johnson, and Stanne (1986) to be effective. This present study follows up on this aspect and also incorporates some instruction by the teachers. Two methods of collecting data, using audio tape and observation, added dimensions to the study. The inclusion of observation schemes in the appendix and the list of some of the software used are helpful if a replication study is planned. The study also raises some questions for further research. Because prior planning and consensus is needed before programming the turtle, it is not a surprise that a Logo environment encourages social interaction and might facilitate metacognitive development.

One of the most comprehensive research studies to investigate the relationship between the use of microcomputers and the development of critical thinking skills among middle school students was one conducted by Perkins in 1984. This quasi-experimental study was divided into phases. The sample was composed of ten intact classes of seventh-grade students who had registered for a class entitled "Problem Solving with the Microcomputer." Five classes chosen at random were designated as the experimental group (98), and the other five became the control group (106). The experimental group was subdivided. During the nine-week course, the experimental group was instructed in critical thinking and problem solving. The instruction was divided into four modules consisting of analogous reasoning, logical reasoning, inductive/deductive reasoning, and problem analysis. Two of the modules were taught with the help of the microcomputer, and two were taught using conventional methods. The two subgroups were not taught by the same method for the modules. The control group received no special instruction in critical thinking. The conventional instruction consisted of lecture, discussion, and paper/pencil worksheets that covered the same instructional objectives as the microcomputer software. Sessions were 50 minutes in length. All participating teachers were computer literate and had received two 3-hour training sessions on problem solving in addition to becoming familiar with the software. In Phase 2 the control group received microcomputer-assisted instruction in all four modules. The measurement instruments used for both phases were the Ross Test of Higher Cognitive Processes, the Test of Cognitive Skills, and the Otis-Lennon Mental Ability Test. The reliability coefficient for the Test of Cognitive Skills was determined to be .81 and construct validity was .86. Using split-half and alternate form, reliability data coefficients were found to be .95 and .93. Construct validity also correlated highly between the Otis-Lennon test and other general scholastic aptitude measures. The data was analyzed using analysis of covariance where the covariates were the pretest scores.

Some findings from the two phase study were that use of the microcomputer to teach critical thinking skills to seventh-grade students produces results equal to, but not greater than those produced by conventional methods. Students who received critical thinking skills instruction which was closely matched to the assessment measure (verbal analogies) showed significantly greater gains than those not receiving critical thinking instruction. The teaching of critical thinking skills produced no significant gains in the scholastic aptitude of seventh-grade students as measured by a standardized scholastic aptitude instrument. The ethical safeguards of the study and the fact that both experimental and control groups received a treatment since all students had signed up for the course, are strengths of the design. The pilot testing of the software and the curriculum together with the emphasis on verifying the reliability and construct validity of the measurement instruments add credibility to the research. Since the teachers were carefully selected, were given training, and rotated between the groups, there were strict controls for teacher variability. The specifics of the study together with the clarity of presentation including tables which show analysis of data for each of the six hypotheses, t-test results on pretest and posttest data, and analysis of covariance on posttest scores for subsections comparing control and experimental groups for both Phase 1 and Phase 2 of the project are invaluable to anyone who plans to replicate the study.

Two studies which examined the effectiveness of computer-assisted instruction (CAI) with mathematics for disadvantaged students were one in Louisiana and one in New Jersey. During the 1980-81 school year the Lafayette

Louisiana Title I program piloted a research project to determine the effectiveness of CAI for mathematics in grades 3-6 (Hotard & Cortez, 1983). An effective pull-out mathematics laboratory program already existed so for this study students in grades 3-6 within the two experimental schools (two of 14 lower socioeconomic area schools) were matched based on the previous spring's score on the CTBS/McGraw Hill Criterion Referenced Test. Each member of the matched pair was assigned randomly to either the CAI or non-CAI group. Both groups received the standard mathematics laboratory instruction with the experimental group using the computer for ten minutes daily during the time spent in the laboratory.

The pre and posttests (CTBS/McGraw Hill normed April, 1975, with an average reliability of .85) were administered and scored by independent examiners who were unaware of which students were in the experimental and which students were in the control groups. The elapsed time between the pre and posttesting was six months (109 instructional days). The mean grade equivalent gain for the CAI group was 1.01 with a standard deviation of .86 whereas the gain for the control group was 0.88 with a standard deviation of .69. Effect size was .16 which although small was significant at the .01 level of confidence. This study illustrates that the use of the computer can provide an effective means for drilling in mathematics which can be also interesting and motivating.

The Newark School District of New Jersey undertook a similar computer-assisted instructional program (Gourgey & others, 1984). In this project supplemental instruction in mathematics was provided for students in grades 2-12 in eleven selected schools. The most frequent criteria for student selection was eligibility for Chapter 1 or State Compensatory Education services.

Two elementary schools used CAI as an adjunct to Chapter 1. The use of the computer took place in the regular classroom with students having regular mathematics instruction followed by the students taking turns doing seatwork related to the lesson and working at the computer terminals. Students in the non remedial elementary classrooms worked in a separate room which was used only for the CAI program. Generally a teacher aide was responsible for supervising the CAI portion in the laboratory but was not responsible for the instruction. The administration of the program varied from site to site. The CAI consisted of intensive drill and practice in mathematics competencies and concepts with the level of difficulty adjusted for each student's level of proficiency. Students generally spent ten minutes daily on mathematics with the computer. The evaluation instrument used to measure the effectiveness of the CAI was the Comprehensive Test of Basic Skills administered throughout the Newark School System in May 1983 and May 1984. A comparison group was randomly selected from Newark's Student Information System to constitute the control group. The analysis of covariance was used to determine the effectiveness of the program. An interesting finding was that the students' achievement entry characteristics on mathematical concepts, applications, and computation were not significant in predicting the learning gains experienced by students using the computer (Walker & Ajumi, 1985). Other implications were that CAI helped students of all abilities in the development of addition, subtraction, and multiplication competencies whereas on the more advanced skills with fractions, measurement, and equations the lower ability students were helped the most.

Other studies specific to the use of CAI in mathematics skill development follow:

The Computer Assisted Instruction in Mathematics Project of the Cleveland Public Schools was designed to provide remedial instruction in mathematics for students in grades 7-12 during the 1982-83 school year (Lanese, 1983). Twenty project sites were equipped with two microcomputers for each project teacher. The microcomputer's use was both in demonstration and individual drill and practice. Objectives of the project were that:

·75% of the students receiving the supplemental instruction would demonstrate a significant increase in mathematical computational skills (pre/post gain of at least 10%).

An effective management system of scheduling computer usage would be developed to permit monitoring the frequency and length of computer involvement for each student.

Teachers would receive inservice training in the operation of the computer and its use as a tool in remediation.

A class in developing remedial educational software would be organized and offered to interested teachers.

Only the objectives involving teachers (three and four) were attained. Unfortunately due to operational difficulties such as the delay in the installation of the hardware and a bus strike which limited the number of students posttested (736 of 979 which resulted in only 432 pre/post matches), the attainment of Objective 1 may have been affected. The assessment instrument used to measure student achievement was a locally constructed test of basic mathematics skills.

Using this instrument, results showed that between 40% and 55% of the students realized the 10% gain projected except in Grade 12 where of the 12 students with pre/post test matches only one third showed gains of 10% or greater.

Even without the operational problems, it would appear that the research design has a number of flaws. Before the project began, a consistent method of monitoring the use of the computer (Objective 2) should have been in place. The assessment instrument itself is suspect as no mention was made of its validity or reliability or of why a 10% gain was selected and exactly what that means.

The effects of computer enhanced instruction with 4,293 grade 9-12 students in 65 high schools, including 3,308 black, 957 white and 28 others who were involved in the Governor's Remediation Initiative (GRI) in Georgia were researched by Lang and others (1987). This program was developed for high school students who had scored below the mean on standardized tests and who were not responding to traditional methods of instruction. A curriculum was developed for mathematics which encompassed the traditional scope and sequence of whole numbers, decimals, fractions, percent, word problems, measurement, geometry, and elementary algebra and which matched the Georgia Basic Skills Assessment Program (BSAP) objectives.

A component of the program was the evaluation of more than 1000 commercially available software titles with 100 of these purchased for use in each of the experimental classrooms. Students selected for the project were classified as remedial on the basis of either being in the lower quartile on the California Test of Basic Skills pre-assessment or of failing to pass the BSAP criterion referenced test in mathematics. The maximum enrollment in each class was 15 students unless there was an aide in which case there could be as many as 20.

Among the questions researched in this study were:

What is the overall effect of the project in teaching mathematics and in helping students to "catch up"?

Do differences in achievement appear for sex?

Do differences in achievement appear between the races?

For the study the dependent variables were CTBS scores and project authored module tests (80% mastery was required). The evaluation model used no control group. All data was analyzed using the Statistical Package for the Social Sciences (1984). Independent *t*-tests were performed to determine the achievement gains by sex and race. ANOVA was performed across the variables of school, teacher, and class. The traditional confidence levels of .05 and .01 were considered acceptable. Dependent *t*-tests were performed for pre/post test gains at each grade level for the CTBS subtests of computation, applications and concepts, and for total math. Because of the possible correlations between the subtests and total math, .001 was used to determine significance here.

The results considered important for this review are:

All comparisons showed statistically significant gains on the CTBS with the exception of the 10th grade gain on the subtest, applications and concepts.

The independent variable sex showed no differences between male and female on CTBS variables, but males outperformed females on the number of modules completed.

For race significant differences were indicated between all CTBS measures (pretest, posttest, gain), but there were no differences between the number of modules completed.

Strengths of the project are the evaluation of the software before selection, the small size of the classes, and the availability of software for each class. Although all teachers in the project had the same training, variability appears to have affected the results. Another weakness is the instrument (CTBS) itself which was evidently not checked for criterion related validity.

