THE RELATIONSHIP OF SELECTED VARIABLES TO MATH ACHIEVEMENT IN A COMPUTER-ASSISTED INSTRUCTIONAL SETTING

DISSERTATION

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By

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The purpose of this study was to explore the variables of I.Q., sex, instructional organization, classroom instructional time, and time in computer-assisted instruction (CAI) in the third and fifth grades in order to determine which of these variables or combinations of variables were the best predictors of mathematics computation and concepts achievement. The study used a one-group pretest-posttest design.

A stratified random sample of 2,000 students was pretested and posttested using the Iowa Tests of Basic Skills. The verbal results of the Cognitive Abilities Test were used as the I.Q. measure. The amount of time in CAI was automatically recorded by the host computer. Information on gender, instructional organization, and classroom instructional time was reported by the teachers. The data collected were analyzed using multiple regression and analysis of variance.

The results indicated that I.Q. had less predictive ability for achievement gain than suggested by earlier

research. I.Q. was less associated with achievement at grade three than grade five. No model which included I.Q. accounted for more than 6% of the variance in achievement gain.

Classroom instructional time was a significant predictor of achievement for grades three and five; however, no model explained more than 7% of the variance. Scores for third graders increased as amounts of classroom instructional time increased. The opposite pattern was found for grade five.

Time in CAI was a significant predictor of achievement for grade five computation. Scores improved for all students, regardless of I.Q., as time in CAI increased.

While sex had limited predictive value for math achievement, females' scores on math concepts were significantly higher than males' scores, regardless of I.Q. and grade level. No evidence was reported that the time variable interacted with sex to the advantage or disadvantage of males or females. Instructional organization was not a significant predictor for math achievement.

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CHAPTER I

INTRODUCTION

A revolution in human communication is here. The force behind this revolution is the powerful combination of silicon chips and microprocessors. These enormous advances in telecommunications are creating an information-based society. The implications of the computer revolution for education necessitate a thorough investigation of what has been, and what is, in order to guide and maximize the positive effect of what will be (Shane, 1982).

The computer was first used in the teaching process in the late 1950s at International Business Machine's (IBM) Watson Research Center (Levien, 1972). In the next decade researchers programmed a digital computer to teach the binary number system. Developers for IBM announced the first authoring language, Coursewriter, in 1960. It was designed to help educators develop instructional units without having to code in a programming language.

University research centers played a major role in further developing educational technology (Hall, 1982; Kiser, 1989). In 1959, under the leadership of Donald Bitzer, engineers, physicists, psychologists, and educators at the University of Illinois began developing a computer-assisted instruction (CAI) system that became known as PLATO (Programmed Logic for Automatic Teaching Operators). Just four years later, Patrick Suppes and Richard Atkinson started development of CAI at Stanford University's Institute of Mathematical Studies in the Social Sciences. In 1964 Harold Mitzel established a CAI laboratory at Pennsylvania State University.

With the invention of the microchip in the late 1960s and the development of simplified programming languages, the conceptual role of computers in education broadened. Papert (1980) and Luehrman (1980) both contended that early notions of the computer-as-tutor were too narrow. They believed that students should use computers to solve problems. Learners, in their view, should control the computer.

Initial reviews designed to integrate findings from the various studies of these first CAI experiences concluded that the use of computers in the teaching process was effective in raising student achievement, especially when used to supplement regular instruction. Vinsonhaler and Bass's review (1972) revealed that elementary school children who received computer-supported drill and practice generally showed performance gains of one to eight months over children who received only traditional instruction. Edwards, Norton, Taylor, Weiss, and Dusseldorp (1975), as well as Bracey (1988), also concluded that CAI was effective in raising student achievement test scores. They further noted that CAI reduced the time it took students to learn.

These positive findings, coupled with the hope of increased problem-solving ability via computer control set forth by Luehrman and Papert, caused educators and parents to take strong interest in educational technology. General interest did not reach its present day fever-like pitch, however, until research and development thrust computers into the average person's everyday life. When computer use became a major issue in the business world and the job market, community members demanded that schools prepare students for life in a technological society.

Educators were not prepared for the swiftness or the scope of this demand. At the end of 1983, only four states required students to demonstrate minimum computer literacy skills by a certain grade level (Christen & Gladstone, 1983). By April 1984, eighteen states had passed similar legislation (Lobello & Blair, 1984). Lobello et al. (1984) projected that $300 million would be spent by public schools in the educational computing race between April and October 1984. In an annual survey of school board members, 97% indicated they would vote for future school budgets that included funds for computers (Betchkal, 1984). Funding support quickly translated to phenomenal increases in the number of school-based microcomputers. In 1988, it was estimated 2.03 million microcomputers were being used in classrooms for instructional purposes (Goodspeed, 1988; Wirthlin Group, 1989).

Yet, educators are still trying to determine how to prepare teachers, how to define computer-related curriculum, and how to structure computer implementation procedures. Inherent in any implementation structure is the determination of who receives instruction, in what curriculum, and for what duration. While research has established a baseline, it is also pointing to areas where further work needs to be done. How effective is computer-assisted teaching in general? Is it especially effective for certain outcomes or certain types of students? Under which condi-tions does it appear to be most effective (Kulik, Kulik, & Bangert-Drowns, 1984)? Others (Hativa & Shorer, 1989; Oden, 1982) suggested that future CAI studies look specifically at learner variables.

This research aspect is important. Identifying those learners who most benefit from CAI can give educators direction in the assignment of students to programs. This study explored some of the learner variables that relate to math achievement resulting from classroom instruction and CAI. Other factors affecting math achievement, such as time on task and instructional grouping, were also examined. The systematic use of computers to improve learning outcomes can best be accomplished only by using the information gained from thorough research and investigation.

Purpose of the Study

The purpose of this study was to analyze the relationship of I.Q., sex of student, total instructional time, time on the computer, and instructional organization in the third and fifth grades in a CAI setting. The relationships were studied to determine which of these variables or combinations of variables were most effective in predicting math achievement.

Research Questions

1. What is the combined contribution of I.Q., sex, grade level, total time on task, and instructional organization to math achievement resulting from classroom instruction and CAI?

2. What is the unique contribution of I.Q. to math achievement when controlling for sex, grade level, total time on task, and instructional organization?

3. What is the unique contribution of sex to math achievement when controlling for I.Q., grade level, total time on task, and instructional organization?

4. What is the unique contribution of grade level to math achievement when controlling for I.Q., sex, total time on task, and instructional organization?

5. What is the unique contribution of total time on task to math achievement when controlling for I.Q., sex, grade level, and instructional organization?

6. What is the unique contribution of computer time to math achievement when controlling for I.Q., sex, grade level, classroom instructional time, and instructional organization?

7. What is the unique contribution of classroom instructional time to math achievement when controlling for I.Q., sex, grade level, computer time, and instructional organization?

8. What is the unique contribution of instructional organization to math achievement when controlling for I.Q., sex, grade level, and total time on task?

9. If significant contributions of selected combinations of these variables are found, which interactions are significant in predicting math achievement?

Significance of the Study

The acquisition of computers for instructional improvement requires school systems to make decisions about how the computers are to be used, who will use them, and for what length of time. Since these decisions help determine the necessary amount and type of hardware and software to be purchased, educators have relied on the available research for guidance and answers. Much of the research has centered on small populations using a wide variety of hardware and software. Many of the studies have also focused on older learners, rather than young students attending elementary and secondary schools. Furthermore, the lack of accurate information concerning computer time on task has made it difficult for educational planners to make informed, research-based decisions about the scheduling issues surrounding CAI.

This study is significant because it focused on several variables that are accepted contributors to achievement and explored their applicability in determining which students would be best served by CAI. The study involved a large number of elementary students who used a commercially available software package on identical hardware systems. The computer systems recorded the actual student-by-student time on the computer over a 29-week period. Evaluation data from this study can assist educators in the structure of programs and the placement of students in them.

Definition of Terms

Computer-Assisted Instruction (CAI)--the use of interactive computers to aide the classroom instruction in mathematics.

I.Q.--the score achieved by each student on the verbal portion of the Cognitive Abilities Test.

Total Time on Task--the time spent in classroom instruction for math as indicated on individual schedules and the time spent in CAI when in the practice, progress, and review modes of the math programs as reflected on the computer logs.

Computer Time--the time spent in CAI when in the practice, progress, and review modes of the math program as measured by when students logged on and logged off.

Classroom Instructional Time--the time scheduled by the classroom teacher for math instruction.

Instructional Organization--classroom structure that falls into two categories: (a) contained, i.e. when one teacher instructs one consistent set of heterogeneously grouped students in all content areas; or (b) non-contained, i.e. all other organizational structures, including team teaching, grade level ability grouping, and departmentalization.

Sex--the identification of students as male or female.

Grade Level--the class assignment in the vertical structure of the school system. Levels for this study were third and fifth grades.

Math Achievement--student performance reflecting classroom instruction and CAI as measured by the Iowa Tests of Basic Skills.

Math Instruction--all classroom and computer instruction offered to students to improve math achievement.

Limitations

1. The instructional quality of computer hardware and software varies greatly and hinders generalizability of this study to other hardware and software configurations.

2. The unique characteristics of the school district limit generalizability of findings in this study to other school systems with similar demographics.

3. The computer hardware and software may be inoperable for short periods of time.

4. Uncontrollable intervening factors may impact school schedules for math instruction.

Assumptions

1. All students received equivalent math instruction in the classroom setting.

2. All students had equal ability to operate the hardware and software.

Summary

Three major forces directed this research effort. The first was the influence of CAI and its expanding use as a method for increasing student achievement (Betchkal, 1984; Goodspeed, 1988; Lobello et al., 1984). Implementation issues were a second force, because determining the conditions under which CAI was most effective seemed critical to the efficient use of new technology. Finally, the personal interest of the researcher in the areas of instructional technology and the learning of mathematics spurred investigation of the variables affecting math achievement and CAI.

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CHAPTER II

SYNTHESIS OF RELATED LITERATURE

Research related to instructional programs that include CAI has been fairly extensive. Yet, a thorough review of that research yielded little evidence to help in the prediction of which groups of students gain the most from classroom instruction and CAI. The studies that were examined gave scant attention to student assignment and overall instructional organization of the program. Although limited microchip technology was reported in the literature, several studies with achievement-related research variables were relevant to the present investigation. Each of the research variables was examined regarding its relationship to the present study.

Computer Use in Education

How is the emergence of technology in society impacting the school curriculum? According to Pogrow (1983), three schools of thought have evolved. The first school reflects a math and science emphasis reminiscent of the Sputnik era. Proponents call for strengthening math and science requirements in order to produce the engineers deemed necessary to maintain a technological lead for the United States.

A second school of thought is the "computer literacy" view. This school sees computer use as a key arbiter of who will and who will not be successful in the future. Computer literacy is defined as a series of computer-use experiences added to the curriculum.

The third approach views the major curricular implication of the changing technology as the need to improve traditional basic skills and the acquisition of higher order thinking skills by the vast majority of students. In other words, the most needed tools for the future are general thinking and problem-solving skills. Holders of this view believe computer technology should be used to improve learning outcomes for both basic and higher order skills, with computer literacy as a side effect of such use (Pogrow, 1983). Computer-assisted instruction was first implemented in 1959 by educators in Illinois. The project was titled PLATO (Programmed Logic for Automatic Teaching Operations). Four upgrades to the PLATO system were installed between 1959 and 1970. Studies on the achievement of students receiving PLATO instruction were conclusive in favor of CAI (von Feldt, 1977). Several universities also investigated the use of computers as educational tools. Research results from these investigations further supported CAI as an instructional enhancement for improved achievement.

The taxonomies used to describe approaches to the problem of basic skill acquisition have usually distinguished among four uses of the computer (Atkinson, 1969; Streibel, 1986; Watson, 1972).

1. Drill and practice--The teacher provides direct instruction to pupils, and the computer provides practice exercises as a follow-up to teacher presentations. This approach incorporates a behavioral technology that makes learning a systematically designed and controlled form of work.

2. Tutorial--The computer presents the concepts and provides the practice exercises on the concepts. Tutorials extend the behavioral technology approach to maximize learners' performance gains.

3. Dialogue--The computer presents both the concepts and the exercises, and the student is free to construct natural language responses, ask questions, and almost completely control the sequence of learning events.

4. Computer-managed instruction--The computer evaluates students either on-line or off-line, guides students to appropriate instructional resources, and keeps records. Many studies looking at the effectiveness of these taxonomies have been completed.

Systematic comparisons of the outcomes of educational computer use and conventional teaching began appearing in print in the late 1960s. In a typical study, the evaluator identified an experimental group and a control group. Computer-assisted instruction was included as part of the instructional program for the experimental group, while members of the control group received their instruction only through traditional teaching methods. At the end of the study, the researcher compared the two groups on achievement. These studies were carried out in a variety of settings, over varied durations, with different numbers of students, and for various purposes (Kulik & Kulik, 1984).

In 1969, Suppes and Morningstar (1969) reported that students taking Russian with the help of CAI outperformed the best student in the control group, or traditional instruction classroom. Lewellen (1971) found that student performance on standardized tests was impacted by CAI. Pupils who received CAI performed better than students taught by conventional means. From a national survey of 1,082 schools using computers (Center for Social Organization of Schools, 1983-84), the following conclusions were drawn:

(a) More computers were available to middle and upper level socio-economic students than low socio-economic students.

(b) When computers were available to low socio-economic level students, the software was more likely to be rote drill and practice instead of the open-ended enrichment and problem-solving types offered to middle and upper level students.

(c) Female students had less involvement than male students with computers in schools, regardless of class or ethnicity.

In recent years, those interested in synthesizing educational research have tried to aggregate results from these diverse studies in order to forge general conclusions about the effectiveness of educational technology. For example, Vinsonhaler and Bass's review (1972), using the box-score method, reported that results from 10 independent studies showed substantial advantages for computer-assisted instruction. Children who were in CAI programs registered achievement gains of one to eight months over students in traditional instructional settings. According to Edwards, Norton, Taylor, Weiss, and Dusseldorp (1975), CAI often produced better results on end-of-course examinations than did conventional teaching. Results for CAI combined with conventional teaching always showed positive effects over conventional teaching alone.

Another method of research systhesis, meta-analysis, takes a more quantitative approach (J. A. Kulik, 1986).

Hartley (1977), Burns and Bozeman (1981), J. A. Kulik, Bangert, and Williams (1983), and C. L. Kulik, J. A. Kulik, and Bangert-Drowns (1984), all used meta-analysis to integrate findings on CAI. Each review reported that students achieved at higher levels when CAI was included in the instructional program. In a synthesis of 25 studies involving CAI, C. L. Kulik, J. A. Kulik, and Bangert-Drowns (1984) found no cases where students in traditional classroom environments received better final examination scores than students in CAI arrangements. They also reported statistically significant achievement differences in favor of CAI in 20 of the 25 studies.

Even though many research studies indicated higher achievement levels when CAI was part of the instructional process, other factors could partially explain the positive effect. Variables such as I.Q., sex, grade level, instructional organization, and time on task were also reported to impact achievement (Beckerman & Good, 1981; Bloom, 1974; Hilton & Berglund, 1974; Slavin, 1987). These same variables may also affect student achievement in a CAI environment (Merritt, 1982; Miller, 1984); however, will the findings on achievement in traditional instructional situations apply to CAI settings? Willis (1984) concluded that there are "theories" involving CAI use, but very few definitive answers.

Whereas CAI was reported to be useful in the improvement of basic skills acquisition, the results on computer-managed instruction (CMI) were less conclusive. CMI acts as a teacher's clerk. It is a form of individualized instruction and therefore requires learners to pace themselves, work independently, and make their own choices. In studies by Akkerhuis (1974) and Coffman and Olsen (1980), the achievement of control students slightly exceeded that of students taught with CMI. In all cases the difference between groups was not significant. The research studies indicated the effects of CAI were clearly more positive than those of CMI.

Findings from more recent studies reported that CAI had stronger effects on student achievement than investigations conducted in the late 1960s and early 1970s (Hartley, 1977; J. A. Kulik, 1981). In a nationwide survey of kindergarten through grade 12 teachers (Wirthlin, 1989), the respondents noted that computers were used for instruction in 98% of the school districts in which teachers were interviewed. Overall, 85% of the respondents felt that the use of computers in the instructional process had a positive impact on the quality of American education. In addition, 72% of the teachers in computer-using schools believed that instructional computers were used effectively in their own school districts. Lack of resources was named by 68% of those polled as one of the greatest obstacles to more effective use of computers in education. Inadequate training or lack of computer experience was named as the primary obstacle by almost one third of the teachers. The fact that only one in ten respondents felt that computers were a fad gives reason to believe that instructional technology has improved and that it has been used to better advantage in recent years.

Math Achievement and Computer-Assisted Instruction

Achievement trends have been the focus of educators and the nation as a whole, especially with the test score declines of the 1960s and 1970s. Many reforms have been enacted to reverse the comparably mediocre ranking of American performance in international comparisons of achievement. Math achievement is central to this concern. For example, A Nation at Risk (1983) called for a new requirement of three years of high school mathematics. Reforms of this type appeared to be reasonable responses given the failure American education has shown in the teaching of mathematics (Koretz, 1988).

Results from the Fourth Mathematics Assessment of the National Assessment of Educational Practices (Silver et al., 1988) suggested that achievement in mathematics took a modest upturn in the 1980s. Signs of improvement among Black and Hispanic students were evident, and the gap in achievement between seventeen-year-old males and females narrowed. However, the overall levels of proficiency fell far below standard. Too few of the nation's best students attained the highest level of proficiency established by the National Assessment of Educational Practices.

Why have American students scored so poorly on mathematic achievement tests? Daane and Post (1988) looked at nine variables which appeared to be related to mathematics achievement at the elementary level. Two hundred eighty-six teachers and their students formed the population for this study. The investigation concluded that four of the nine variables were found to have a significant relationship to elementary mathematics achievement. The first two variables, teachers' attitudes toward mathematics and teachers' attitudes toward their ability to teach mathematics, proved to be prime determiners of students' attitudes and performance. The teachers who disliked the subject spent less time in the subject of mathematics, and students' scores were lower. The third variable, perceived discipline problems in the classroom, placed a limit on the amount of time spent on instruction. The fourth significant variable, the number of college mathematics courses taken by teachers, showed that the more mathematical knowledge a teacher has, the better the mathematics instruction.

In an analysis of student beliefs and their influence on mathematical performance, Garofalo (1989) proposed that success has more to do with students' views of the structure of mathematics and their ability to use that structure, than with the knowledge of specific mathematical content such as facts, algorithms, and procedures. The analysis suggested that educators should restructure the teaching of mathematics from the traditional method of demonstrating a procedure, giving examples, and assigning practice problems to a problem-solving and mathematical reasoning approach. Garofalo (1989) concluded that:

> The mathematics classroom must be vibrant and interactive and have an atmosphere of inquisitiveness, exploration and discovery. The mathematics teacher should be more of a facilitator and discussion leader and less of a dispenser of information (p. 504).

The use of computers to improve the mathematics learning environment is on the rise. Nearly half of the thirteen-year-olds and over half of the seventeen-year-olds in the Fourth NAEP Mathematics Assessment (Silver et al., 1988) reported having access to computers to learn mathematics. These figures represented a major increase over previous assessments. No national survey of elementary level computer access was available.

Many of the research studies conducted to assess the impact of computer-assisted instruction have focused on mathematics. Most researchers have concurred that CAI positively affects math achievement, but some have found otherwise. Abramson and Weiner (1971) reported that while attitudes toward the CAI program on the part of students, teachers, administrators, and parents were favorable, math achievement results showed no significant pattern favoring CAI over non-CAI groups. In a study dealing with the use of microcomputers in the teaching of algebra, no significant difference was observed on the mean posttest achievement scores between the control and experimental groups (Ganguli, 1990). When interactive video technology was introduced into first grade mathematics classrooms, researchers measured no significant difference between control and experimental groups in achievement (Peterson & Webb, 1988); however, a statistically significant difference was reported between the groups in their attitudes toward mathematics. The year-end attitudes of students taught with technology were significantly more positive than the year-end attitudes of students taught by traditional methods.

In contrast, many research projects revealed increased student math achievement as a result of CAI. Vinsonhaler and Bass (1972) found that elementary school children who received CAI drill and practice in math generally showed performance gains of one to eight months over children who received only traditional math instruction. Hartley (1977) found that CAI increased mathematics achievement in elementary students by an average of 0.41 standard deviations, or from the 50th to the 66th percentile. In looking at students in grades 6 through 12, J. A. Kulik et al. (1983) found that CAI raised the math examination scores of students by 0.32 standard deviations. When Kiser (1989) studied the effects of CAI, particularly the impact of computer-generated graphics, students in the experimental group earned significantly higher posttest achievement scores than students who received traditional treatment. Rieber (1983) investigated the effectiveness of LOGO's turtle graphics, both in developing systematic thought and in teaching simple geometry concepts to second grade children. The CAI group performed significantly better than the traditional group on thinking skills in geometry.

While CAI improved college student examination scores 0.10 standard deviations, the gain at this level was the smallest reported. In the same review, J. A. Kulik (1981) pointed out that CAI raised math achievement scores by approximately 0.40 standard deviations at the elementary level and 0.30 standard deviations at the high school level.

The success of CAI in elevating mathematics achievement may stem from a combination of factors. Bracey (1982) reported that drill and practice in whole numbers, percents, fractions, and decimals resulted in increased computation scores. While drill and practice was generally effective, Burns and Bozeman (1981) found tutorial instruction caused more improvement in achievement. Other factors contributing to the success of CAI in improving mathematics achievement have been the structured success in drill and practice and/or tutorial sequences, the immediacy of feedback, constant student interaction causing high level engagement, and the high number of rewards for correct work ("Study Surfaces," 1979).

Kiser (1989) suggested four reasons for educators to use CAI:

(a) to deepen understanding and motivation to learn traditional topics;

(b) to improve student attitudes toward learning mathematics;

(c) to decrease the time required to achieve unit mastery and/or increase the retention rate; and

(d) to lead to more effective information-processing strategies by matching cognitive styles of the learners (p. 40).

In a nationwide survey of teachers on how they used instructional computers (Wirthlin, 1989), 86% of the respondents said that CAI promoted students' problem-solving abilities. Some 87% felt that the use of computers in the classroom stimulated greater interest in math and science. Finally, 82% of the teachers said that using computers for instruction had increased their students' motivation for learning.

I.Q. and Computer-Assisted Instruction

The relationship between intelligence and achievement has been the focus of many research studies. In his book on children's intelligence, Sattler (1974) reported a correlation of .60 between a child's I.Q. score and school grades or performance. While the correlation is not perfect, it holds that most students with high I.Q. scores are high achievers and those with low I.Q. scores are low achievers.

The first issue to be explored when considering I.Q. variables in the context of a CAI setting is determining how the students' CAI experience differs from the regular classroom experience. Anderson (1981) found in a study of student responses to classroom instruction that the seatwork assigned to low-ability students was qualitatively different from that assigned to high-ability students. The seatwork tended to be too difficult and thereby caused low-ability students to concentrate on task completion rather than task understanding. Similar findings were reported by

Romberg (1983). He discovered that low-ability students were given more practice and less opportunity to explore and discuss mathematical ideas than high-ability students. More recent research (Pogrow, 1983) in cognitive psychology suggested that development of analytic thinking proceeds independently of basic memory-related learning. As a result, it is important to emphasize the exploration of mathematical ideas even at stages, or among students, where there are low levels of basic skill attainment.

The CAI component of math instruction has no prior knowledge of individual student ability. It does not withhold learning sequences based on I.Q. perception. Because CAI has no expectation for students, it does not penalize low-ability learners, nor does it provide high-ability students with a greater opportunity to learn.

Another issue to be explored regarding I.Q. variables in the context of a CAI setting is consideration of the effectiveness of the CAI treatment for different ability levels. Research findings have not been conclusive in this regard. C. L. Kulik and J. A. Kulik (1984) reported greater effects from CAI on low-ability pupils. The average effect on the low-ability pupils in the four studies they reviewed was an increase in achievement test scores of 0.55 standard deviations; high-ability students increased an average of 0.06 standard deviations. Davies (1972) also reported significant math achievement gains for students in the low-ability range.

However, in a meta-analysis on the pedagogical effects of CAI in math, Burns and Bozeman (1981) reported that CAI drill and practice programs were significantly more effective in promoting increased student achievement among high-ability and low-ability students. The achievement of average-ability students was not significantly enhanced by CAI.

In his survey of more than 4,000 schools nationwide, Becker (1988) asked teachers what they believed to be the impact of computers on learning outcomes. Eight thousand computer-using educators responded and said they saw significant benefits for high-ability and low-ability students. Programming activities, higher-order thinking simulations, and writing skills were cited as opportunities for high-ability students. Low-ability students were perceived to have increased chances to master basic math and language arts skills when receiving CAI. Only 7% of the teachers using CAI believed that learning in core school subjects by regular-ability students was "much improved" because of computers.

Hativa and Shorer (1989) examined the effects of CAI in relation to the variables of socio-economic status, aptitude, and gender. All of the third through sixth grade students in the study used the same drill and practice programs in mathematics. CAI resulted in achievement gains that were significantly greater for high-ability over low-ability students, for advantaged over disadvantaged children, and for boys over girls.