The sample for a study on learning style shifts and mathematics achievement resulting from CAI settings (Clariana & Smith, 1988) consisted of ten boys and 13 girls who were members of a combined seventh and eighth grade class. From October until February the students received approximately 30 minutes of CAI mathematics instruction per day, three times a week. The major questions researched were:

Is there a correspondence between learning style preference and a special form of CAI, in this case The World Institute of Computer Assisted Teaching (WICAT)?

Do any of Kolb's LSI measures relate to achievement in a CAI environment?

Learning style preference data (LSI, Kolb) and mathematics achievement data (Iowa Test of Basic Skills, ITBS) were collected in October and again in February for the LSI and March for the ITBS. Using the stepwise multiple regression (SPSSx) of all the variables with posttest ITBS (mathematics) as the dependent variable, pretest ITBS entered the equation first being significant at the .0000 level of confidence and multiple B=0.75. Concrete experience (CE) entered at step 2 and was significant at .001 with B=0.5. The equation with the two variables was:

$$y = -17.47143 + .95355 \text{ (pre ITBS)} + 2.13486 \text{ (CE of LSI)}$$

The two variables accounted for 81% of the variance. None of the other variables entered the equation. When math pre to posttest gain was blocked, both the high ability and the low ability groups showed a shift from diverger type (preference for reflective observation, RO, and concrete experience, CE) to an accommodator type where the learner changes learning style to fit the teaching method. The high ability group shifted on the average more than the low ability group.

Although the design of this study with the low reliability of the instrumentation makes it difficult to interpret a causal relationship, the findings do suggest that matching instructional method including type of CAI and learning style preference is of utmost importance for low ability students. Therefore, learning style preference should be considered when designing a study with low ability students and CAI.

In 1985 a group of Memphis businessmen together with educators from the city and county public schools and private and parochial schools after investigating several available technologies selected the WICAT S-300 instructional system for a research project (Clariana & Schultz, 1988). St. Anne School near Memphis was chosen as the pilot site with the College of Education at Memphis State University providing research assistance. As one of the researchers was involved in the previous study cited, it appears that some of the same students were used in both studies. The project itself began in 1986.

The research questions examined in this project were:

Does daily computer use as a complement to the regular school day result in improved scores on the ITBS?

Is daily computer use effective with all ability groups?

Is daily computer use equally effective for all curriculum areas?

St. Anne School is a Catholic school with an enrollment of about 220 students (K-8). The student population is 90% white and from blue collar worker families. For the project the students spent 30-35 minutes daily in mathematics with the computer, 15-18 minutes in language arts with the computer, and approximately 30 minutes in reading with the computer. Since all students grades 1-8 were included in the study, there was no control group.

The ITBS scores of all students for the four years were analyzed. The average gain in each curriculum area before WICAT was 0.85 grade equivalents per year whereas the average gain with WICAT was 1.17 grade equivalents per year. The groups were split at the median into two groups, and the ITBS scores of these groups were analyzed. For the high ability group yearly pre-treatment gains were 0.97 grade equivalents and post-treatment gains were 1.19. For the low ability group pre-treatment gains were 0.72 grade equivalents and post-treatment gains were 1.15. This suggests that although CAI WICAT is beneficial for all students, it is most effective with students below the median in achievement. Three curriculum areas were included in the evaluation, reading, language arts, and mathematics. Pre-treatment gains for reading and mathematics were 0.89 grade equivalents and post-treatment 1.14. Language arts showed the greatest gain with CAI from 0.76 to 1.23 grade equivalents.

A weakness of this study is the apparent neglect in determining the construct validity between the ITBS and the objectives of the WICAT system. In addition before generalizing the implications to the population of low ability students in elementary and middle schools, demographics should be considered as the sample (accessible population) for this study comes from a special population.

The Computer Pilot Program was implemented in 1986-87 in New York City Schools (Guerrero & Swan, 1988). The target population was "at risk" students. Computer laboratories were placed in nine elementary and intermediate schools and ten high schools. The goals of the program were to determine the CAI systems that are effective in increasing student attendance, student achievement in mathematics and reading, and in improving the attitudes of students and staff toward CAI.

One of the CAI systems examined was WICAT. WICAT is a multi-user system that can support up to 32 stations. It can be adapted for use with both IBM and Apple microcomputers enabling the use of standard software as well as the software provided by WICAT. WICAT uses color, graphics, animation, and sound. Headsets are supplied for each workstation. The management component tracks student progress.

In January 1987 WICAT was installed at P.S. 31 in the Bronx. Among the users were 95 Chapter 1 mathematics students. The 15 workstations were used for three 45 minute sessions a week. In the spring a qualitative evaluation using interviews with the staff and a sample of students was performed. School administrators, program coordinators, teachers, paraprofessionals, and students were all generally positive about the system. Although plans for a follow-up research study in which achievement test scores and attendance records were used was recommended, it appears that this has not been completed.

At other sites in New York City additional CAI systems were examined similarly. The systems were: Autoskills, Computer Curriculum Corporation, Comprehensive Competencies Program, Corvus/Ideal, Degem, PALS, PC/Class, PLATO, and Tandy/ESC. Most participants who were interviewed were positive about each of these systems also.

Two recommendations that came out of the study were:

Investigate to determine whether test scores and attendance records support the feelings of those interviewed.

Analyze closely the systems to determine which systems are effective with a particular group.

Analyze the cost effectiveness of the systems and their ease of use.

Increase the amount of staff development.

Another study involving WICAT was undertaken at Salina School in Dearbon, Michigan from 1985-1988 (Mys & Petrie, 1988). Activities such as drill and practice, tutorial, and simulations were components.

In November 1985 the WICAT system was installed at Salina School. All classroom teachers received training. The instructional use was in reading and mathematics. The students received their regular reading and/or mathematics instruction in the WICAT computer laboratory. Students in the program were in grades 2-4. There were 1,100 students in 1985-86, 1,280 in 1986-87, and 1,405 in 1987-88. The lessons were 20-30 minutes in length, three to four times per week. Since nearly all of the students received the treatment, it was not possible to utilize experimental and control groups in the research design. Instead analysis of "same" student reading and/or mathematics achievement test data was used as the basis of determining the effectiveness of the program. The analysis of pre/post student achievement test data growth was compared to: (a) prior achievement growth, (b) normal achievement growth determined by national norms, (c) achievement growth of similar students in other Dearbon schools, and (d) achievement levels on the pretest.

The instruments used to evaluate the gains were the Metropolitan Achievement Test (METRO), the Iowa Test of Basic Skills (ITBS), and the Michigan Educational Assessment Program (MEAP). Results showed that the mean gain for second-grade students in mathematics increased from eight to 12 grade equivalent months and for third grade from seven to ten months. Low achieving mathematics students showed the most gain at 14 months. Over the three year period for Grade 4 METRO/ITBS mathematics gains were significant when compared with other Dearbon schools. In addition the performance on MEAP of fourth grade students mastering reading skills increased from a mean of 42.2 % to 51.2% after treatment with 60.5% attaining mastery in 1987. Although MAEP gains in mathematics were small, there were significant gains in mathematics as assessed by the ITBS.

Effective components of the project were the teacher training in the use of the WICAT system, including each year the training of new teachers. Although three assessment instruments were used, no additional testing was needed as all tests were a part of the district evaluation program. The three instruments allowed for multi-comparisons. Short term as well as long term gains were examined. The one year analysis focused on gains between May 1987 and May 1988 whereas the Grade 2 students were followed from November 1985 until May 1988. Although there was no control group, the use of comprehensive "same" group data was extensive. Student gains were also reported by achievement quartiles.

Cannaday (1989) for his dissertation compared three approaches to instruction: computer-assisted instruction, cooperative learning, and teacher directed to determine the relative effectiveness in improving the mathematics performance of low achieving students. The 99 students in the study had just completed Grade 5 and were randomly assigned to one of the treatment groups during a five-week summer remediation program. Teachers in the program selected the approach that they preferred and were trained in its use prior to the project. The ITBS Grade 4 total math score was used in assigning students randomly by ability range to a treatment group. Fifth grade ITBS math scores from the test administered the previous spring served as the pretest measure. During the last week of the summer program the students were readministered this test and the subtest scores of concepts, problem solving, and computation, and total math were used as the posttest dependent measures. Data was analyzed using ANCOVA with total math score as the covariate. Although no significant differences were found between the three groups in improving student performance on any of the subtests or total math, substantial growth was exhibited for each group with the computer-assisted group attaining the greatest gain.

Summary of Research

The theme for the September, 1989 issue of Educational Leadership is "Preparing Today's Students for Tomorrow's World." Articles by Dede, Shane, Steen, and Benjamin all speak of using technology to enhance the learning process and the student's ability to solve problems. Weir and the researchers at the Laboratory of Comparative Human Cognition in San Diego strongly suggest that the computer be in the control of the teachers and that the learning environment match the individual learning style of the child as learning in a computer-based environment is more than just relying on a piece of software to do the job. Researchers at the Bank Street College of Education in New York during the past ten years have developed and tested programs such as the "Voyage of the Mimi" which use technology to develop a problem solving environment. They have also investigated the effectiveness of various types of software on critical thinking skills (Pea, 1986).

Goals of the Harvard Graduate School of Education (1988) as presented in their position paper are to study ways to improve mathematics, science, and computing and to make results of the work easily applicable to classroom practice. They believe that the computer is a tool and should not be the main focus of attention and that teacher directed and computer directed learning should be integrated.