This finding in favor of high-ability students was corroborated by a study involving entry level college students (Adams II, Waldrop, Justen III, & McCrosky, 1987). Results showed that while grade point average (GPA) and American College Test (ACT) scores were significantly related to performance both with and without CAI, they were better predictors for achievement with CAI. The ACT and GPA scores accounted for 75% of the variance on the combined scores with CAI, while the two factors accounted only for 48% of the variance on combined scores without CAI. The data suggested that high-ability students benefit more from CAI than do low-ability students.

Divergent results were reported by McCollister, Burts, Wright, and Hildreth (1986) when they studied the effects of CAI vs. teacher-assisted instruction and ability level on the arithmetic achievement scores of kindergarten students. Although main effects for both treatment and ability level were found, no significant interaction was reported.

The research findings therefore appear inconclusive on the issue of how different ability levels gain from the use of CAI. This fragmentation includes both the differentiation of the CAI experience from the classroom experience and the effectiveness of the treatment for different ability levels.

Sex, Math Achievement, and Computer-Assisted Instruction

Many researchers have studied gender-related differences in the learning of mathematics. A fairly consistent pattern of sex differences in mathematics achievement was found in data collected prior to the 1970s. In their classic review of gender differences, Maccoby and Jacklin (1974) concluded that sex differences favoring boys in mathematics ability were well established. Maccoby (1966) proposed that:

> Members of each sex are encouraged in, and become interested in and proficient at, the kinds of tasks that are most relevant to the roles they fill currently or are expected to fill in the future (p. 40).

During the last decade or so, additional research in this area typically showed that until age 10, either no differences were found (Callahan & Clements, 1984; Dossey, Mullis, Lindquist, & Chambers, 1988; McKay, 1979; Peterson & Fennema, 1985) or the differences that were found favored females (Brandon, Newton, & Hammond, 1985; Hawn, Ellet, & Des Jardines, 1981). A notable exception came from Lewis and Hoover's study (1986) on the standardization of the Iowa Test of Basic Skills: boys outperformed girls on the problem-solving subtest in the second grade, but the differences decreased in the fifth grade and disappeared by eighth grade.

During the junior high school years, a mixed pattern emerged from the research. Tsai and Walberg (1979) reported a slight difference in favor of girls, whereas Hilton and Berglund (1974) showed a small difference in favor of boys. Connor and Serbin (1985) found no gender-related differences.

By the end of high school, differences favoring males were reported (Jones, Burton, & Davenport, 1987; Ramist & Arbeiter, 1986). Sex differences favoring boys were more common on problem-solving tests, and girls sometimes scored higher than boys on tests that required only computation (Carpenter, Lindquist, Matthews, & Silver, 1983).

Theories attempting to explain sex differences are not convergent. One argument, offered by Benbow (1986) stated that there was a biological explanation for the dominance of males in the area of high mathematical achievement. Environmental arguments focused on other reasons for the gender differences. While there was evidence to support the hypothesis that differential coursework accounted for a considerable amount of the sex difference (Pallas &

Alexander, 1983), other studies indicated that the course-work theory did not account for all of the sex variations in mathematical tasks (Friedman, 1987; Ramist & Arbeiter, 1986).

Girls' poorer performance in high school mathematics was most frequently explained in terms of differing sex-role socialization patterns (Benbow & Stanley, 1982; Brophy, 1985; Fennema & Peterson, 1985; Meece, Parsons, Kaczala, Goff, & Futterman, 1982). Sex differences concerning interest in mathematics, perceived value of mathematics, and students' perceptions of their ability to perform mathematics seemed to mesh with this explanation. High school girls had lower mathematics self-concepts and achievement levels than boys, but sex differences in mathematics self-concepts were larger and began earlier than achievement differences (Meese et al., 1982). Linn and Hyde (1989) and Friedman (1989) reported that some of the gender differences were not general, but specific to certain cognitive processes, such as spatial skills involving mental rotation and mechanical reasoning.

While research findings favored high school boys in mathematical achievement, mounting evidence has indicated that such differences are decreasing. When comparing studies done before and after 1974, the more recent ones suggested that sex differences in mathematics are diminishing (Brophy, 1985; Friedman, 1989; Linn & Hyde, 1989; Marsh, 1989). Furthermore, the differences in favor of males were reported to be decreasing over a short period of time. This finding did not support the biological explanation for the differences (Friedman, 1989). Instead, it appears that cultural and situational interactions have promoted gender equity and that further intervention in the learning environment may decrease gender-related mathematics differences (Linn & Hyde, 1989).

The research findings regarding sex and CAI also lack consensus. Henderson (1983) reported that females who had not made normal progress in mathematical learning demonstrated higher achievement scores after using CAI than normally functioning male students in a control group. The results indicated that CAI in math yielded more benefit for females than for males.

One explanation for the difference between sexes was reported by Lockheed and Harris (1984). In this study perceptions of oneself as a problem solver were positively associated with math success. The perceptions of oneself as a problem solver were also positively associated with cooperative groupings for boys, but not for girls. Since group leadership and group communication were found to be male-dominated by the sixth grade, it appeared that females were not exercising group problem-solving behaviors. This fact, in turn, was reflected in the self perceptions of their problem-solving ability and their mathematical success. By providing problem-solving situations outside the group dynamic via CAI, females may experience greater mathematical success.

Other researchers found that CAI benefitted males over females. In an earlier study, Lockheed (1976) presented CAI as an example of a task with specific demand characteristics that tended to impact more favorably on males. Burns and Bozeman (1981) reported that CAI was significantly more effective in stimulating greater achievement gains among boys at the intermediate grade levels than were traditional pedagogical models. No basis was found for an analogous conclusion relative to achievement among intermediate level girls. Fletcher and Atkinson (1972) studied gender-related differences on achievement in a CAI setting. They reported that CAI was beneficial to both sexes, but relatively more effective for boys. When Hativa and Shorer (1989) looked at the effect of gender differences in CAI gains in arithmetic, the gap between boys and girls grew significantly when advancing from third grade to fourth grade. In fact, throughout the four years of the study, boys outperformed girls and gained more in CAI achievement level.

Still another study (Enemark & Wise, 1981) concluded that sex had no effect on math achievement in a CAI setting. This finding was reinforced by Shu (1983), who stated that much of the available software was schema-based instruction. Her research revealed that children, regardless of sex, performed significantly better on schema-based instruction than children who received text-based instruction. While considerable work has been completed regarding the variable of sex in CAI settings, the results lack consensus.

Grade Level, Math Achievement, and Computer-Assisted Instruction

Only a few studies have examined grade level interaction with math achievement in a CAI environment, and these few have yielded conflicting conclusions. The meta-analysis by C. L. Kulik, J. A. Kulik, and Bangert-Drowns (1984) on computer-based education reported that CAI use in the primary grades at the elementary level resulted in the most dramatic improvement in achievement. McConnell (1983) found that CAI improved the learning of total math and computational skills significantly more than a paper and pencil drill and practice program or the regular district math curriculum; however, CAI was most effective at the third grade level and least effective at the sixth.

Other research looked at the effect of CAI in the elementary grades versus the high school levels.

Restricting his view to mathematics education, J. A. Kulik (1981) pointed out that CAI raised mathematics achievement scores by approximately 0.40 standard deviations at the elementary level, 0.30 standard deviations at the high school level, and 0.10 standard deviations at the college level. He concluded that CAI effectiveness was a function of instructional level. He suggested that learners at the lower levels of instruction need the stimulation and guidance provided by the highly interactive medium. At the upper levels of instruction, an interactive instructional medium was not as important to achievement.

Still other studies reported no significant variance in achievement attributable to the grade levels of the students. Burns and Bozeman (1981) reported that CAI was equally effective in promoting increased student achievement at the elementary and secondary levels. Results from a three-year study of an elementary and secondary CAI Title I project involving reading and mathematics showed significant gains in favor of the CAI program, but reported no interaction between the treatment and grade level (Lavin & Sanders, 1983). In a recent meta-analysis of six studies, C. L. Kulik, J. A. Kulik, and Bangert-Drowns (1984) noted that grade level did not appear to be related to differing math achievement effects.

When the Wirthlin Group (1989) surveyed pre-kindergarten through twelfth grade classroom teachers, 82% of the respondents felt that computers should be introduced in the first through fifth grades; in fact, 41% specified that introduction should occur no later than first grade. Additionally, high school teachers (55%) were less likely than pre-kindergarten, kindergarten, and first grade teachers (65%) to feel that computers had been used effectively.

With so few studies examining the effect of grade level interaction with CAI, school leaders have little empirical evidence to guide their decisions on program design and implementation. Conclusive data are yet to be presented showing CAI achievement differences related to grade level, if the differences do in fact exist.

Instructional Organization and Math Achievement

Instructional organization refers to the method used to assign students to classes. The typical self-contained classroom clusters a group of students of mixed abilities for instruction. This heterogeneity of abilities is the focus of this portion of the literature review.

Ability grouping is one of the oldest and most controversial issues in education. Numerous studies have examined the various forms of between-class ability grouping (e.g., tracking, streaming) and within-class grouping (e.g., reading, math groups). Lists of advantages and disadvantages of ability grouping have been given by theorists and reviewers for more than fifty years (Billett, 1932; Borg, 1965; Good & Marshall, 1984; Miller & Otto, 1930). Ability grouping is supposed to increase student achievement by reducing the heterogeneity of the instructional group, making it more likely for the teacher to provide instruction that is neither too easy nor too hard for most students. Ability grouping is assumed to allow the teacher to increase the pace and level of instruction for high achievers and provide more individual help, repetition, and review for low achievers. It is supposed to provide motivation to high achievers to work hard and learn more, and to allow low achievers to experience success by not having to compete with more able agemates (Atkinson & O'Connor, 1963).

Two main arguments against ability grouping center on the fact that this practice requires the creation of groups of low achievers. These students are deprived of the example and stimulation provided by high achievers. Furthermore, assignment to a low-ability group communicates low expectations for students which might be self-fulfilling (Good & Marshall, 1984). Evertson (1982) and Oakes (1985) found that low-ability, homogeneously structured groups of students experienced a slower pace and lower quality of instruction than students in high-achieving groups. A lack of appropriate behavior models fostered a "behavioral contagion" among homogeneously grouped low achievers (Felmlee & Eder, 1983), so that these groups spent less time on task than other groups.

Numerous studies have supported heterogeneous grouping for instruction. Veldman and Sanford (1984) explored the influence of class-ability level on student achievement. Their analysis suggested that better learning environments were associated with classes of high-mean ability, and that both high-ability students and low-ability students achieved more in high-ability classes. Differences in class environment associated with ability level had more impact on the achievement of low-ability students. Low-ability students were found to be more dependent on class norms than were high-ability students.

In a study of the concepts of ability and effort in Japan and the United States, Holloway (1988) identified that effort, rather than ability, was considered by Japanese parents to be the primary determinant of achievement. She concluded that ability grouping and other similar forms of labeling made it unlikely that the effort attributions of students could dominate the learning environment.

Evertson (1982) looked at average-ability and low-ability classes. He noted a higher incidence of off-task, inappropriate, and disruptive student behavior in the low-ability classes. Sanford (1980) examined the effects of the range or spread of student ability within classes. While extreme class heterogeneity placed greater demands on teachers, no negative effects were found on student achievement.

In a study of 86 fifth grade classes, Goldberg, Passow, and Justman (1966) found evidence favoring broad heterogeneous grouping plans for all students except the most gifted (I.Q. 130+), who did equally well in broad or narrow range ability classes. The study showed the presence of gifted students was beneficial for the achievement of most students in most subjects, whereas the presence of low achievers was neither beneficial nor detrimental overall.

The strongest statement in support of heterogeneous ability grouping came from the findings in Slavin's best-evidence synthesis (1987). He recommended using within-class grouping for upper-elementary mathematics and cross-grade level grouping for reading. With these exceptions, Slavin stated there was good reason to avoid ability-grouped class assignment.

Still other researchers (Borg, 1966; Yates, 1966) reported that ability grouping had positive effects on student achievement for learners of all abilities. Borg (1966) reported that ability grouping allowed more adequate curricular and pedagogical adjustments. These adjustments were reported to have positive effects on student achievement. More recent research by Begle (1979) supported ability grouping of students for instruction. He pointed out that grouping allowed the most able students to learn more mathematics than they would otherwise; at the same time, less able students did just as well on both cognitive and affective variables despite the absence of stronger students from the classroom. Meta-analyses on ability grouping in elementary schools (C. L. Kulik & J. A. Kulik, 1984) and in secondary schools (C. L Kulik & J. A. Kulik, 1982) claimed small positive achievement effects for between-class ability grouping. Slightly positive effects were reported for average and below average students, while high-ability students registered highly positive effects.

These conflicting reports give little clearcut direction to educators. Instructional organization involving CAI may be easily manipulated and should be guided by conclusive research.

Time on Task, Math Achievement, and Computer-Assisted Instruction

In this portion of the literature review, time on task is discussed first in relation to general achievement and then in relation to computer-assisted instruction. Both discussions are relevant to the time on task variable as explored in this investigation.

The issue of time on task was highly researched in the late 1960s and 1970s. Most of the researchers concluded that increased time on task in a specific subject correlated with higher achievement in that same subject (Anderson, 1975; Bloom, 1974; Cooley & Leinhardt, 1982; Stallings & Kaskowitz, 1974). Frederick and Walberg (1980) concluded from their extensive review of research that, other things being equal, the amount learned is generally proportional to the time spent learning. They also noted, "Time devoted to school learning appears to be a moderate predictor of school achievement" (Frederick & Walberg, 1980, p. 193). In a synthesis of 2,575 research studies, Walberg (1988) suggested nine generalizable factors as the major influences on academic achievement. Of those nine factors, two were school related experiences, one of which was the amount of time students engaged in learning. Walberg (1988) concluded that only if the other eight factors were held constant would time alone appear as a powerful determinant of achievement.

The amount of time allocated for mathematics instruction varies in total and by learning task. Larson (1983) reported that most teachers taught mathematics for 20 minutes to one hour per day. Teachers lectured during mathematics instruction for an average of 10 minutes per day (Evertson, 1982). Seatwork comprised the largest portion of allocated mathematics time, 20 to 30 minutes per day. About 20% of the typical elementary school day was structured for mathematics learning, with the number of minutes increasing with each higher grade level (Suydam & Osborne, 1977). Walberg (1988) concluded that outstanding accomplishment in science and mathematics, because of the highly specialized abstract symbolism, required the greatest concentration and time on task.

In a more recent study, Peterson, Swing, Stark, and Waas (1984) reported that student engagement in mathematics, or time on task as assessed by classroom observers, was unrelated to student achievement. However, students' self reports of their attending to the lesson were significantly related to achievement. This brings to the forefront the time on task issue: the quality of the time that students spend attending to the academic task, the actual cognitive processes involved in processing the mathematics information presented during instruction.

The quantity of time allotted for a learning task is also critical. A ratio of the time needed to learn a task and the time spent to learn a task accounted for 91% of the explained variance in student learning, in a study by Gettinger (1984). Time allocation was the most manipulated variable in a study on actual time use (Romberg, 1983). Sindelar's research (1983) on time indicated the critical nature of time allocation. In his study different time allotments were set, with each allotment containing different combinations of teacher instruction and seatwork (without interaction). He concluded that the more time in sustained instructional activity, the greater the achievement.

Many researchers noted a strong relationship between the success of CAI in raising achievement to time on task variance. Pogrow (1983) reported intensive use of CAI for 20 minutes per day, for four to five days per week, for at least half a year increased student learning by an amount equivalent to reducing the pupil teacher ratio to 2:1. C. L. Kulik, J. A. Kulik, and Bangert-Drowns (1984) found that in a typical application students received approximately 26 hours of CAI--15 minutes per day, for four days a week, and for a total of 26 weeks. The effect of this instruction was to raise student achievement scores by 0.48 standard deviations, or from the 50th to the 68th percentile. Studies conducted by the Educational Testing showed that children who had access to the computer for mathematics instruction for only 10 minutes a day scored significantly higher than those who did not (Bracey, 1982). Twenty minutes a day doubled the gain as the study progressed. These reported time allocations have large time variances and no studies indicated an upper-end time allocation that yielded little or no improvement in achievement.

Vockell (1987), in his analysis of computer use and academic learning time, went so far as to say that in situations where computers enhanced achievement, they did so because they increased effective learning time. He concluded that one of the main criteria in the decision to use CAI should be whether or not the computer use would increase academic learning time for individual students. This conclusion was supported by teachers who responded to a nationwide survey (Wirthlin, 1989). Eighty-two percent of the computer-using teachers felt CAI had increased their students' motivation to learn. More than eight out of ten teachers (82%) believed that increasing students' time on task was one advantage of using instructional computers. This sentiment was especially prevalent among pre-kindergarten through first great teachers (87%), when compared with high school teachers (78%).

Not all studies revealed a positive relationship between achievement and time spent in CAI. Easterling (1982) conducted a study to determine the effect of CAI as a supplement to regular classroom instruction in reading and mathematics. The students used a drill and practice CAI program in reading and mathematics for 15-minute sessions two times per week for 16 weeks. The researcher reported no significant improvement on the posttest achievement measure.

While time on task is often reported to positively impact student achievement, two studies reported that CAI improved the task behavior of students (Austin, 1983; Merritt, 1982). In both studies students were reported to have willingly given their attention and effort to the CAI tasks. J. A. Kulik et al. (1983) noted that two of the studies in their meta-analysis found savings from 39% to 88% in the amount of time students took to learn a given unit.

Although a number of the studies reported a positive relationship between increased time on task with CAI and improved achievement, conclusions are not definitive. Time parameters are still unclear and researchers have suggested further exploration of this highly manipulable variable.

Summary

The research on computer-assisted instruction leaves many unanswered questions. After noting that most of the studies have dealt with limited curriculum and student populations, Bracey (1988) so aptly concluded:

> So where are we after all? Even if we consider all of them [studies] to be without damning flaws, together they do not come close to providing prescriptive data for deciding whether and how to use computers as adjuncts for instruction (p. 71).

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CHAPTER III

PROCEDURES

Research Design

This study explored the student and organizational variables of I.Q., sex, instructional organization, total instructional time, classroom instructional time, and computer-assisted instruction time as they impacted math achievement. No control group was used since no comment was to be made regarding the causality of any of the variables. The One-Group Pretest-Posttest design described by Campbell and Stanley (1963) was chosen for this study, since it was impossible to obtain a control group.

Analysis of the One-Group Pretest-Posttest design revealed several threats to internal validity, including history, maturation, testing, reactivity, instrumentation, and statistical regression (Campbell & Stanley, 1963). In the absence of a control group, the factors of history and maturation could not be eliminated. Although testing can be a weakness in this design, the seven- to eight-month delay between achievement test administrations minimized this concern. The fall test administration was scored on fall norms and the spring test administration was scored on spring norms. This scoring technique controlled for instrument decay. Reactivity, or the effect to be expected whenever the testing process itself is a stimulus to change, was not a concern in this study. The fall testing process was part of the regular school routine for all elementary students. Therefore, it did not appear to students as a special treatment; instead it was regarded as a regular assessment of achievement. In regard to statistical regression, the groups were not selected for their extremity. In fact, the population was randomly selected from a pool of over 3,206 students. Therefore, statistical regression was limited to errors in measurement.

Borg and Gall (1979) stated the most problematic concern with the One-Group Pretest-Posttest design is the assumption that changes in the dependent variable are not caused by factors other than those included in the study. They suggested that the time between the pretest and posttest be kept short and that the study only include variables which are reasonably stable, unlikely to change without direct action taken by the experimenter. The dependent variable, math achievement, and all of the independent variables in this study were considered stable. Use of the large random sample also ensured to some extent that the uncontrolled variables would be operating randomly and therefore would not have a systematic effect on the results (Borg & Gall, 1979). Measurement of math achievement was determined from scores on the pretest and posttest. Borg and Gall (1979) cited many problems associated with change scores calculated by simply subtracting the pretest score from the posttest score. Such a change score does not allow for the following:

1. The range of difficulty of test items is limited and therefore the test does not measure the entire range of achievement.
2. The change score is confounded by regression toward the mean.
3. The intervals in test scores are at unequal levels.
4. A given change score may reflect different patterns of strengths and weaknesses for different students because the test contains a variety of subtests.
5. As the correlation between pretest and posttest scores increases, the reliability of the change score decreases.

Instead, Borg and Gall (1979) suggested that analysis of covariance be used to adjust for initial differences in pretest means. In this study the pretest score was used as a covariate for the posttest score. The part of the posttest score which was not accounted for by the pretest score, the residual score, was used to represent the change in math achievement.

Subjects included in this study were selected by stratified random sampling. This method helped to protect the validity of the experiment by controlling the influence of extraneous variables (Ferguson, 1981).

Multiple regression analysis was used to analyze the collective and separate contributions of I.Q., sex, grade level, instructional organization, and time on task to the variation of math achievement. Through this procedure it was possible to study the relationship between two or more variables while the effects of the other variables were held constant. Multiple regression analysis estimated the contribution of each variable to the variance of the dependent measure over and above the contributions of the other variables. Full and restricted regression models provided data relative to the amounts of variance specific to each variable, the level of significance for each variable, and which variables in the model were key in explaining the variance of the dependent measure (Kerlinger & Pedhazur, 1973).

Description of the Research Setting

The research took place in thirty elementary schools located in a north Texas suburban school district. Each school included instructional areas where classroom instruction in math took place. In addition, each school housed a CAI lab where additional math instruction occurred.

Each CAI lab was equipped with a WICAT Professional System. This system included a super micro host computer with two megabytes of main memory (one megabyte of main memory allocated to digital speech synthesis), one 160 megabyte hard disk for secondary storage, and a Motorola 68,000 microprocessor. The host computer powered thirty student terminals configured in a lab setting. The student terminals, powered by the host, displayed unique lessons, identical lessons, or various combinations of lessons. All student interactions were processed and recorded by the host computer. Reports of these interactions were compiled and generated on a high-speed printer.

The software used for CAI in math was an enhanced version of the "SRA Math." WICAT developed this software for SRA on a contractual basis. The math software was primarily drill and practice, with instructional helps available to students after wrong answers. Each strand in the program included an optional placement test. After placement in a strand, students worked in the progress mode or practice mode.

The progress mode automatically moved students through the curriculum based on success or failure. If students completed a lesson with 80% accuracy or better, they were moved to the next harder lesson. If students completed a lesson with less than 50% accuracy, they were moved back to the next easier lesson. If students completed a lesson with an accuracy level between 50% and 80%, they were presented the same lesson again. The progress mode also included an automatic review cycle that took students back to previous lessons on a regular rotation.

The practice mode, set at teacher option, allowed students to drill at specific levels for a length of time specified by the teacher. This mode was often used to check accuracy on a given lesson at a specific time or to work on a new concept prior to presentation of the concept in the progress mode.

Each CAI lab was run by a paraprofessional, the system manager. It was her job to handle the technical interface between the hardware, software, and the instructional lesson presentation. The system managers received general training in July 1984 and content specific training in August and November 1984.

Teachers accompanied their classes to the CAI lab. The teacher's role was to act as the instructional leader in the lab. Integration of classroom instruction and the CAI was the end goal. Teachers received two days of inservice preparation in August 1984 regarding the math curriculum and one day of inservice in November 1984 on the reading curriculum.

The students' preparation for CAI experience included 150 minutes of instruction over a ten-day period. This included lab conduct, lab purposes, keyboard familiarization, and an on-site lab visit. As new curricula were introduced, this procedure was repeated.

The principal in each school was responsible for setting the CAI schedule. All students in grades one through five attended the lab daily. Students had their own terminal for the entire period in the lab. Two days a week students had computer-assisted math instruction. The remaining three days were devoted to language arts instruction. Since the size of the school determined the length of each CAI session, the schedules varied from fifteen minutes per session per day to thirty minutes per session per day. An internal clock in the computer allowed a record to be maintained of each student's cumulative minutes in each curriculum.

The Population

The study was conducted in a large suburban school district located near a metropolitan area. The school district included 33 elementary schools, serving approximately 15,000 students in kindergarten through grade five. The ethnic population was approximately 7% Mexican American, 7% Black, 3% Oriental and Indian, and 83% other (which includes Anglo).

Students considered for inclusion in this study were from the third and fifth grades. All selected students participated in computer-assisted math instruction and completed the fall administration of the Cognitive Abilities Test and the fall and spring administrations of the Iowa Tests of Basic Skills.

All students satisfying these criteria were placed in a sample pool which totalled 3,206. Through disproportional stratified random sampling 2,000 were selected; 1,000 students from each grade level. The sample in each level contained 500 boys, half of whom were from contained classrooms; and 500 girls, half of whom were from contained classrooms. The variables of I.Q. and time on task were not considered in the sample selection process.

Instrumentation

The Iowa Tests of Basic Skills (ITBS) was used as the pretest and posttest measures of math achievement. Third grade students completed Form 8, Level 9 and fifth grade students completed Form 8, Level 11. The ITBS was administered as part of the annual routine in October 1984. A special administration of the ITBS occurred in late April 1985. The same form of the test was given for both achievement measures to ensure test/re-test reliability.

The seven-month gap between the test administrations held the repeated measures effect to a minimum. Only the ITBS subtests of Math Problems and Math Computation were considered for this study. The ITBS was an established norm referenced test with reliability coefficient ranges from .84 to .96 for the major tests and from .70 to .93 for the subtests (Harris, 1978).