The research which was examined in detail for the review of literature was reported between 1981 and 1989. In these studies the relationship between the use of computers and skill development was investigated. Twelve of the research studies used an experimental or quasi-experimental quantitative design. In six of the studies, though, no control group was used. The other studies were a naturalistic qualitative study which used both an observer and transcriptions from audio tapes and a qualitative study using interviews. The subjects in the studies ranged in age from Grade 1 to Grade 12, with the majority of the studies involving students essentially classified as middle grade students. In some of the studies subjects were randomly selected for the groups. For the Perkins study intact classes were randomly assigned. Students in six of the studies were designated as disadvantaged, remedial, or "at risk" students who were potential school "drop outs." In the other studies some students were volunteers or were part of a larger special group such as the experiment with learning disabled students and the one with students from a larger Logo project. Two studies involved students in an entire school. The studies involved students in the east or midwest and from urban, suburban, or inner city schools. The questions researched in the studies were:

(1) What are the comparable effects of computer-assisted cooperative, computer-assisted competitive, and computer-assisted individualistic learning in a navigation unit?

(2) What is the effectiveness of a computer simulation in enhancing both factual level knowledge and higher cognitive skills in a unit on health?

(3) What are the effects of using convergent and divergent software on the development of student's critical thinking skills?

(4) What are the differences in social and cognitive interactions between children in Logo and CAI environments?

(5) Is teaching critical thinking skills using computer-aided instruction more effective than teaching these skills using conventional methods?

(6) Is CAI effective in raising the mathematics achievement level of disadvantaged students (remedial) in grades 2-12.

(7) Can CAI help improve students' (both remedial and non-remedial) mathematics achievement beyond the level that would be expected in regular classroom instruction?

(8) Is there a correspondence between learning style preference and WICAT; do any of Kolb's LSI measures relate to achievement in a CAI environment?

(9) In grades 1-8 does daily computer use result in improved scores on ITBS; is it effective with students of all abilities; and is it equally effective in all curriculum areas?

(10) What CAI systems are most effective in increasing student attendance, student achievement in mathematics and reading, and in improving attitudes of students and staff toward CAI?

(11) What achievement gains in reading and mathematics result from the use of WICAT?

(12) What are the comparable effects of teacher directed, computer-assisted, and cooperative learning on the mathematics performance of low achieving rising sixth-grade students who attend a five week summer program.

Results from these studies which will influence the present study are:

(1) The computer-assisted cooperative group exhibited the greatest ability to apply facts for those test items requiring higher level reasoning and problem solving ability, and the cooperative group had more success in complex problem solving situations involving mapping and navigation.

(2) A combination of structured teacher and computer simulation was effective in teaching both factual level and higher cognitive skills when the problem solving skills which are tested were those taught in the simulation.

(3) Although a group that used divergent thinking software scored higher than a convergent thinking group on all creative thinking components of the Torrence Test, the only significant difference was in figural fluency. Critical thinking was not significantly affected by the convergent treatment.

(4) The Logo group displayed significant differences as related to the CAI group in rule determination, in resolution of conflict, and in self-directed work.

(5) Significant gains were found in the verbal analogy skills of students in Grade 7 who had been instructed in analogies using both the microcomputer and conventional methods. No significant differences were found between the control, microcomputer, and conventional groups on logical reasoning, inductive/deductive reasoning, or problem analysis skills (Bass & Perkins, 1984).

(6) CAI appeared to be effective in improving scores on the CTBS and ITBS (mathematics) for disadvantaged/remedial students.

(7) Although pretest scores were the most significant variable in affecting gains in mathematics achievement as measured by the ITBS, findings did suggest that matching instructional method including type of CAI and learning style is important when designing a study with CAI and low ability students.

(8) Although language arts was the curriculum area most affected by use of WICAT, there were significant gains in reading and mathematics achievement. Students below the median exhibited the greater gains.

(9) Students and teachers were generally positive about all CAI systems in affecting changes in attitudes about CAI.

(10) Although all Grade 6 students in a remedial summer program showed improvement in performance on the mathematics subtests of the ITBS with the group using the computer scoring highest, the differences were not significant.

A summary of the conclusions from the fourteen studies support the notion that a combination of instruction by the teacher and planned use of the microcomputer is effective in developing mathematical skills. A cooperative learning environment in which students can talk and plan together works better than an individualistic or competitive atmosphere.

The review of literature on skill development in mathematics and the use of the computer in developing these skills has the following implications which will be addressed in the present study.

1. Both instruction by the teacher and effective use of computers are needed.

2. There is a need to identify software which will effectively develop specific skills in mathematics.

3. Staff development for teachers, including suggestions on ways to introduce the software and to effectively use it

with students, in both whole group and small groups, is essential.

4. A cooperative learning environment should be used when appropriate.

5. It is essential that a test which is a reliable and valid measure for assessing the mathematical skills tested on the State Literacy Passport Test be developed.

The question which remains to be investigated is, "Will the microcomputer be a more effective tool when teaching skills in mathematics to sixth-grade low achieving students than more conventional methods?"

Chapter 3
Procedures

Population and Selection of the Sample

The site for the research study was a suburban school division in Virginia with 24 elementary schools (K-5), five middle schools (6-8), and four senior high schools (9-12). Approximately, 50% of the students were white, 48% were black, and 2% were Hispanics, Asians, and other minorities.

The target population consisted of all students who failed the mathematics section of the State Literacy Passport Test which was administered in the spring of 1990 to Grade 6 students. The sample consisted of the students whose parent(s) or guardian gave permission for them to attend the summer program. Approximately, 100 11-13 year-old students representing each middle school who met the criteria were selected for the program.

Two middle schools, one at each end of the city, were selected as sites. The students were randomly assigned at the two sites to a group. Each group was then checked for balance with respect to gender and race, and adjustments were made where necessary. Each group was randomly assigned to a teacher, and each teacher was randomly assigned to either microcomputer or non microcomputer treatment.

The project covered five weeks of instruction, four days a week for two and one-half hours and was held July 9 - August 9, 1990. Both groups studied the topics tested on the State Literacy Passport Test: numbers and numeration; computation with whole numbers, fractions, and decimals; measurement and geometry; and applications. Although the primary goal of the project was to improve achievement in the skill areas just enumerated, concept development through the use of manipulatives including the calculator, cooperative learning activities centered around problem solving, mathematics as connections, and mathematics as communication both oral and written were the vehicles incorporated into the program for both groups. The development of a positive self-image was also an important goal. Some representative activities are included in Appendix A. The lessons for both groups incorporated these representative examples, but students in the microcomputer group were assigned in pairs to a computer for follow-up, whereas students in the non microcomputer group worked on more conventional follow-up activities (see Appendix B). The teachers in both groups were available to answer questions, to help, and to give encouragement. Approximately, 20% of the time spent in the classroom (30 minutes) was spent with the microcomputer group using software supportive of the designated SOL skills while the students in the other group were involved in group or individual planned activities such as games and puzzles which also supported the SOL skills.

All teachers in the program received more than 30 hours of training in June before the project began (see Appendix C). Since teachers in Hampton are all computer literate, the emphasis was on integrating the microcomputer with mathematics instruction, on using specific software which supported the topics included in the LPT, on cooperative learning, and on "hands on" activities. The teacher's guide was developed during the 1989-90 school year by middle school teachers. The project director coordinated this activity. This guide included ideas and recommended presentations for each group.

Instrumentation

A literacy passport test, an alternate to the State LPT, was developed by the project director using the item specifications supplied by the testing department of the State Department of Education. The test items were examined for content validity by a mathematics supervisor in another school division, by a mathematics educator at the college level, and by a testing/evaluation specialist.

The 91 items were field tested in the spring with approximately 50 students who ranged in ability from low achieving to gifted/talented in mathematics. Concepts on the test were:

Numbers & numeration	13 items
Relations & functions	8 items
Computation, whole numbers	17 items
Computation, fractions	10 items
Computation, decimals	10 items
Measurement & geometry	17 items
Applications	16 items

Scores on the field testing ranged from 36 to 91 items correct. Concurrent validity between the developed test and the LPT administered in the spring exhibited a correlation coefficient of .80 and R squared = .65 (see Table 3.1). Due to time constraints it was impossible to use test/retest to determine reliability. Instead split-half correlation was used to determine the coefficient of internal consistency. The reliability coefficient was found to be greater than .90 (see Table 3.2). The items themselves were examined to find both the difficulty index and the reliability (see Table 3.3). Item difficulty ranged from .34 to 1.00 with only five items having a difficulty index less than .60. Item reliability ranged from zero to .86. Only one-third of the items had reliability less than .45. Items with low reliability had high difficulty (were easy) as expected but are items that all students are expected to answer correctly. Item 8 having a reliability of -.44 was the only item with a negative reliability. This item was on estimation. On close examination it was determined that the less able students by using straight computation not estimation would get the correct answer more often than students using an estimation procedure. For this reason the item was replaced with a more appropriate item on estimation.