The Cognitive Abilities Test (CAT) was used as the I.Q. measure. This test was concurrently normed with the ITBS (Hopkins, 1978). Third grade students completed Level A of the Multi-Level Edition. Fifth graders completed Level C of the Multi-Level Edition. The CAT was administered as part of the annual routine in October 1984. Raw scores from the CAT were changed into universal scale scores. Then the scale scores were converted into standard age scores which are normalized standard scores with a mean of 100 and standard deviation of 16. The K-R 20 reliability estimates of the raw scores were very high, ranging from .87 to .96 (Hopkins, 1978). Although three scores were available from the test, only the verbal score was used in this study. Use of the verbal battery score alone was preferable since no single score reflecting all three batteries was available. According to Nichols (1978), a profile of all three scores had no demonstrated validity and could be misleading.

Procedures for Collection of Data

Permission was obtained to utilize third and fifth grade students in a large suburban school district. Approximately 1,550 third grade students and 1,660 fifth grade students who completed the instruments and received computer-assisted math instruction were eligible for participation in the study.

The measure instruments were administered by the teachers. The ITBS and CAT were given as part of the annual routine to students in October 1984. Make-up sessions were provided by the guidance counselors for students who were absent. The ITBS was administered during the last week in April 1985 and the first week of May 1985 as the posttest measure. Make-up sessions again were provided by the guidance counselors.

The individual students' total time on task figures were calculated as the sum of the scheduled classroom instruction time specified for mathematics and the CAI time spent in mathematics. The classroom instructional time was based on the individual schools' master schedules. The master schedules included the daily schedule for each teacher by content area. The CAI time on task figures were maintained by the host computer by content area for each student. The minutes were cumulative and reflected the elapsed time from student log-on to log-off. In the mathematics program the reported time included progress, practice, and review work. The sum of the classroom time and the CAI time was used as the total time on task for math instruction.

To determine the instructional organization of each class, school district records were used. This information was verified by the individual classroom teachers.

Procedures for Analysis of Data

The ITBS tests and the CAT tests were machine scored in the usual manner. During the last week in April 1985, the summary reports containing the CAI time on task were generated for all students in grades three and five. All of the data were analyzed by computer.

First, correlation tables were calculated in order to determine the relationships between the independent variables of I.Q., sex, instructional organization, classroom instructional time, and time in CAI to the dependent measures of mathematics computation and mathematics concepts. Using the correlation coefficients to determine the order of entry, stepwise regression models were generated. From the independent variables and their interactions, a "best" set of predictors was calculated for each dependent measure.

By using full and restricted regression models, the contribution of the independent variables and their interactions to the variance of gain in mathematics achievement was determined. The contribution that each variable made to predictability of mathematics achievement beyond that of the other independent variables was calculated by a series of comparisons between the full model and restricted models.

FULL MODEL: Mathematics achievement gain is a function of I.Q., sex, instructional organization, classroom instructional time, and time in CAI.

$$Y^1 = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5$$

(Kerlinger & Pedhazur, 1973)

where, Y^1 was equal to predicted scores of achievement gain;
a was equal to the intercept constant;
b was the regression coefficient; and
x was the score of the independent variable.

RESTRICTED MODELS: 1. Mathematics achievement gain is a function of sex, instructional organization, classroom instructional time, and time in CAI. The R^2 was calculated excluding I.Q.

2. Mathematics achievement gain is a function of I.Q., instructional organization, classroom instructional time, and time in CAI. The R^2 was calculated excluding sex.
3. Mathematics achievement gain is a function of I.Q., sex, classroom instructional time, and time in CAI. The R^2 was calculated excluding instructional organization.
4. Mathematics achievement gain is a function of I.Q., sex, instructional organization, and time in CAI. The R^2 was calculated excluding classroom instructional time.
5. Mathematics achievement gain is a function of I.Q., sex, instructional organization, and classroom instructional time. The R^2 was calculated excluding time in CAI.

The contribution of each variable was calculated using the formula:

$$F = \frac{(R^2y \;.\; 12 \;\ldots\; k_1 - R^2y \;.\; 12 \;\ldots\; k_2) \;/\; (k_1 - k_2)}{(1 - R^2y \;.\; 12 \;\ldots\; k_1) \;/\; (N - k_1 - 1)}$$

(Kerlinger & Pedhazur, 1973)

where R^2y . 12 ... k_1 was equal to the full model;

R^2y . 12 ... k_2 was equal to the restricted model;

k_1 was equal to the degree of freedom for the full model;

k_2 was equal to the degrees of freedom for the restricted model; and

N was equal to the number in the population.

After all computations were made, the data were entered into tables for reporting and interpretation.

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CHAPTER IV

PRESENTATION OF FINDINGS

The purpose of the study was to explore the variables of I.Q., sex, instructional organization, classroom instructional time, and time in CAI in the third and fifth grades in order to determine which of these variables or combination of variables were the best predictors of mathematics computation achievement and concepts achievement. Data collected for the statistical analysis included: (1) demographic information on each student regarding sex, grade level, and instructional organization of the mathematics classroom; (2) student achievement scores on the Math Problems (concepts) and the Math Computation subtests of the Iowa Tests of Basic Skills for the fall and spring of the 1984-85 school year; (3) student scores on the Cognitive Abilities Test for the fall of the 1984-85 school year; (4) individual computer time data recorded when students logged on and off the computer; and (5) classroom time in mathematics reported by the individual classroom teacher.

Demographic Information

Thirty schools were included in the study; however, four were eliminated prior to statistical analyses due to a lack of complete information concerning computer time. Using stratified random sampling, 2,000 students were selected from the original sample pool of 3,206 on the basis of grade level, sex, and instructional organization. The data for grades three and five are shown in Tables 1 and 2.

Table 1

Grade Three Population Breakdown

	Boys	Girls	Total
Contained	250	250	500
Non-Contained	250	250	500
Total	500	500	1,000

Table 2

Grade Five Population Breakdown

	Boys	Girls	Total
Contained	250	250	500
Non-Contained	250	250	500
Total	500	500	1,000

Time Data

The classroom instructional time for mathematics was quantified by the individual classroom teachers. The time on the computer was recorded by the host computer, subtracting the time the student logged on from the time the student logged off. Total time was calculated by adding the classroom time and the computer time. Results for grades three and five are contained in Table 3.

Table 3

Time Data for Grade Three and Grade Five in Minutes

Grade Level	Time Label	Mean	Standard Deviation	Minimum Time	Maximum Time
3	Classroom	8,615.870	759.279	5,800	9,950
	Computer	583.595	236.678	149	1,252
	Total	9,199.465	833.152	6,245	11,202
5	Classroom	8,463.424	727.053	6,525	9,950
	Computer	702.217	225.886	256	1,445
	Total	9,165.641	783.549	7,250	10,970

Cognitive Abilities Test

Students' verbal scores from the Cognitive Abilities Test were also obtained from individual student records. Results for grades three and five are presented in Table 4.

Table 4

I.Q. Data for Grade Three and Grade Five

Grade Level	Mean	Standard Deviation	Minimum I.Q.	Maximum I.Q.
3	100.695	13.295	62	141
5	102.702	14.052	60	145

Achievement Scores

The mathematics computation and concepts scores from the Iowa Tests of Basic Skills (ITBS) were obtained from each student's record for the fall and spring administrations of the test. The ITBS reports three types of norms: grade equivalents, age equivalents, and standard scores. Grade equivalents were used for this study.

The gain scores were calculated using the scores from the fall administration of the ITBS as covariates for the spring scores in order to control for those parts of the spring scores which could be accounted for by the fall scores. The resulting residual scores were used to represent achievement gain and, therefore, the mean score for achievement gain was zero. The data on mathematics computation gain for grade three and grade five are presented in Table 5.

Table 5

Residual Achievement Gain Scores on Computation for Grade Three and Grade Five

Grade Level	Mean	Standard Deviation	Minimum Residual	Maximum Residual
3	0.0	0.564	-2.098	2.157
5	0.0	0.765	-4.890	2.873

The data on concepts gain for grades three and five are presented in Table 6.

Table 6

Residual Achievement Gain Scores on Concepts for Grade Three and Grade Five

Grade Level	Mean	Standard Deviation	Minimum Residual	Maximum Residual
3	0.0	0.718	-3.088	3.151
5	0.0	0.872	-4.760	3.190

Statistical Analysis

The SYSTAT: A System for Statistics computer package was used to analyze the data. The data for each grade level and subtest were entered separately.

To determine the relationship between computation achievement (as measured by the residual gain scores) and the independent variables of I.Q., instructional organization, classroom instructional time, and time in CAI, Pearson correlation matrices were calculated. The correlation coefficients for grade three computation are included in Table 7.

Table 7

Correlation Matrix of Five Independent Variables with Computation Achievement for Grade Three

Variable	1	2	3	4	5	6
1. Sex	1.000					
2. Instruct. Organ.	-0.002	1.000				
3. Class Time	0.017	0.250	1.000			
4. I.Q.	0.056	0.107	0.098	1.000		
5. CAI Time	0.035	-0.213	0.171	0.059	1.000	
6. Computat. Residual	0.108	-0.008	0.093	0.076	0.112	1.000

The correlation coefficients for grade five computation are shown in Table 8.

Table 8

Correlation Matrix of Five Independent Variables with Computation Achievement for Grade Five

Variable	1	2	3	4	5	6
1. Sex	1.000					
2. Instruct. Organ.	0.003	1.000				
3. Class Time	-0.027	0.055	1.000			
4. I.Q.	0.022	0.250	-0.021	1.000		
5. CAI Time	0.041	-0.176	0.104	-0.008	1.000	
6. Computat. Residual	0.085	0.018	-0.129	0.161	0.044	1.000

To determine the relationship between concepts achievement (as measured by the residual gain scores) and the independent variables of I.Q., instructional organization, classroom instructional time, and time in CAI, Pearson correlation matrices were calculated. The correlation coefficients for grade three concepts are included in Table 9. Classroom instructional time and instructional organization showed the highest correlation coefficients of the five independent variables. Results showed I.Q. to have the lowest correlation with grade three concepts.

Table 9

Correlation Matrix of Five Independent Variables with Concepts Achievement for Grade Three

Variable	1	2	3	4	5	6
1. Sex	1.000					
2. Instruct. Organ.	-0.002	1.000				
3. Class Time	0.017	0.250	1.000			
4. I.Q.	0.056	0.107	0.098	1.000		
5. CAI Time	0.035	-0.213	0.171	0.059	1.000	
6. Concepts Residual	0.029	0.060	0.078	0.015	0.032	1.000

The correlation coefficients for grade five concepts achievement are reported in Table 10. The I.Q. variable posted the highest correlation for grade five. This is the opposite relationship from that reported between I.Q. and third grade concepts achievement. The variable of instructional organization showed the second highest correlation for grade five concepts. A negative correlational relationship resulted between grade five concepts and classroom instructional time.

Table 10

Correlation Matrix of Five Independent Variables with Concepts Achievement for Grade Five

Variable	1	2	3	4	5	6
1. Sex	1.000					
2. Instruct. Organ.	0.003	1.000				
3. Class Time	-0.027	0.055	1.000			
4. I.Q.	0.022	0.250	-0.021	1.000		
5. CAI Time	0.041	-0.176	0.104	-0.008	1.000	
6. Concepts Residual	0.022	0.095	-0.040	0.243	0.022	1.000

For each dependent measure, the independent variables and their interactions were entered into a stepwise regression model for the purpose of determining the best subset of predictors. The order of entry was based on the correlation coefficients. The stepwise regression analysis yielded the variables and their interactions which accounted for the largest amount of variance in mathematics achievement. A "best" model resulted for each of the four dependent measures. A listing of the interactions is presented in Table 11.

Table 11

Variable Interactions for Grade Three and Grade Five

I.Q. and Sex
I.Q. and Instructional Organization
I.Q. and Class Time
I.Q. and CAI Time
Sex and Instructional Organization
Sex and Class Time
Sex and CAI Time
Instructional Organization and Class Time
Instructional Organization and CAI Time
Class Time and CAI Time

The full model stated that achievement gain is a function of I.Q., sex, instructional organization, classroom instructional time, and time in CAI. By using the predictor subsets resulting from the stepwise regression procedures, models representing the highest level of prediction were constructed for each achievement subtest by grade level. The results of the analyses are presented in Tables 12, 13, 14, and 15.