Table 3.1

CONCURRENT VALIDITY CORRELATION BETWEEN THE STATE LITERACY PASSPORT TEST AND THE PROJECT DEVELOPED LPT

Count	Covariance	Correlation	R-Squared
50	124.147	.804	.646

Table 3.2

SPLIT-HALF CORRELATION USING ODD AND EVEN ITEMS

Count	Covariance	Correlation	R-Squared
50	42.471	.905	.82

TABLE 3.3

LITERACY PASSPORT TEST ITEM DIFFICULTY AND ITEM RELIABILITY

A: DIFFICULTY INDEX
B: ITEM RELIABILITY

	A	B		A	B		A	B
1	82%	61%	32	70%	49%	63	96%	0%
2	70%	33%	33	90%	55%	64	96%	32%
3	86%	55%	34	88%	49%	65	78%	65%
4	72%	74%	35	84%	70%	66	56%	84%
5	100%	0%	36	84%	55%	67	68%	55%
6	70%	74%	37	94%	56%	68	88%	20%
7	98%	0%	38	86%	42%	69	76%	73%
8	68%	-44%	39	82%	72%	70	34%	55%
9	70%	72%	40	90%	56%	71	54%	73%
10	76%	47%	41	84%	37%	72	90%	56%
11	82%	55%	42	82%	81%	73	94%	85%
12	74%	55%	43	64%	84%	74	98%	32%
13	84%	72%	44	78%	55%	75	92%	37%
14	90%	13%	45	78%	55%	76	70%	72%
15	90%	42%	46	64%	86%	77	98%	32%
16	56%	65%	47	84%	70%	78	86%	55%
17	72%	81%	48	86%	55%	79	98%	32%
18	70%	72%	49	88%	49%	80	72%	49%
19	70%	74%	50	78%	49%	81	92%	20%
20	56%	65%	51	66%	43%	82	82%	72%
21	70%	81%	52	64%	74%	83	80%	72%
22	94%	0%	53	62%	65%	84	70%	49%
23	94%	0%	54	56%	55%	85	66%	86%
24	90%	14%	55	62%	72%	86	76%	72%
25	98%	32%	56	82%	55%	87	60%	86%
26	94%	32%	57	62%	70%	88	74%	81%
27	86%	42%	58	74%	81%	89	82%	74%
28	78%	70%	59	100%	0%	90	62%	86%
29	80%	55%	60	72%	74%	91	80%	70%
30	84%	42%	61	100%	0%			
31	84%	25%	62	84%	25%			

Research Hypotheses

H:1 There will be no significant difference in the overall performance on the literacy passport mathematics test developed by the project director between students using the microcomputer and those not using the microcomputer.

H:2 There will be no significant difference in performance on the subtest on numbers and numeration of the literacy passport mathematics test between students using the microcomputer and those not using the microcomputer.

H:3 There will be no significant difference in performance on the subtest on relations and functions of the literacy passport mathematics test between students using the microcomputer and those not using the microcomputer.

H:4 There will be no significant difference in performance on the subtest on computation of whole numbers of the literacy passport mathematics test between students using the microcomputer and those not using the microcomputer.

H:5 There will be no significant difference in performance on the subtest on computation with decimals of the literacy passport mathematics test between students using the microcomputer and those not using the microcomputer.

H:6 There will be no significant difference in performance on the subtest on computation with fractions of the literacy passport mathematics test between students using the microcomputer and those not using the microcomputer.

H:7 There will be no significant difference in performance on the subtest on measurement and geometry of the literacy passport mathematics test between students using the microcomputer and those not using the microcomputer.

H:8 There will be no significant difference in performance on the subtest on applications of the literacy passport mathematics test between students using the microcomputer and those not using the microcomputer.

Experimental Design

Since students were randomly assigned at each site to one of the groups and each group was then randomly assigned to a teacher, the study was an experimental design (Borg & Gall, 1989). Students were divided into subgroups by score range using data from the State LPT and randomly assigned, by drawing numbered slips of paper, at each site to Group A-D or A-E. After checking for equity for race, sex, and LPT score and making adjustments as needed, each group was then assigned randomly to a teacher who was then assigned randomly to either the microcomputer or non microcomputer treatment. Teachers were willing to be assigned to either treatment.

Transportation was furnished for the students at both sites. Students reported directly to their assigned classroom on arrival at the school and at the end of the day were escorted to the bus. Breaks during the day were limited and were scheduled so that group contact was minimized. The sites selected were those which required the least transportation time for the students. Since the "teen" store, the festival/music theme, and earning "musical notes" were innovations to be shared by all students in the program, it was hoped that bus conversations about the summer program would center around one of these thus reducing any possible effect of contamination.

Teachers selected for all summer school programs in Hampton must apply for the specific program, be recommended by their principal, and then interviewed by a selection committee. Teachers selected for the program were asked which treatment they preferred. For those having no preference (all of them) a random assignment was made. All teachers received the same training. From the evaluation of the project we hoped to determine what treatment works best with this type of student, and those methods will be incorporated during the regular school year following the study and for the summer program the following year.

To control for teacher variability a detailed teacher's guide to be used with both groups was developed as the teacher presentation to each group was to be identical. Follow-up activities, for each skill, were supplied the teachers in the non microcomputer group and detailed plans including the introduction of the software, its correlation with the mathematics skill, and its use were given the teachers in the microcomputer group. Student performance, reviews of appropriate software contained in professional mathematics education and computer journals and "in house" evaluation of software, and cost and availability determined the software used within the program. Extensive staff development sessions of more than 30 hours were held during June 1990.

During the research project visits and classroom observations were made at each site by the project director to monitor implementation. The coordinator within each school also monitored the program. Logs and notes were kept by each teacher and by the students in each group as the writing process was an integral part of the program.

A team of twelve teachers under the supervision of the Director of Secondary Instruction, the Remediation Specialist for the Summer School Program, and the Mathematics Curriculum Specialist developed the teacher's guide. A summer intern and the remediation specialist administered the program at each site.

Financial support for the summer program itself came from the funds allocated by the State for remediation. The funds for staff development and for the purchase of some of the software came through a Title II grant.

The hardware used with the microcomputer group consisted of Apple IIGS microcomputers from the computer laboratories in the middle schools. Much of the software used with the microcomputer group was from Minnesota Educational Computer Corporation (MECC) as the school system has a site license and can therefore duplicate the computer programs as needed. All software used in the program (see Appendix D) was evaluated for consistency with the principles which are the basis of the program, for adherence to the rules of instructional design, for content match to the specific skills tested on the State Literacy Passport Test, and for the documentation and ease of its use (Clements, 1989).

Analysis

Scores from the mathematics section of the State LPT administered, March 28, 29, 1990 were used for pretest data. The posttest was the literacy test developed by the project director. This test was given both sets of students during the fifth week of the summer program. The tests were scored by the Hampton City Data Processing Center.

Since the subjects were randomly assigned at each site, a *t*-test was used to test for significant differences between the groups using the microcomputer and those using other activities (Borg & Gall, 1989). The .05 level of confidence was selected for the study.

Ethical Safeguards

All students in the study were students who did not pass the mathematics section of the State Literacy Passport Test the previous spring and whose parent(s) or guardian signed a contract of commitment to the program. The content addressed was that which is included in the Hampton City Schools Mathematics Program. Students were informed that they were part of a project to determine the effectiveness of different methods in enhancing the development of mathematics skills. Students not in the microcomputer group were told that they would be using the microcomputer during the fifth week of the program following the testing.

Chapter 4

Analysis of Results

The purpose of this study was to determine whether teaching the mathematics skills tested on the State Literacy Passport Test with the microcomputer produces a greater incréase in students' mathematics scores on a test developed by the project director similar to the State LPT than those not using the microcomputer.

After the students completed the tests, they were collected and scored by the Data Processing Center. Using the State LPT as the pretest, posttest achievement, the dependent variable, was computed for the total test and for each subtest. This resultant data was analyzed using Macintosh StatView. The means and standard deviations for pretest and posttest were computed for both groups (see Table 4.1). The pretest means for the total test and all subtests but computation with whole numbers and numbers and numeration were found to be comparable. The pretest means on the computation with whole numbers subtest was significant ($t(87) = 1.946$, $p < .05$) in favor of the non microcomputer group (see Table 4.2). The pretest means on the numbers and numeration subtest did not appear to be comparable although on analyzing the data the difference ($t(87) = -1.143$, $.1 < p < .375$) was not found to be significant at $p<.05$ (see Table 4.3). The unpaired t-values were then found for the total test and subtests to determine significance.

TABLE 4.1

A SUMMARY OF PRE/POST TEST MEANS AND STANDARD DEVIATIONS

	NON-MICROCOMPUTER					MICROCOMPUTER				
		PRETEST		POSTTEST			PRETEST		POSTTEST	
	N 39	X	SD	X	SD	N 50	X	SD	X	SD
NUM/NUMBERS		6.333	3.115	8.641	2.661		7.04	2.755	9.66	2.172
REL/FUNC		3.538	1.533	4.59	1.534		3.62	1.589	4.72	1.617
WHOLE		11.744	2.721	11.103	3.447		10.44	3.424	11.9	2.779
DECIMALS		4.179	1.73	4.641	2.117		4	2.03	5.64	2.068
FRACTIONS		3.795	1.908	4.282	1.835		4.04	2.176	5.58	2.26
MEAS/GEOM		10.103	2.36	11.282	2.513		10.02	2.36	12.1	2.063
APPL		7.718	2.564	8.333	2.832		8.1	3.24	8.8	2.626
TOTALS		47.41	8.463	52.872	10.984		47.16	10.454	58.36	10.291

*NUMBER PRE/POST MATCHES

TABLE 4.2

UNPAIRED t-TEST WHOLE NUMBERS PRETEST SCORES

X: WHOLE NUMBERS PRETEST NON MICROCOMPUTER

Y: WHOLE NUMBERS PRETEST MICROCOMPUTER

DF:	X Count:	Y Count:	Mean X:	Mean Y:	Unpaired t Value:
87	39	50	11.744	10.44	1.946
					$.025 < p \leq .05$

TABLE 4.3

UNPAIRED t-TEST NUMBERS/NUMERATION PRETEST SCORES

X: NUMBERS/NUMERATION PRETEST NON MICROCOMPUTER

Y: NUMBERS/NUMERATION PRETEST MICROCOMPUTER

DF:	X Count:	Y Count:	Mean X:	Mean Y:	Unpaired t Value:
87	39	50	6.333	7.04	-1.134
					$.1 < p \leq .375$

Hypothesis H:1

There will be no significant difference in the overall performance on the literacy passport mathematics test developed by the project director between students using the microcomputer and those not using the microcomputer.