Through stepwise regression it was determined that the independent variables of sex, instructional organization, CAI time, and I.Q. made no significant contribution to the predictability of computation achievement gain in grade three. Table 12 reveals that classroom instructional time, the interaction of I.Q. and time in CAI, and the interaction of I.Q. and sex made significant contributions to predictability. Although the model is statistically significant at less than the .001 level, it is important to note that the adjusted R square representing the percentage of variance in computation achievement that can be accounted for by the

Table 12

Contribution of Variables to Computation Achievement in Grade Three

Variable	DF	Sum of Squares	F	Sig. F.
Class Time	1	1.484	4.791	0.029*
I.Q. and CAI Time	1	2.529	8.165	0.004**
I.Q. and Sex	1	3.301	10.658	0.001***
R Square	.031			
Adjusted R Square	.028		Significant F Change	0.001***

$*p < .05$

$**p < .01$

$***p \leq .001$

variables in the model was .028. This leaves 97.2% of the variance still unaccounted for when considering the computation achievement gains for students in third grade. Regression analysis revealed that classroom instructional time and the interaction of instructional organization and sex comprised the subset explaining the greatest amount of variance in grade three concepts achievement.

Table 13 shows classroom instructional time was the only independent variable which made a significant contribution to the predictability of concepts achievement. The interaction of instructional organization and sex was also part of the "best" model; however, the inter-action was not

Table 13

<u>Contribution of Variables to Concepts Achievement in Grade Three</u>

Variable	DF	Sum of Squares	F	Sig. F.
Class Time	1	2.317	4.525	0.034*
Inst. Org. and Sex	1	1.180	2.305	0.129
R Square	.008			
Adjusted R Square	.006		Significant F Change	0.015*

*p < .05

significant at less than the .05 level. With an adjusted R square of only .006, the model leaves 99.4% of the variance in concepts achievement gain for third graders unaccounted for.

Table 14 shows that all independent variables, except for instructional organization, were included in the model concerning computation achievement in fifth grade. One interaction, classroom instructional time and time in CAI,

Table 14

Contribution of Variables to Computation Achievement in Grade Five

Variable	DF	Sum of Squares	F	Sig. F.
I.Q.	1	14.455	26.252	0.001**
Class Time	1	13.521	24.555	0.001**
Sex	1	3.007	5.461	0.020*
CAI Time	1	7.505	13.629	0.001**
Class Time and CAI Time	1	8.205	14.900	0.001**
R Square		.065		
Adjusted R Square		.060	Significant F Change	0.001**

*p < .05

**p ≤ .001

was also a part of the model. All predictors made a significant contribution to the predictability of the dependent measure at less than the .05 level, with four of the five predictors significant at the .001 level. The adjusted R square for the model was .060, leaving 94% of the variance unaccounted for in grade five computation scores.

Table 15 reveals that I.Q. was the only independent variable which made a significant contribution to the predictability of concepts achievement in fifth grade. The interaction of I.Q. and time in CAI was included in the model; however, the interaction was not significant at less than the .05 level. With an adjusted R square of .061, the

Table 15

Contribution of Variables to Concepts Achievement in Grade Five

Variable	DF	Sum of Squares	F	Sig. F.
I.Q.	1	39.759	55.627	0.001*
I.Q. and CAI Time	1	2.653	3.711	0.054
R Square	.063			
Adjusted R Square	.061		Significant F Change	0.001*

*p $\leq$ .001

model leaves 93.9% of the variance in fifth graders' concepts scores unaccounted for.

To further investigate the relationships between the independent variables and the achievement scores, analysis of variance tests were performed. High, average, and low parameters for the continuous independent variables (I.Q., classroom instructional time, and time in CAI) were established using the following formulas.

High = (mean + 1 standard deviation) to the highest score with the upper limit being inclusive

Average = (mean - 1 standard deviation) to the (mean + 1 standard deviation)

Low = Lowest score to the (mean - 1 standard deviation) with the lower limit being inclusive

The residual gain scores were used in the calculations, thereby controlling for the effect of the fall scores. The analysis of variance tested the spring score means for the categories of independent variables to determine if they were significantly different from one another. All achievement scores are reported by grade level in residual score form.

Grade Three

Achievement was grouped for computation and concepts by low, average, and high levels of I.Q. using the formulas described. Table 16 shows the range of I.Q. scores and the number of students in each level.

Table 16

I.Q. Levels for Grade Three

Level	N	Mean	Minimum I.Q.	Maximum I.Q.
Low	174	81.391	62	87
Average	650	100.597	88	113
High	176	120.142	114	141

The average level I.Q. group posted the highest mean residual computation score. The high I.Q. group was next, followed by the low I.Q. group. While the average I.Q. level showed the highest mean score, this group also

Table 17

Computation Achievement Scores by I.Q. Levels - Grade Three

Level	Mean	Minimum Residual	Maximum Residual
Low	-0.240	-1.974	1.269
Average	-0.050	-2.098	2.157
High	-0.107	-1.378	1.022

represented the largest range between the minimum and maximum scores. Analysis of variance showed the differences between the means to be significant at the .001 level. The data are presented in Tables 17 and 18.

Table 18

Test of Significance for Differences Between The Means of Computation Achievement Scores for Levels of I.Q. - Grade Three

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	313.231	997	0.314		
I.Q.	4.979	2	2.489	7.924	.001*

*p $\leq$ .001

When comparing the concepts achievement scores by I.Q. levels, the average level showed the highest residual mean, followed by the high I.Q. level and the low I.Q. level respectively. The difference between the minimum residual and the maximum residual was largest for the average I.Q. level. The lack of range between the means was borne out by the analysis of variance which showed no significant differences between the means. The data are shown in Tables 19 and 20.

Table 19

Concepts Achievement Scores by I.Q. Levels - Grade Three

Level	Mean	Minimum Residual	Maximum Residual
Low	-0.169	-3.088	2.172
Average	-0.095	-2.608	2.842
High	-0.124	-2.271	3.151

Table 20

Test of Significance for Differences Between The Means of Concepts Achievement Scores for Levels of I.Q. - Grade Three

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	514.061	997	0.516		
I.Q.	0.776	2	0.388	.753	.471

Computation and concepts achievement scores were grouped by low, average, and high levels of classroom instructional time using the formulas described. Only 9.3% of the third grade students received low levels of scheduled classroom time for mathematics. Table 21 shows the range of classroom instructional time and the number of students in each level.

Table 21

Classroom Instructional Time Levels for Grade Three

Level	N	Mean	Minimum Class Time	Maximum Class Time
Low	93	6,772.903	5,800	7,540
Average	743	8,634.038	7,975	8,700
High	164	9,578.604	9,425	9,950

The mean achievement scores of third graders for computation revealed that achievement levels increased as classroom instructional time levels increased. Analysis of variance showed the differences between the means to be significant at less than the .05 level. The data are shown in Tables 22 and 23.

Table 22

Computation Achievement Scores by Classroom Instructional Time Levels - Grade Three

Level	Mean	Minimum Residual	Maximum Residual
Low	-0.238	-1.378	1.106
Average	-0.086	-2.098	2.157
High	-0.042	-1.518	1.169

Table 23

Test of Significance for Differences Between The Means of Computation Achievement Scores for Levels of Classroom Instructional Time - Grade Three

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	315.787	997	0.317		
Class Time	2.423	2	1.211	3.824	.022*

*p < .05

When evaluating the concepts achievement scores by levels of classroom instructional time, the mean scores increased as levels of classroom instructional time increased. The mean scores for all three time levels were below the group mean of zero. The difference between the minimum residual score and the maximum residual score was greatest for students receiving average amounts of classroom instructional time. The smallest difference between minimum and maximum residual scores occurred with low amounts of classroom instructional time. Although each level posted a higher gain score mean, analysis of variance indicated no significant differences between the means. The data are presented in Tables 24 and 25.

Table 24

Concepts Achievement Scores by Classroom Instructional Time Levels - Grade Three

Level	Mean	Minimum Residual	Maximum Residual
Low	-0.166	-1.610	1.722
Average	-0.131	-3.088	3.151
High	-0.001	-2.271	2.842

Table 25

Test of Significance for Differences Between The Means of Concepts Achievement Scores for Levels of Classroom Instructional Time - Grade Three

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	512.252	997	0.514		
Class Time	2.585	2	1.292	2.516	.081

Computation and concepts achievement scores were leveled by time in CAI using the formulas described. Table 26 shows the range of time in CAI levels and the number of students in each level.

Table 26

CAI Time Levels for Grade Three

Level	N	Mean	Minimum CAI Time	Maximum CAI Time
Low	157	275.134	149	345
Average	836	636.311	347	1,167
High	7	1,206.143	1,185	1,252

The computation scores of third graders, when grouped by time in CAI levels, revealed that achievement means increased as time in CAI increased. Analysis of variance showed the differences between the means to be significant at less than the .01 level. The data are shown in Tables 27 and 28.

Table 27

Computation Achievement Scores by CAI Time Levels - Grade Three

Level	Mean	Minimum Residual	Maximum Residual
Low	-0.212	-2.042	2.157
Average	-0.073	-2.098	1.941
High	0.201	-0.462	1.094

Table 28

Test of Significance for Differences Between The Means of Computation Achievement Scores for Levels of CAI Time - Grade Three

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	315.047	997	0.316		
CAI Time	3.163	2	1.582	5.005	.007*

*p < .01

When analyzing the concepts scores by levels of time in CAI, the mean scores increased as CAI time increased. Although each level of CAI time posted a higher mean, analysis of variance showed no significant differences between the means. The data are shown in Tables 29 and 30.

Table 29

Concepts Achievement Scores by CAI Time Levels - Grade Three

Level	Mean	Minimum Residual	Maximum Residual
Low	-0.170	-2.600	2.172
Average	-0.105	-3.088	3.151
High	0.233	-0.889	1.091

Table 30

Test of Significance for Differences Between The Means of Concepts Achievement Scores for Levels of CAI Time - Grade Three

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	513.443	997	0.515		
CAI Time	1.394	2	0.697	1.353	.250

The computation scores of third graders, when grouped by sex, showed that females outperformed males. The mean for females was higher, as well as their having higher minimum and maximum residual scores. However, the analysis of variance showed no significant difference between the mean scores of males and females. The data are shown in Tables 31 and 32.

Table 31

Computation Achievement Scores by Sex - Grade Three

Sex	Mean	Minimum Residual	Maximum Residual
Male	-0.134	-3.088	2.172
Female	-0.092	-2.608	3.151

Table 32

Test of Significance for Difference Between the Means of Computation Achievement Scores by Sex - Grade Three

Source of Variation	Mean	Standard Deviation	T Statistic	P
Sex	-0.113	0.718	.930	.353

The concepts mean score for third grade females was higher than the concepts mean for males. Males posted the larger range of residual scores. Males also earned higher minimum and maximum scores than females. Analysis of variance between the concept means calculated by sex showed a significant difference favoring females at the .001 level. The data for third grade concepts achievement by sex are reported in Tables 33 and 34.

Table 33

Concepts Achievement Scores by Sex - Grade Three

Sex	Mean	Minimum Residual	Maximum Residual
Male	-0.154	-2.042	2.157
Female	-0.033	-2.098	1.941

Table 34

Test of Significance for Difference Between The Means of Concepts Achievement Scores by Sex - Grade Three

Source of Variation	Mean	Standard Deviation	T Statistic	P
Sex	-0.093	0.564	3.422	.001*

*p $\leq$ .001

The computation scores of third graders, when evaluated by type of instructional organization, showed that students in non-contained classroom settings posted higher mean, minimum, and maximum residual achievement scores. When the means were tested for variance, the difference was not significant at the .05 level. The data are presented in Tables 35 and 36.

Table 35

Computation Achievement Scores by Instructional Organization - Grade Three

Instructional Organization	Mean	Minimum Residual	Maximum Residual
Contained	-0.156	-3.088	2.172
Non-Contained	-0.070	-2.310	3.151

Table 36

Test of Significance for Difference Between The Means of Computation Achievement Scores by Instructional Organization - Grade Three

Source of Variation	Mean	Standard Deviation	T Statistic	P
Instruct. Organ.	-0.113	0.718	1.907	.057

When analyzing the concepts achievement scores by type of instructional organization, the mean for contained classroom settings was slightly higher than the mean for non-contained classrooms. Analysis of variance showed no significant difference between the means. The data are shown in Tables 37 and 38.

Table 37

Concepts Achievement Scores by Instructional Organization - Grade Three

Instruct. Organ.	Mean	Minimum Residual	Maximum Residual
Contained	-0.089	-2.098	2.157
Non-Contained	-0.098	-1.518	1.169

Table 38

Test of Significance for Difference Between The Means of Concepts Achievement Scores by Instructional Organization - Grade Three

Source of Variation	Mean	Standard Deviation	T Statistic	P
Instruct. Organ.	-0.093	0.564	.246	.806

The best regression model for predicting computation achievement in third grade included the interaction of I.Q. and CAI time. The interaction was a significant predictor at less than the .01 level. To further investigate, a 3x3 analysis of variance was performed. The mean achievement scores are reported in Table 39. The differences between the means, when grouped by levels of I.Q., were not significant. When the computation scores were compared by amounts of time in CAI, the differences were significant at the .001 level. As levels of time in CAI increased, achievement scores also increased.

The interaction of I.Q. and CAI time was found not to be significant in the analysis of variance. In other words, the achievement scores were uniformly higher with regard to increasing CAI time, regardless of which I.Q. level was being studied. The analysis of variance data are shown in Table 40.

Table 39

Computation Mean Achievement Scores for I.Q. by CAI Time - Grade Three

CAI Time	Low	Average	High
I.Q.			
Low	-0.358	-0.255	0.298
Average	-0.095	-0.056	0.040
High	-0.173	-0.124	-0.013

Table 40

Test of Significance for Differences Between The Means of Computation Achievement Scores for I.Q. by CAI Time - Grade Three

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	306.918	991	0.310		
I.Q.	0.587	2	0.294	0.948	0.389
CAI Time	4.724	2	2.362	7.627	0.001*
I.Q. and CAI Time	2.673	4	0.668	2.157	0.072

*p $\leq$ .001

The best regression model for predicting computation achievement for third graders included another significant interaction, I.Q. and sex. The mean achievement scores for I.Q. levels by sex are reported in Table 41.

Table 41

Computation Mean Achievement Scores for I.Q. By Sex - Grade Three

Sex	Male	Female
I.Q.		
Low	-0.286	-0.183
Average	-0.111	0.006
High	-0.181	-0.064

The analysis of variance showed significant differences at the .001 level for the mean scores when grouped by level of I.Q. Students with average ability earned the highest scores, followed by scores from high-ability and low-ability students in that order. When mean scores were grouped by sex and tested with analysis of variance, the difference was significant at less than the .05 level. Third grade females scored higher than third grade males.

The interaction of I.Q. and sex was not significant. This means the achievement scores are uniformly higher for females over males, regardless of which I.Q. level was considered. The interaction did not present a significant confounding effect. The analysis of variance data are shown in Table 42.

Table 42

Test of Significance for Differences Between The Means of Computation Achievement Scores for I.Q. by Sex - Grade Three

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	309.835	994	0.312		
I.Q.	4.674	2	2.337	7.498	0.001**
Sex	1.946	1	1.946	6.242	0.013*
I.Q. and Sex	0.008	2	0.004	0.012	0.982

*$p < .05$

**$p \leq .001$

Grade Five

Residual achievement scores were grouped for mathematics computation and concepts by low, average, and high levels of I.Q. The standard deviation formulas previously described were used to divide the scores into levels. Table 43 shows the range of I.Q. scores for each ability level of students. The number of students and the mean score for each level is also reported.

Table 43

I.Q. Levels for Grade Five

Level	N	Mean	Minimum I.Q.	Maximum I.Q.
Low	142	80.379	60	88
Average	698	102.355	89	116
High	160	124.444	117	145

The mean residual computation score increased as the level of I.Q. increased. The low I.Q. level showed the highest maximum residual, and the average I.Q. level had the lowest minimum residual. Analysis of variance indicated the differences between the means for I.Q. levels to be significant at the .001 level. The data are shown in Tables 44 and 45.

Table 44

Computation Achievement Scores by I.Q. Levels - Grade Five

Level	Mean	Minimum Residual	Maximum Residual
Low	-0.121	-2.258	2.873
Average	0.087	-4.890	2.354
High	0.314	-2.890	2.110

Table 45

<u>Test of Significance for Differences Between The Means of Computation Achievement Scores for Levels of I.Q. - Grade Five</u>

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	572.624	997	0.573		
I.Q.	14.503	2	7.252	12.664	0.001*

*$p \leq .001$

When comparing the concepts achievement scores by I.Q. levels, the means increased as the I.Q. level increased. The average I.Q. level posted both the lowest and highest residual scores, giving the average I.Q. level the biggest range of achievement. The analysis of variance showed

Table 46

<u>Concepts Achievement Scores by I.Q. Levels - Grade Five</u>

Level	Mean	Minimum Residual	Maximum Residual
Low	-0.313	-2.810	2.451
Average	0.117	-4.760	3.190
High	0.365	-2.050	2.240

significant differences at the .001 level between the means for I.Q. levels. The data are presented in Tables 46 and 47.

Table 47

Test of Significance for Differences Between The Means of Concepts Achievement Scores for Levels of I.Q. - Grade Five

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	726.261	997	0.726		
I.Q.	36.266	2	18.133	24.967	0.001*

*$p \leq .001$

Computation and concepts achievement scores were grouped by low, average, and high levels of classroom instructional

Table 48

Classroom Instructional Time Levels for Grade Five

Level	N	Mean	Minimum Class Time	Maximum Class Time
Low	185	7,269.595	6,525	7,540
Average	690	8,570.672	7,830	8,990
High	125	9,610.742	9,425	9,950

time using the formulas described. Table 48 shows the range of classroom instructional time and the number of students in each level.

The mean achievement scores of fifth graders for computation declined as classroom instructional time increased.

Table 49

Computation Achievement Scores by Classroom Instructional Time Levels - Grade Five

Level	Mean	Minimum Residual	Maximum Residual
Low	0.273	-1.894	2.250
Average	0.069	-2.890	2.873
High	-0.038	-4.890	1.910

Table 50

Test of Significance for Differences Between The Means of Computation Achievement Scores for Levels of Classroom Instructional Time - Grade Five

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	578.539	997	0.579		
Class Time	8.589	2	4.294	7.423	0.001*

$^{*}p \leq .001$

The lowest residual score was in the high class time group and the highest residual score came from the average class time level. The range between the minimum residual score and the maximum residual score was greatest for the group receiving high amounts of classroom instructional time. Students who received low levels of classroom mathematics instruction showed the smallest range between extreme residual scores. Analysis of variance showed the differences between the means to be significant at the .001 level. The data are shown in Tables 49 and 50.

When evaluating the concepts achievement scores by classroom instructional time levels, the low level showed the highest mean. The average class time level had the lowest mean score. The range between the minimum residual score and the maximum residual score was greatest for the group receiving low amounts of classroom instructional time. Students who received average levels of classroom mathematics instruction showed the smallest range between extreme residual scores. Analysis of variance indicated the differences between the means to be significant at less than the .05 level. The data are reported in Tables 51 and 52.

Table 51

Concepts Achievement Scores by Classroom Instructional Time Levels - Grade Five

Level	Mean	Minimum Residual	Maximum Residual
Low	0.231	-3.851	3.190
Average	0.062	-2.810	2.882
High	0.160	-4.760	2.240

Table 52

Test of Significance for Differences Between The Means of Concepts Achievement Scores for Levels of Classroom Instructional Time - Grade Five

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	757.339	997	0.757		
Class Time	5.188	2	2.594	3.425	0.034*

*p < .05

Computation and concepts achievement scores were leveled by time in CAI using the formulas described. Table 53 shows the range of time in CAI levels and the number of students in each level.

Table 53

CAI Time Levels for Grade Five

Level	N	Mean	Minimum CAI Time	Maximum CAI Time
Low	151	392.085	256	476
Average	684	681.509	477	928
High	165	1,075.764	929	1,445

The computation scores of fifth graders, when grouped by time in CAI levels, revealed that achievement means increased as time in CAI increased. However, analysis of variance showed no significant differences between the means. The data are shown in Tables 54 and 55.

Table 54

Computation Achievement Scores by CAI Time Levels - Grade Five

Level	Mean	Minimum Residual	Maximum Residual
Low	0.088	-1.798	2.250
Average	0.091	-4.890	2.873
High	0.105	-2.258	2.258

Table 55

Test of Significance for Differences Between The Means of Computation Achievement Scores for Levels of CAI Time - Grade Five

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	587.097	997	0.587		
CAI Time	0.031	2	0.015	.026	.970

When analyzing the concepts achievement scores by levels of time in CAI, the mean for high of CAI time ranked highest. The next highest mean was posted by the low CAI time level, followed by the score from the average level. Analysis of variance showed no significant differences between the means. The data are shown in Tables 56 and 57.

Table 56

Concepts Achievement Scores by CAI Time Levels - Grade Five

Level	Mean	Minimum Residual	Maximum Residual
Low	0.119	-1.560	1.680
Average	0.104	-4.760	3.190
High	0.350	-1.230	1.920

Table 57

Test of Significance for Differences Between The Means of Concepts Achievement Scores for Levels of CAI Time - Grade Five

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	760.605	997	0.761		
CAI Time	1.922	2	0.961	1.263	.285

The computation mean scores of fifth graders, when grouped by sex, showed that females outperformed males. The range from minimum to maximum residuals was greater for males, with both extremes surpassing scores by females. Analysis of variance showed no significant difference between the mean scores for males and females. The data are presented in Tables 58 and 59.

Table 58

Computation Achievement Scores By Sex - Grade Five

Sex	Mean	Minimum Residual	Maximum Residual
Male	0.094	-4.760	3.190
Female	0.132	-2.371	2.882

Table 59

Test of Significance for Difference Between the Means of Computation Achievement Scores by Sex - Grade Five

Source of Variation	Mean	Standard Deviation	T Statistic	P
Sex	0.113	0.872	.688	.492

The concepts mean for fifth grade females was higher than the concepts mean for males. Males showed the widest range of residual scores, with both the upper and lower extremes surpassing scores of females. Analysis of variance indicated a significant difference at less than the .01 level between the mean concepts scores for males and females. The data for grade five concepts achievement by sex are reported in Tables 60 and 61.

Table 60

Concepts Achievement Scores By Sex - Grade Five

Sex	Mean	Minimum Residual	Maximum Residual
Male	0.028	-4.890	2.873
Female	0.159	-1.894	2.354

Table 61

Test of Significance for Difference Between the Means of Concepts Achievement Scores by Sex - Grade Five

Source of Variation	Mean	Standard Deviation	T Statistic	P
Sex	0.093	0.765	2.713	.007*

*p < .01

The computation scores of fifth graders, when evaluated by type of instructional organization, showed that students in the non-contained classroom settings had higher mean, minimum, and maximum residual achievement scores. When the means were tested by analysis of variance, there was a significant difference at less than the .01 level. The data are presented in Tables 62 and 63.

Table 62

Computation Achievement Scores by Instructional Organization - Grade Five

Instruct. Organ.	Mean	Minimum Residual	Maximum Residual
Contained	0.023	-4.623	2.821
Non-Contained	0.196	-3.851	3.190

Table 63

Test of Significance for Difference Between the Means of Computation Achievement Scores by Instructional Organization - Grade Five

Source of Variation	Mean	Standard Deviation	T Statistic	P
Instruc. Organ.	0.133	0.872	3.006	.003*

*$p \leq .01$

When analyzing the concepts achievement scores of fifth graders by type of instructional organization, the mean for non-contained classroom settings was higher than the mean for contained classrooms. Analysis of variance showed no significant difference between the means. The data are shown in Tables 64 and 65.

Table 64

Concepts Achievement Scores by Instructional Organization - Grade Five

Instruct. Organ.	Mean	Minimum Residual	Maximum Residual
Contained	0.079	-4.890	2.873
Non-Contained	0.107	-2.030	2.250

Table 65

Test of Significance for Difference Between The Means of Concepts Achievement Scores by Instructional Organization - Grade Five

Source of Variation	Mean	Standard Deviation	T Statistic	P
Instruct. Organ.	0.093	0.765	.584	.560

The best regression model for predicting fifth grade computation achievement included a significant interaction between classroom instructional time and time in CAI. A 3x3 analysis of variance was performed to further investigate

Table 66

Computation Mean Achievement Scores for Class Time by CAI Time - Grade Five

CAI Time	Low	Average	High
Class Time			
Low	0.460	0.210	0.292
Average	-0.690	0.061	0.114
High	-0.496	-0.018	0.101

the interaction. The mean achievement scores are reported in Table 66.

The differences between means, when grouped by levels of time in CAI, were not significant. When scores were compared, grouped by levels of classroom instructional time, differences between the means were significant at the .001 level. Achievement by students receiving low levels of classroom instructional time exceeded achievement from students receiving average or high amounts of class time. Students who received average amounts of classroom instructional time were second in achievement rank, followed

Table 67

Test of Significance for Differences Between the Means of Computation Achievement Scores for Class Time by CAI Time - Grade Five

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Sig. of F
Within cells	572.146	991	0.576		
Class Time	9.127	2	4.564	7.928	.001*
CAI Time	1.520	2	0.760	1.321	.269
Class Time and CAI Time	5.442	4	1.361	2.364	.051

$^*p \leq .001$

by the scores of students who received high levels of classroom time.

The interaction of classroom instructional time and time in CAI was not significant. This means that achievement scores were were uniformly higher with regard to decreasing classroom instructional time, regardless of which level of CAI time was under consideration. The analysis of variance data are shown in Table 67.