The results of the data analysis indicated a posttest mean of 52.9 for the non microcomputer group and a mean of 58.4 for the microcomputer group, indicating a 5.5 point gain for the non microcomputer group and a 11.1 point gain for the microcomputer group. An unpaired *t*-test was performed between the posttests of the two groups to determine whether a significant difference ($p<.05$) was obtained as a result of using the microcomputer. A significant difference ($t(87) = -2.522$, $p < .01$) was obtained using the posttest data (see Table 4.4). On the basis of the difference in the posttest scores in favor of the group using microcomputers, Hypothesis H:1 was rejected.

TABLE 4.4

HYPOTHESIS 1 UNPAIRED t-TEST FOR POSTTEST TOTAL SCORES

X: TOTAL POSTTEST NON MICROCOMPUTER

Y: TOTAL POSTTEST MICROCOMPUTER

DF:	X Count:	Y Count:	Mean X:	Mean Y:	Unpaired t Value:
87	39	50	52.872	58.36	-2.424
					$.005 < p \leq .01$

Hypothesis H:2

There will be no significant difference in the overall performance on the subtest on numbers and numeration of the literacy passport mathematics test between students using the microcomputer and those not using the microcomputer.

Data analysis results indicated a posttest mean of 8.6 for the non microcomputer group and a posttest mean of 9.7 for the microcomputer group. An unpaired *t*-test was performed between the two groups. A significant difference ($t(87) = -1.989$, $p < .025$) was obtained using the posttest data (see Table 4.5), but since the posttest gains were not significant, Hypothesis H:2 was accepted.

TABLE 4.5

HYPOTHESIS 2 UNPAIRED t-TEST NUMERATION POSTTEST SCORES

X: NUMERATION POSTTEST NON MICROCOMPUTER
Y: NUMERATION POSTTEST MICROCOMPUTER

DF:	X Count:	Y Count:	Mean X:	Mean Y:	Unpaired t Value:
87	39	50	8.641	9.66	-1.989
					$.01 < p \leq .025$

Hypothesis H:3

There will be no significant difference in the overall performance on the subtest on relations and functions of the literacy passport test between students using the microcomputer and those not using the microcomputer.

Posttest means on the subtest for relations and functions were computed for the two groups. The results indicated a posttest mean of 4.6 for the non microcomputer group and a posttest mean of 4.7 for the microcomputer group. An unpaired t-test indicated no significant difference ($t(87) = -.386$, $.1 < p < .375$) between the two groups on posttest scores (see Table 4.6), so Hypothesis H:3 was accepted.

TABLE 4.6

HYPOTHESIS 3 UNPAIRED t-TEST RELATIONS POSTTEST SCORES

X: RELATIONS POSTTEST NON MICROCOMPUTER
Y: RELATIONS POSTTEST MICROCOMPUTER

DF:	X Count:	Y Count:	Mean X:	Mean Y:	Unpaired t Value:
87	39	50	4.59	4.72	-.386
					$.1 < p \leq .375$

Hypothesis H:4

There will be no significant difference in the overall performance on the subtest on computation with whole numbers of the literacy passport mathematics test between students using the microcomputer and those not using the microcomputer.

Posttest means were computed for each group. The non microcomputer group had a mean posttest score of 11.1 and the microcomputer group had a posttest mean of 11.9. An unpaired *t*-test indicated no significant difference ($t(87) = -1.208$, $.1 < p < .375$) between the two groups on posttest scores (see Table 4.7). Since the microcomputer group, though started out with a significant deficit ($t(87) = 1.946$, $.025 < .05$) and surprassed the non microcomputer group on posttest means, Hypothesis H.4 was rejected in favor of the group using the microcomputer.

TABLE 4.7

. HYPOTHESIS 4 UNPAIRED t-TEST WHOLE NUMBERS POSTTEST

X: WHOLE NUMBERS POSTTEST NON MICROCOMPUTER

Y: WHOLE NUMBERS POSTTEST MICROCOMPUTER

DF:	X Count:	Y Count:	Mean X:	Mean Y:	Unpaired t Value:
87	39	50	11.103	11.9	-1.208
					$.1<p\leq.375$

Hypothesis H:5

There will be no significant difference in the overall performance on the subtest of computation with decimals of the literacy passport mathematics test between students using the microcomputer and those not using the microcomputer.

Posttest means were computed for both groups. The results indicated a posttest mean of 4.6 for the non microcomputer group and a posttest mean of 5.6 for the microcomputer group. An unpaired t-test was performed between the two groups to determine whether a significant difference ($p<.05$) in posttest scores was obtained as a result of using the microcomputer. A significant difference ($t(87) = -2.284$, $p < .025$) was obtained as a result of using the microcomputer (see Table 4.8). On the basis of this, Hypothesis H:5 was rejected in favor of the group using the microcomputers.

TABLE 4.8

HYPOTHESIS 5 UNPAIRED t-TEST DECIMALS POSTTEST SCORES

X: DECIMALS POSTTEST NON MICROCOMPUTER

Y: DECIMALS POSTTEST MICROCOMPUTER

DF:	X Count:	Y Count:	Mean X:	Mean Y:	Unpaired t Value:
87	39	50	4.641	5.64	-2.284
					$.01<p\leq.025$

Hypothesis H:6

There will be no significant difference in the overall performance on the subtest on computation with fractions of the literacy passport mathematics test between students using the microcomputer and those not using the microcomputer.

Posttest means were computed for the two groups. The results indicated a posttest mean of 4.3 for the non microcomputer group and a posttest mean of 5.6 for the microcomputer group. An unpaired *t*-test was performed between the two groups to determine whether a significant difference ($p<.05$) in posttest scores was obtained as a result of using the microcomputer. A significant difference $t(87) = -2.914$, $p < .005$) was obtained as a result of using the microcomputer (see Table 4.9). On the basis of this, Hypothesis H:6 was rejected in favor of the group using the microcomputer.

TABLE 4.9

HYPOTHESIS 6 UNPAIRED t-TEST FRACTIONS POSTTEST SCORES

X: FRACTIONS POSTTEST NON MICROCOMPUTER
Y; FRACTIONS MICROCOMPUTER

DF:	X Count:	Y Count:	Mean X:	Mean Y:	Unpaired t Value:
87	39	50	4.282	5.58	-2.914
					$.0005<p\leq.005$

Hypothesis H:7

There will be no significant difference in the overall performance on the subtest on measurement and geometry on the literacy passport mathematics test between students using the microcomputer and those not using the microcomputer.

On computing the posttest means, a posttest mean of 11.3 was obtained for the non microcomputer group and a posttest mean of 12.1 for the microcomputer group. An unpaired *t*-test was performed between the two groups to determine whether a significant difference ($p<.05$) was obtained as a result of using the microcomputer. A significant difference ($t(87) = -1.686$, $p<.05$) was obtained as a result of using the microcomputer (see Table 4.10). On the basis of this, Hypothesis H:7 was rejected in favor of the group using the microcomputers.

TABLE 4.10

HYPOTHESIS 7 UNPAIRED t-TEST MEASUREMENT POSTTEST SCORES

X: MEASUREMENT/GEOMETRY POSTTEST NON MICROCOMPUTER
Y: MEASUREMENT/GEOMETRY POSTTEST MICROCOMPUTER

DF:	X Count:	Y Count:	Mean X:	Mean Y:	Unpaired t Value:
87	39	50	11.282	12.1	-1.686
					$.025<p\leq.05$

Hypothesis H:8

There will be no significant difference in the overall performance on the subtest on applications on the literacy passport mathematics test between students using the microcomputer and those not using the microcomputer.

Data analysis results indicated a posttest mean of 8.3 for the non microcomputer group and a posttest mean of 8.8 for the microcomputer group. An unpaired *t*-test was performed between the posttests of the two groups to determine whether a significant difference, ($p \leq .05$), was obtained as a result of using the microcomputer. No significance ($t(87) = -.804$, $p > .05$) was found (see Table 4.11), so Hypothesis H:8 was accepted.

TABLE 4.11

HYPOTHESIS 8 UNPAIRED t-TEST APPLICATIONS POSTTEST

X: APPLICATIONS POSTTEST NON MICROCOMPUTER
Y: APPLICATIONS POSTTEST MICROCOMPUTER

DF:	X Count:	Y Count:	Mean X:	Mean Y:	Unpaired t Value:
87	39	50	8.333	8.8	-.804
					$.1 < p \leq .375$

Summary

T-tests to determine statistical significance indicated that students using the microcomputer achieved higher posttest scores on a literacy passport mathematics test which tested the Virginia Standards of Learning for grades 4-6 than students not using the microcomputer.

Unpaired t-tests to determine statistical significance indicated that students using the microcomputer also achieved higher posttest scores on the subtests on computation with decimals, computation with fractions, and measurement and geometry than those not using the microcomputer.

.On the computation with whole numbers subtest an unpaired t-test for posttest scores indicated no significant difference for the microcomputer group. The microcomputer group, though, started out with a deficit and through remediation surpassed the non microcomputer group. The opposite was true with the numbers and numeration subtest, where an unpaired t-test for posttest scores indicated a significant difference for the microcomputer group, but this difference is mitigated by pretest means which favored the microcomputer group. Actual gains in this instance were virtually the same for both groups.

Chapter 5

Conclusions

The purpose of this study was to determine the effectiveness of using the microcomputer to remediate students, who did not pass the mathematics section of the Virginia Literacy Passport Test, during a five week summer program.

Summary

The Standards of Quality for Public Schools in Virginia require that students pass a Literacy Passport Test in mathematics, reading, and writing administered to Grade 6 students beginning in 1989-90 or to Grade 7 and Grade 8 students who were not successful in Grade 6 or Grade 7. It is the responsibility of the local school divisions to provide remediation programs for those who are not successful. Students must pass all three sections of the test to be classified as ninth graders. The LPT addresses the Virginia Standards of Learning for grades 4 through 6.

National and international studies (A Nation at Risk, Educating Americans for the 21st Century, 1983; SIMS, Fourth Mathematics Assessment, 1986; Everybody Counts, 1989) have cited the need for improving the achievement of

United States students in mathematics and for utilizing the power of technology in instruction.

A review of research supports the use of microcomputers with upper elementary and middle school students to enhance the learning of mathematics skills. Roblyer, Castine, and King (1988) in their meta-analysis found that the average effect size for studies involving microcomputers and mathematics was in the medium to high range and that studies of low achieving students who used the microcomputer had an average effect size also in the high medium range.

The summer program was created as a result of the need to remediate students who had not passed the newly adopted Literacy Passport Test. In developing the program several important questions were considered: (a) How could we teach students who previously have not been successful in mathematics differently in order to facilitate academic success, and (b) could we expect greater student gains when using nontraditional strategies? The selection of computer-assisted instruction as a follow-up to teacher directed instruction was based on prior research findings. This study extends the previous research on the effectiveness of using microcomputers to improve the mathematics achievement of low achieving middle school students.

Methodology

The target population for the study included approximately 275 rising seventh grade students who did not pass the mathematics section of the State LPT in March, 1990. Letters were sent to the parents asking to enroll these students in a summer school mathematics program. About forty percent of the parents committed to the program.

Students and teachers were randomly assigned to either the microcomputer or non microcomputer group based on the total raw scores on the LPT. Nine classes were formed with five being taught using the microcomputer. Teachers who taught in the summer program received more than 30 hours of staff development prior to the summer session and used the teacher's guide prepared by middle school teachers. The topics for the lesson plans included: numeration and numbers, relations and functions, computation with whole numbers, computation with decimals, computation with fractions, measurement and geometry, and applications. The lessons for both summer school groups included identical teacher directed activities. Students in the microcomputer group were assigned in pairs to a microcomputer and spent approximately 20% of the day (30 minutes) using the microcomputer for follow-up activities whereas the students in the non microcomputer group worked on more conventional follow-up activities such as games and puzzles. The students attended classes for two and one-half hours, four days a week for five weeks. The theme of music was used throughout with students earning musical notes with which they could buy items at the teen store.

A literacy passport test developed by the project director was used as the posttest assessment. It was examined for content validity and was field tested in the spring with 50 sixth grade students of varied abilities. Concurrent validity between the developed test and the LPT was greater than .80. Using split-half correlation the reliability coefficient was found to be greater than .90. The State LPT was used as the pretest for the study. Thirty-nine students from the non microcomputer group and fifty students from the microcomputer group had pretest/posttest matches.

Major Findings

Posttest raw scores for the total test and all subtests were computed, and *t*-tests were performed to determine if there were significant differences between the posttest scores of students using the microcomputer and those not using the microcomputer.

Significant differences in posttest scores were indicated for the total test and for the subtests of: computation with decimals, computation with fractions, and measurement and geometry. On the subtest on computation with whole numbers students in the microcomputer group experienced significant posttest gains, but the posttest differences were not significant due to the differences in pretest scores.

Implications

The major findings of the study suggest that using the microcomputer does promote the development of mathematics skills for the low achieving middle school students. Whether the microcomputer alone or the interaction of the students with each other and the computer are responsible should be researched in another study.

Since the areas of computation with decimals, computation with fractions, and measurement and geometry were affected most with significant gains in computation with whole numbers also, it appears that the specific software used might have affected the results. MECC does have a variety of software programs which were used in the project that address computational skills with whole numbers, decimals, and fractions. Some of these are tutorial such as: Decimal Concepts, Quotient Quest, Conquering Decimals, Conquering Whole Numbers, and Fraction Concepts whereas others such as Number Munchers and Fraction Munchers have a game format. Barnum's Quarter Mile which emphasized drill in a competitive format also was popular with students and teachers. There appeared to be a positive relationship between the tutorial and game format software and student gains. Although MECC Market Place and Scholastic Math Shop are listed as simulations they probably worked best as reinforcement of whole number and decimal concepts (see Appendix D for a list of software).

MECC software was also used for the concepts of measurement and geometry. This software included Measureworks, Elementary Mathematics Volume 1, and Plane Geometry. Although EZ Logo is on an elementary level students did learn some geometry as they programmed the turtle.

Gains on the subtest on numbers and numeration, although not significant, do suggest that some of the software used was effective. Since the project MECC has revised their programs on estimation, and these will be used in the future.

The software which was used for the section on applications for the project did not address the specific skills of determining whether problems had "just enough", "not enough", and "more than enough information" which were tested on the LPT but rather emphasized logical thinking and problem solving. It would, therefore, appear that students perform best in problem situations when the presentation is closest to that which is tested and, therefore, software such as

SVE Word Problems should be included in future programs which address the application skills of the LPT.

Although there were essentially three types of software --CAI/tutorial, simulation, and games--used in the project, no attempt was made to determine whether one type was more effective than another.

During the five week summer program the learning environment in which the treatments took place assumed added importance. Very often in a research project more attention is given to a treatment and less importance to the classroom and school environment. Students, teachers, and parents reacted very positively to the thematic approach, the movie, the pizza party, the teen store and the awards ceremony which were highlights for both groups.

Recommendations for Future Research

As a result of the analysis of data from this study recommendations for future research which will provide additional information regarding the effectiveness of the microcomputer in increasing the mathematics achievement of middle school students are as follows:

1. Conduct the research over a longer period of time so that computation could be de-emphasized, but students as a result of seeing the importance of learning mathematics for real life applications would learn to compute.

2. Conduct a study to determine the effectiveness of different kinds of software such as CAI, tutorial, simulations, and games on the development of mathematics competencies.

3. Conduct a study to determine the effectiveness of individualistic computer-assisted instruction vs. pairing for computer-assisted instruction.

4. Conduct a study to evaluate the effectiveness of software which had been specifically matched to the levels of instruction and difficulty for identified student needs and which addresses the diagnosed errors of these students.

5. Conduct a similar study during the regular school year to determine the effectiveness of using the microcomputer with non-remedial middle school mathematics students.

Reflections

A limitation of the research study is that the mathematics competencies tested in the program are only those which were tested on the Virginia Literacy Passport Test. The result is that many of the competencies listed in the NCTM Curriculum and Evaluation Standards for School Mathematics (1989) were not included in the assessment of the project. It is hoped that in the future the Virginia Standards of Learning for Mathematics for grades 4-6 will emphasize computation less, will encourage the use of calculators where appropriate, and will be based on the NCTM curriculum standards, particularly, the standards--mathematics as problem solving, mathematics as communication, mathematics as reasoning, and mathematics as connections--which were a vital part of the summer program even though they were not tested.

APPENDIX A

SAMPLE ACTIVITIES

TOPIC	DAY	ACTIVITIES
OPENING DAY	1st	Getting to Know You Who Am I? I'm a Disney Character. Write a "Name Poem"
NUMBERS/NUMERATION		
PLACE VALUE, WHOLE #	1st	Chip Trading Guess the Value of the Blocks Logic Puzzle "Rock Tour" Calculator Activity "Place Value"
READ/WRITE DECIMALS COMPARE WHOLE #	2nd	Comparative Shopping Cooperative Learning Strips "Comparing Decimals" Tetrahedron Puzzle
ROUNDING	3rd	Choral Round Up Cooperative Learning (CLA) "Number Detective" Aim for a Bull's Eye
COORDINATE GEOMETRY ESTIMATION	4th	Coordinate Activity Using Desks The Beat Goes On Educated Guesses- Peanut Butter/Crackers

SAMPLE ACTIVITIES

TOPIC	DAY	ACTIVITIES
COORDINATE GEOMETRY ESTIMATION		Guessing Smart Calculator Shopping
COMPUTATION WHOLE NUMBERS	1st	Sum Letters in Your Name Funny Facts of History
DECIMALS	2nd	"How Much?" Using Old Newspapers & Magazines How Much Change? What If? Boom Box Sound Signal Words CLA Problem Solving "Create Your Own Problem"
EQUIVALENT FRACTIONS	3rd	Fractured Names Film "Weird Numbers" Reactions to the Film CLA Write a Commercial about the Film
FRACTIONS +, -	4th	Fraction Strips Use 7 - 4's to Make 100, 8 - 8's to Make 1000, etc. Magic Squares with Fractions
FRACTIONS X, ÷ SUFFICIENT/INSUFF. DATA	5th	Boy Are You Smart - transparency

SAMPLE ACTIVITIES

TOPIC	DAY	ACTIVITIES
FRACTIONS X, ÷ SUFFICIENT/INSUFF. DATA		Triple Decker Writing Activity Electric Slide Multiplication Guide CLA "Every Little Step" Cut Apart Using Recipes CLA Word Problems Cut Apart
REVIEW & PROBLEM SOLVING	6th & 7th	Computational Intrique Tooth Pick Problems Homework Headaches Pro's & Con's Going for a Spin - Calculator Activity, Using Mileage Chart & Map Record Sales Solving Problems Using A Chart Math Memory Test Logical Reasoning Patterns
MEASUREMENT/GEOMETRY		
LINEAR MEASURE IDENTIFY PTS, LINES, ETC	1st	Measure Actual Objects Using a Ruler

SAMPLE ACTIVITIES

TOPIC	DAY	ACTIVITIES
PARALLEL PERIMETER		Geoboard Activities Create Your Own Picture Tangram Activities Label Actual Objects
PERIMETER		Geometric Shapes Write "Geometry in the World Around Us"
PERIMETER/AREA	2nd	Real World Examples Use Centimeter Paper - Area CLA Find Areas of Windows, Doors, etc by Measuring Dimensions CLA Create a Label for CD Geoboard Activities
LENGTH/PERIMETER/ AREA	3rd	Mystery Shapes Measure Using Trundle Wheel CLA List Examples of Perimeter/Area Problem Solving - Wallpapering, Painting, etc. CLA Using Attribute & Pattern Blocks & Tangrams

SAMPLE ACTIVITIES

TOPIC	DAY	ACTIVITIES
TIME/MONEY/VOLUME/ MASS	4th	Counting "Play Money" How Many Ways Can You Make $1.00? Measurement Centers
CULMINATING ACTIVITIES	5th & 6th	CLA Complete Musical Theme Park Complete CD Cover CLA Determine Approx. Distances Using Busch Gardens Map

APPENDIX B

FOLLOW-UP ACTIVITIES AND SOFTWARE

	SOL'S	ACTIVITY SHEETS	SOFTWARE
NUMBERS/NUMERATION			
4.01, 5.01, 6.01	**The student will:** identify place value up to nine digit whole numbers	Use MECC Conquering Math Worksheet Generator	MECC "Path Tactics"
4.03, 5.02, 6.02	round whole number 99,999 or less to nearest ten, hundred, thousand, or ten-thousand	"Number Detective" "Record Sales" (Day 1) "Concert Tickets" (Day 1)	MECC "Number Munchers" Salina "Math Games, "Round Table" "Math Strategies" Lessons 1 & 2
4.04, 5.03	estimate results of simple computation problems involving	Worksheet B (Day 1) "Faster Than a Chicken"	SRA "Estimation" MECC "Estimation" (limited number of copies, may not

FOLLOW-UP ACTIVITIES AND SOFTWARE

	SOL'S	ACTIVITY SHEETS	SOFTWARE
	addition, subtraction, multiplication and division of whole numbers	"Estimating Products" "Estimation Hot Line" "Why is a Baseball Team Like a Pancake?" Keyboard Worksheet "Putting Together a Stereo System" "On the Road"	copy) Holt "Math Unlimited Adventures in Problem Solving" Disk 1 - Activity 1, 3 Silver Burdette Courseware - "Strategies in Problem Solving II", "Duets-Patterns" SRA "Math Strategies" Lessons 3-6
4.11, 5.08	read and write decimals as tenths and hundredths	All students do same activities	No software

FOLLOW-UP ACTIVITIES AND SOFTWARE

	SOL'S	ACTIVITY SHEETS	SOFTWARE
RELATIONS/FUNCTIONS	**The student will:**		
4.02, 5.09	compare whole numbers using >, <, =	"Boom Box" Worksheet "Composing & Ordering Number Detective"	Holt Mathematics Unlimited "Adventures in Problem Solving" Act. 1-4
6.08	compare decimals through thousandths using >, <, =	"Decimal Comparison" Worksheets (Day 2)	MECC "Decimal Concepts" Houghton Mifflin "Mathematic Activities" Level 5, Disk C Barnum "Quarter Mile"
5.16	name points as ordered pairs & associate ordered pairs with points in the first quadrant of a coordinate plane	"Riddle Math"	Sunburst "Battleship" MECC "Coordinate Math" MECC "Elementary Mathematics" Vol. 1

FOLLOW-UP ACTIVITIES AND SOFTWARE

	SOL'S	ACTIVITY SHEETS	SOFTWARE
COMPUTATION WHOLE NUMBERS			
	The student will:		
4.05, 4.10, 5.04, 5.07, 6.04, 6.07	add, subtract, multiply & divide whole numbers	**DAY ONE** "Playing the Sounds of the Multiplication Chart" "Can't Beat It" "Turn On To Math" "Record Spin With Professor Ben" "Drumming to the Sounds of Division" "Computer Print-Out" "Multiplication Puzzle" **DAY TWO** See additional sheets	MECC "Conquering Whole Numbers" MECC "Number Munchers" MECC "Quotent Quest" MECC "Multiplication Puzzles" MECC "Speedway Math" MECC "Subtraction Puzzles"

FOLLOW-UP ACTIVITIES AND SOFTWARE

	SOL'S	ACTIVITY SHEETS	SOFTWARE
4.22, 5.21, 6.19	solve word problems involving +, -, x, and division whole numbers	"Station Identification" (Day 1 Computation) See activities at end of computation Day 5	MECC "Path Tactics" Silver Burdette "Strategies for Problem Solving"
COMPUTATION DECIMALS			
	The student will:		
4.12, 4.13, 5.10, 5.11, 6.9, 6.12	add, substract, multiply and divide decimals	"Famous Quotations" (Day 1) "What is the Title of This Picture?" (Day 1) "Alto Addition Presto" (Day 2) "Multiplication Fascination" (Day 2) "Musical Math Score"	MECC "Decimal Concepts" MECC "Conquering Decimals" MECC "Market Place"

FOLLOW-UP ACTIVITIES AND SOFTWARE

	SOL'S	ACTIVITY SHEETS	SOFTWARE
		(Day 2) Other sheets Day 2	
COMPUTATION FRACTIONS			
	The student will:		
4.14, 4.15,	add, subtract, &	"Zip Zap" (Day 4)	MECC "Fraction Concepts & Munchers"
5.13, 5.14, 6.13. 6.15	multiply fractions	"Adding Like Fractions" Subtraction Worksheet (Day 4) See Optional Activities Day 5	MECC "Conquering Fractions" Salina "Math Games"

FOLLOW-UP ACTIVITIES AND SOFTWARE

	SOL'S	ACTIVITY SHEETS	SOFTWARE
5.12	find fractions equivalent to a given fraction	See Worksheets (Day 3) "Folded Fractions" (Day 3)	MECC "Fraction Munchers" Salina "Math Games"
6.2	solve word problems requiring the use of addition, subtraction, multiplication of fractional numbers	See word problems Days 3-5	MECC "Conquering Fractions"
MEASURMENT/GEOMETRY			
	The student will:		
4.16	measure length in metric & customary	Use meter/yard stick and rulers to measure actual objects in the	MECC "Measure Works" MECC "Elementary Mathematics" Vol. 1

FOLLOW-UP ACTIVITIES AND SOFTWARE

	SOL'S	ACTIVITY SHEETS	SOFTWARE
		classroom. See "Use a Chair to Teach Math" (Day 4 Work Sheet) "It's Off to the Races" (Day 1) Work Sheets B & C (Day 1)	
4.17	measure liquid volume using metric & U.S. customary units	Cooperative Learning Centers (Day 4) "Kool Aid" Worksheet (Day 4)	MECC "Measure Works"
4.18	determine the value of a collection of money which has total value less than $10.00	Work Sheet Money (Day 4) "Add the Shapes " (Day 4)	MECC "Money Works" MECC "Elementary Math" Vol. 1

FOLLOW-UP ACTIVITIES AND SOFTWARE

	SOL'S	ACTIVITY SHEETS	SOFTWARE
		"Make the Shapes" (Day 4)	
4.19	tell time to the nearest minute	Work Sheet B & C (Day 4) Time Message (Day 4)	MECC "Clock Works"
4.20	given an appropriate figure, identify points, line segments & angles	Geoboard Exploration "Marshmallow Tooth-pick Geometry" (Day 1) Work Sheet A & B (Day 1)	MECC "EZ LOGO" MECC "Plane Geometry" Problem Solving II Find the Rule: Guess & Test
5.15	measure weight/mass using metric & U.S. customary	Learning Centers (Day 4) "Kool Aid" Worksheet (Day 4)	MECC "Measure Works"

FOLLOW-UP ACTIVITIES AND SOFTWARE

	SOL'S	ACTIVITY SHEETS	SOFTWARE
5.17	given appropriate information, identify those lines which illustrate the concepts of parallelism	Work Sheet A (Day 2)	MECC "EZ LOGO"
5.18	identify from a set of statements those which represent an application of the concept of perimeter application	Work Sheet (Day 1) Geoboard Explorations "Onward and Upward" (Day 2) "Perimeter Code" Worksheet (Day 1) SOL Worksheet 5.18 (p. 2) SOL Worksheet A5.18 (p. 3) Day 3 Activity Sheet	MECC "Measure Works"

FOLLOW-UP ACTIVITIES AND SOFTWARE

	SOL'S	ACTIVITY SHEETS	SOFTWARE
5.19	identify from a set of statements those which represent an application of the concept of area	Tangram Sheets (Day 2) Day 3 Activity Sheets	MECC "Measure Works"
6.16	add and subtract measurements without regrouping of measurement units	Worksheet A & B (Day 4)	Work Sheet A & B (Day 4) (no software)
6.17	find the perimeter of a polygon having six sides or less	Geoboard Extensions SOL Work Sheets A & B (Day 1) Convex Polygons from the Tangram Puzzle (students can	MECC "Plane Geometry" MECC "Measureworks"

FOLLOW-UP ACTIVITIES AND SOFTWARE

	SOL'S	ACTIVITY SHEETS	SOFTWARE
		determine perimeters of pieces) "Onward & Upward" Worksheet (Day 2)	
6.18	given an appropriate drawing, find the area for squares and rectangles	"A Square Deal" (Day 2) Tangram Sheets (Day 2) Work Sheet A (Day 2) Counting Square to Find Areas (Day 3) Work Sheet B (Day 3) "Why Did Orgo Use Yeast & Shoe Polish" (Day 3) "What is the Title of This Picture" (Day 2)	MECC "Measureworks" Houghton-Mifflin Courseware Level 5 "Centipede Racers" Disk B

FOLLOW-UP ACTIVITIES AND SOFTWARE

	SOL'S	ACTIVITY SHEETS	SOFTWARE
		Area of Rectangle Worksheets (Day 2)	
APPLICATIONS			
	The student will:		
4.24, 5.22, 6.22	solve "non-routine" problems	See optional activities at the end of computation Day 5	MECC "Path Tactics"
6.21	determine if given problem includes efficient or unnecessary information	SOL Worksheet 6.21 pp. 3, 4	SOL Worksheet 6.21 pp 3, 4 No software

APPENDIX C

PLANS FOR STAFF DEVELOPMENT
GRADE 7 MATHEMATICS TEACHERS
DAVIS MIDDLE SCHOOL
11-14 JUNE 1990
8:30 A.M. - 4:30 P.M.

Schedule: Days 1-4

8:30 - 8:45 a.m. Opening
8:45 - 11:45 a.m. Session I
11:45 - 1:00 p.m. Lunch
1:00 - 4:15 p.m. Session II

DAY ONE
Small Groups

SELF ESTEEM - Peggy Brooks
COOPERATIVE LEARNING -
Lillie Calloway
Mary Wallen

DAY TWO
Small Groups

"HANDS ON" AND OTHER IDEAS
Joyce Weeks
Connie Elmore
Bruce Butler

COMPUTER - Georgia Scott and Jennifer Carrigan will demonstrate teacher utilities such as Slide Show and FredWriter; strategies for using one or two micro-computers within the classroom, large group instruction with the LCD and instruction in the computer lab.
Trouble shooting, connecting/disconnecting and

	evaluation of software correlated to LPT objectives - Bruce Butler Georgia Scott Jennifer Carrigan
DAY THREE	
Small groups	Use of the **CALCULATOR** in concept development, problem solving, and other activities - Joy Garrett Virginia Brown Brenolder Johnson
	QUANTITATIVE LITERACY - Statistical display of data - Dr. Ann Trahanovsky Orletsky Susan Bailey Kay Quitko Charlotte Copley
DAY FOUR	
Small groups or individual	**SOFTWARE EVALUATION** **DESIGNING A LESSON INTEGRATING STRATEGIES FROM WORKSHOP**

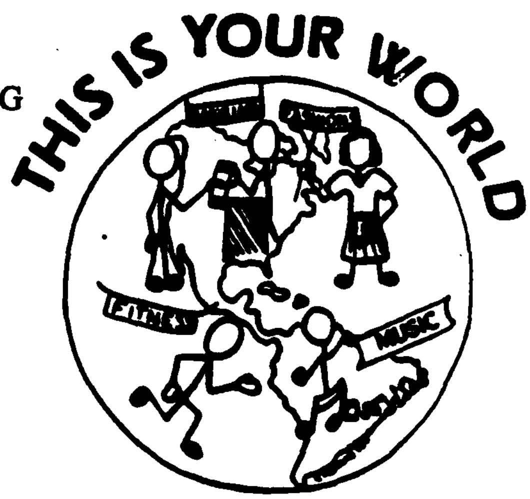
SUMMER PASSPORT PROGRAM

20 JUNE 1990

ROOM 202

HAMPTON CITY SCHOOL ADMINISTRATIVE CENTER

8:30 - 9:30	WELCOME
	SALARY INFORMATION
	OVERVIEW OF SUMMER PROGRAM
	PURPOSE ACHIEVEMENT SELF CONCEPT
	CLASS LISTS/ROOM ASSIGNMENTS
	INSTRUCTIONAL MATERIALS
	COMMUNICATIONS WITH PARENTS
9:30 - 11:30	TEAM PLANNING
11:30 - 1:00	LUNCH
1:00 - 3:30	TEAM PLANNING



APPENDIX D

PASSPORT SOFTWARE

SOL'S		SOFTWARE
NUMBERS/NUMERATION		
	The student will:	
4.01, 5.01, 6.01	identify place value to nine digit whole numbers	MECC "Path Tactics" Drill/Practice MECC "Elementary Mathematics VI" Tutorial
4.03, 5.02, 6.02	round whole numbers 99,999 or less to nearest ten, hundred, thousand, or ten-thousand	Salina "Math Games, Round Table" Drill/Practice Houghton Mifflin Mathematics Activities Courseware Disk A, Level 5 Tutorial MECC "Number Munchers" Game
4.04, 5.03	estimate results of simple computation problems	SRA "Estimation" Drill/Practice MECC "Estimation" Drill/Practice

PASSPORT SOFTWARE

SOL'S		SOFTWARE
	involving addition, subtraction, multiplication and division of whole	Holt Mathematics Unlimited "Adventures in Problem Solving" Disk 1, Act 1, 2 SRA "Math Strategies" Problem Solving
4.04, 5.03	numbers	Lessons 1-3 Houghton Mifflin Mathematics Activities Courseware, Level 5 Tutorial Silver Burdette Courseware "Strategies in Problem Solving II- Duets- Patterns" Problem Solving
4.11, 5.08	read and write decimals as tenths hundredths	

PASSPORT SOFTWARE

SOL'S		SOFTWARE
RELATIONS/FUNCTIONS		
	The student will:	
4.02, 5.09	compare whole numbers using >, <,=	Holt Mathematics Unlimited "Adventures in Problem Solving" Act. 1-4 Drill/Practice/Problem Solving
6.08	compare decimals through thousandths using >, <,=	MECC "Decimal Concepts" Drill/Practice Houghton-Mifflin Mathematics Software Level 5, Disk C Barnum's "Quarter Mile" Practice/Competition
5.16	name points as ordered pairs and associate ordered pairs with points in the first	Sunburst "Battleship" Game Format MECC "Coordinate Math" Drill/Practice

PASSPORT SOFTWARE

SOL'S		SOFTWARE
	quadrant	MECC "Elementary Mathematics", Vol I Tutorial
COMPUTATION WHOLE #		
	The student will: add, subtract, multiply, and	MECC "Conquering Whole Numbers" Drill/Practice
4.05, 4.10 5.04, 5.07 6.04, 6.07	divide whole numbers	MECC "Number Munchers" Game MECC "Quotient Quest" Drill/Practice MECC "Multiplication Puzzles" D/P MECC "Speedway Math" D/P MECC "Subtraction Puzzles" D/P Houghton Mifflin Mathematics Activities Courseware, Level 4 T Scholastic "Math Shop" Simulation

PASSPORT SOFTWARE

SOL'S		SOFTWARE
4.22, 5.21, 6.19	solve word problems using +, x, and divide whole numbers	MECC "Path Tactics" D/P Silver Burdette "Strategies for Problem Solving" Act. 1 PS Scholastic "Math Shop" Simulation
COMPUTATION DECIMALS		
	The student will:	
4.12, 4.13, 5.10, 5.11 6.9, 6.12	add, subtract, multiply & divide decimals	MECC "Decimals Concepts" D/P MECC "Conquering Decimals" D/P MECC "Market Place" Simulation Scholastic "Math Shop" Simulation
COMPUTATION FRACTIONS		
	The student will:	
5.12	find fractions equivalent to	MECC "Fraction Munchers" Game

PASSPORT SOFTWARE

SOL'S		SOFTWARE
	a given fraction.	MECC "Fraction Concepts" D/P Salina "Math Games" Tutorial
4.14, 4.15 5.13, 5.14	add, subtract, & multiply fractions.	MECC "Fraction Concepts" D/P MECC "Fraction Munchers" Game
6.13, 6.15		MECC "Conquering Fraction" D/P Salina "Math Games" Tutorial
6.12	solve word problems requiring the use of +, -, x fractional numbers.	MECC "Conquering Fractions" D/P

MEASUREMENT/GEOMETRY

	The student will:	
4.16	measure length in metric &	MECC "Measure Works" Tutorial

PASSPORT SOFTWARE

SOL'S		SOFTWARE
	U. S. customary units.	MECC "Elementary Mathematics, Vol. I" Tutorial
4.17	measure liquid volume using metric & U.S. Customary units.	MECC "Measure Works" Tutorial
4.18	determine the value of a collection of money which has total value of $10.00.	MECC "Money Works" Tutorial MECC "Elementary Math, Vol 1" T
4.19	tell time to the nearest minute.	MECC "Clock Works" Tutorial
4.20	given an appropriate figure, identify points, lines, line segments, & angles.	MECC "EZ LOGO" Programming MECC "Plane Geometry" Drill/Practice

PASSPORT SOFTWARE

SOL'S		SOFTWARE
5.15	Measure weight/mass using metric & U. S. Customary units.	MECC "Measure Works" Drill/Practice
5.17	given appropriate information, identify those lines which illustrate the concepts of parallelism.	MECC "Plane Geometry" Drill/Practice MECC "EZ LOGO" Programming
MEASUREMENT/GEOMETRY		
	The student will:	
5.18	identify from a set of statements those which represent an application of the concept of perimeter.	MECC "Measure Works" Tutorial Houghton Mifflin Mathematics Activities Courseware Level 5 Tutorial

PASSPORT SOFTWARE

SOL'S		SOFTWARE	
5.19	identify from a set of statements those which represent an application of the concept of area.	MECC "Measure Works" Houghton Mifflin Mathematics Activities Courseware Level 5	Tutorial Tutorial
6.16	add & - measurements without regroup.	Scholastic "Math Shop"	Simulation
6.17	find the perimeter of polygons having 6 sides or less.	MECC "Plane Geometry"	Drill/Practice
6.18	find the area of squares & rectangles.	MECC "Plane Geometry"	Drill/Practice

APPLICATIONS

	The student will:		
4.24, 5.22, 6.22	solve "non routine"	The Learning Company "Gertrude's	

PASSPORT SOFTWARE

SOL'S	SOFTWARE
problems.	Secret" Problem Solving (Puzzles) MECC "EZ LOGO" PS (Programming)

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