Summary

Classroom instructional time was the only independent variable to make a significant contribution to the predictability of computation achievement gain in grade three. The interactions of I.Q. and time in CAI, along with I.Q. and sex, were also found to be significant. Although the model was a significant predictor of third grade computation achievement gain at the .001 level, it accounted for only 2.8% of the variance in gain scores.

Classroom instructional time was also the only independent variable to make a significant contribution to the predictability of concepts achievement gain in third grade. One interaction, instructional organization and sex, was found to be significant. The model was significant at less than the .05 level, but it left 99.4% of the variance unexplained.

Four independent variables, I.Q., classroom instructional time, sex, and time in CAI, made significant contributions to the predictability of fifth grade computation achievement gain. The interaction of classroom instructional time and time in CAI was also found to be significant. Although the model for grade five computation was significant at the .001 level, it left 94% of variance in gain unaccounted for.

Only one independent variable, I.Q., was found to be a significant predictor of fifth grade concepts achievement gain. The interaction of I.Q. and time in CAI qualified for inclusion in the model; but, it was not a statistically significant predictor. The model was significant at the .001 level; however, only 6.1% of the variance was explained.

CHAPTER V

FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this study was to explore the variables of I.Q., sex, instructional organization, classroom instructional time, and time in CAI in the third and fifth grades in order to determine which of the variables or combination of variables were the best predictors of both computation achievement and concepts achievement in mathematics. The sample for each grade level contained 500 boys and 500 girls, with half of each group from contained classrooms. The total sample of 2,000 third and fifth grade students was from a large suburban school district in northeast Texas.

The students were given the Iowa Tests of Basic Skills (ITBS). Third grade students completed Form 8, Level 9, and fifth grade students completed Form 8, Level 11 in the fall of 1984 and the spring of 1985. Only the ITBS subtest results of Math Problems and Math Computation were considered for this study. The Cognitive Abilities Test (CAT) was also given during the fall of 1984. Students were introduced to the WICAT program for mathematics during September 1984.

After the spring administration of the ITBS in 1985, the data were collected and evaluated using multiple regression and analysis of variance. The results obtained from the analyses were used to determine the predictors of mathematics computation and concepts achievement.

Findings

The findings concerning dependent measures for each grade follow.

Mathematics Computation Achievement for Grade Three

Results of the stepwise multiple regression analysis indicated that classroom instructional time, the interaction of I.Q. and time in CAI, and the interaction of I.Q. and sex were the variables in the model yielding the highest possible R square for the prediction of computation achievement by third grade students. The adjusted R square for the model was .028, leaving 97.2% of the variance unexplained. Classroom instructional time was a significant predictor at less than the .05 level. The interaction of I.Q. and time in CAI was significant at less than the .01 level, with the interaction of I.Q. and sex showing significance at the .001 level. The full model was significant at the .001 level.

Analysis of variance calculations were performed on all of the independent variables, as well as the interactions which were significant in the full model. When computation scores were compared by low, average, and high I.Q. levels, significant differences at the .001 level were found between the means. Students in the average I.Q. level posted the highest mean achievement score. The high I.Q. group was next, followed by the low I.Q. group.

Computation achievement scores were also classified by low, average, and high amounts of classroom instructional time and time in CAI. When mean scores were compared by levels of classroom instructional time, significant differences at less than the .05 level were reported. The mean computation achievement scores increased as time in classroom instruction increased. Results were similar for time in CAI. Achievement means increased as time in CAI increased. The differences between the achievement means, when leveled by time in CAI, were significant at less than the .01 level.

To compare the performance of males and females, analysis of variance was completed on the computation achievement scores grouped by sex. Although the mean for females was higher than the mean for males, the difference was not significant.

When achievement scores for contained and non-contained classrooms were compared, the non-contained mean was higher than that of the contained classrooms. Comparison of instructional arrangements using analysis of variance showed that the difference in favor of non-contained classroom settings was not significant.

Two interactions were found to be significant predictors of third grade computation achievement in the full regression models. Both interactions were examined using analysis of variance. When considering the interaction of I.Q. and time in CAI, differences between the means were not significant when scores were grouped by levels of I.Q. The differences between the means, when grouped by levels of time in CAI, were significant at the .001 level. As levels of time in CAI increased, achievement scores also increased. The interaction of I.Q. and time in CAI was not significant.

Analysis of variance results for the second interaction, I.Q. and sex, showed that when scores were grouped by levels of I.Q., differences between the means were significant at the .001 level. Average-ability students scored highest, followed by students with high ability and low ability respectively. When mean scores were evaluated by sex, a difference at less than the .05 level of significance was reported. Females earned higher scores than males.

The interaction of I.Q. and sex was not significant in the analysis of variance test.

Mathematics Concepts Achievement for Grade Three

The stepwise multiple regression analysis indicated that classroom instructional time and the interaction between instructional organization and sex were the variables in the model yielding the highest possible R square for the prediction of concepts achievement by students in the third grade. The adjusted R square for the model was .006, leaving 99.4% of the variance unaccounted for. Classroom instructional time was a significant predictor at less than the .05 level. The interaction of instructional organization and sex was not significant. The full model was significant at less than the .05 level.

Analysis of variance calculations were performed on all of the independent variables. When concepts scores were compared by low, average, and high levels of I.Q., the average I.Q. group posted the highest mean score followed by the high I.Q. group and then the low I.Q. group. However, the differences between the means were not significant.

Concepts achievement scores were also evaluated by low, average, and high amounts of classroom instructional time. While the mean scores rose as classroom instructional time increased, the differences between the means were not significant. Results were similar for the levels of time in CAI. Concepts achievement means increased as time in CAI increased; however, the differences between the means were not significant.

To compare the achievement of males and females on mathematics concepts, analysis of variance was completed on residual scores grouped by sex. Females posted a higher mean score than males. The difference between the means was significant at the .001 level.

A comparison of concepts achievement scores grouped by contained and non-contained classrooms showed the mean for contained classrooms to be slightly higher. The difference between the means was not significant.

Mathematics Computation Achievement for Grade Five

Results of the stepwise multiple regression analysis indicated that I.Q., classroom instructional time, sex, time in CAI, and the interaction of classroom instructional time and time in CAI were the variables in the model yielding the highest possible R square for the prediction of computation achievement for fifth grade students. The adjusted R square for the model was .060, leaving 94% of the variance unaccounted for. I.Q., classroom instructional time, time in CAI, and the interaction of classroom instructional time and time in CAI were all significant predictors at the .001 level. The sex variable was significant at less than the .05 level. The full model was significant at the .001 level.

Analysis of variance calculations were completed on all of the independent variables plus the significant interaction which was part of the full model. Comparison of the mean computation scores by low, average, and high levels of I.Q. revealed that the means increased as the level of I.Q. rose. The differences between the means were significant at the .001 level.

Computation scores were also classified by low, average, and high amounts of classroom instructional time and time in CAI. When mean scores were compared by levels of classroom instructional time, significant differences at the .001 level were reported. Fifth grade mean scores declined as classroom instructional time increased. While the opposite pattern was reported for scores when grouped by levels of time in CAI, the differences between the means were not significant.

To compare the achievement of males and females, analysis of variance was completed on the computation scores grouped by sex. Fifth grade females outperformed their male counterparts; however, the difference between the means was not significant.

When achievement scores for contained and non-contained classrooms were compared, the non-contained mean was higher than that of the contained classroom. Analysis of variance showed the difference between the means was significant at less than the .01 level.

One interaction, classroom instructional time and time in CAI, was found to be a significant predictor of fifth grade computation achievement in the full regression model. Analysis of variance revealed no significant differences between means when scores were grouped by levels of time in CAI. When scores were grouped by levels of classroom instructional time, the differences between the means were significant at the .001 level. Students receiving low levels of classroom time earned the highest achievement scores, followed by students receiving average and high levels of classroom instructional time, in that order. With a p value of .051, the interaction of classroom instructional time and time in CAI was found not to be significant in the analysis of variance.

Mathematics Concepts Achievement for Grade Five

The stepwise multiple regression analysis indicated that I.Q. and the interaction of I.Q. and time in CAI were the variables in the regression model yielding the highest possible R square for the prediction of concepts achievement by fifth grade students. The adjusted R square was .061, leaving 93.9% of the variance unexplained. I.Q. was a significant predictor at the .001 level. The interaction of I.Q. and time in CAI was not significant. The full model was significant at the .001 level.

Analysis of variance calculations were completed on the independent variables. When concepts scores were compared by low, average, and high levels of I.Q., the means increased as the I.Q. level rose. The differences between the means were significant at the .001 level.

Concepts achievement scores were also evaluated by low, average, and high amounts of classroom instructional time and time in CAI. When comparing the concepts means by levels of classroom instructional time, the differences were significant at less than the .05 level. The low classroom time level posted the highest mean, followed by the means from the high and average levels respectively. A different pattern resulted for scores when grouped by levels of time in CAI. The highest mean score was associated with the highest level of CAI time, with the scores from the low and average levels following, in that order. The differences between the means were not significant.

To compare the achievement of fifth grade males and females on mathematics concepts, analysis of variance was performed on residual scores grouped by sex. The mean score for females was higher than the mean score for males. The difference between the means was significant at less than the .01 level.

Analysis of variance on concepts achievement scores grouped by contained and non-contained classrooms showed the mean for non-contained classrooms was higher than that of contained classrooms. The difference between the means, however, was not significant.

Tables 68 and 69 illustrate the findings for the main research variables and interactions for grades three and five. The following legend is to be used for interpretation:

I.Q. . . . . I.Q.
Sex . . . . Sex
Instructional Organization . . . . I.Org.
Classroom Instructional Time . . . . Class
Time in CAI . . . . CAI
I.Q. and Sex I1
I.Q. and Instructional Organization I2
I.Q. and Classroom Instructional Time I3
I.Q. and Time in CAI I4
Sex and Instructional Organization I5
Sex and Classroom Instructional Time I6

Sex and Time in CAI I7

Instructional Organization and

Classroom Instructional Time I8

Instructional Organization and

Time in CAI I9

Classroom Instructional Time and

Time in CAI I10

Table 68

<u>Summary of Analysis of Variance Findings for</u>

<u>Grade Three and Grade Five</u>

	Grade Three		Grade Five	
	Computation	Concepts	Computation	Concepts
I.Q.	.001****	NS	.001****	.001****
Sex	NS*	.001****	NS	.007***
I.Org.	NS	NS	.003***	NS
Class	.022**	NS	.001****	.034**
CAI	.007***	NS	NS	NS
I1	NS	-	-	-
I4	NS	-	-	-
I10	-	-	NS	-

*NS = Not Significant

**p $\leq$ .05

***p $\leq$ .01

****p $\leq$ .001

Table 69

Summary of Multiple Regression Findings for Grade Three and Grade Five

	Grade Three		Grade Five	
	Computation	Concepts	Computation	Concepts
I.Q.	NS*	NS	.001****	.001****
Sex	NS	NS	.020**	NS
I.Org.	NS	NS	NS	NS
Class	.029**	.034**	.001****	NS
CAI	NS	NS	.001****	NS
I1	.001****	NS	NS	NS
I2	NS	NS	NS	NS
I3	NS	NS	NS	NS
I4	.004***	NS	NS	NS
I5	NS	NS	NS	NS
I6	NS	NS	NS	NS
I7	NS	NS	NS	NS
I8	NS	NS	NS	NS
I9	NS	NS	NS	NS
I10	NS	NS	.001****	NS

*NS = Not Significant

**$p \leq .05$

***$p \leq .01$

****$p \leq .001$

Discussion of Findings

I.Q. and Achievement

Earlier research regarding the relationship between I.Q. and achievement reported a positive correlation of .60 between a child's I.Q. score and school grades (Sattler, 1974). This study found correlations between I.Q. and the residual scores on the dependent measures as follows:

Dependent Measures	Correlation Coefficients
Grade Three Computation and I.Q.	.076
Grade Three Concepts and I.Q.	.015
Grade Five Computation and I.Q.	.161
Grade Five Concepts and I.Q.	.243

Although the correlations for fifth grade students in this study were higher than the correlations for third grade students, none of the coefficients approached the level reported by Sattler (1974).

The main variable of I.Q. qualified only as a predictor in the full models for fifth grade computation and fifth grade concepts. In both models I.Q. was a significant predictor at the .001 level. Even though I.Q. did not serve as a main variable in the regression model for third grade computation achievement, the interactions which were both significant at less than the .01 level included I.Q. When the interaction of I.Q. and time in CAI was investigated using analysis of variance, achievement scores at low, average, and high levels of ability were not significantly different. When the interaction of I.Q. and sex was analyzed using the same test, the differences in scores for the three I.Q. levels were significant at the .001 level. Average-ability students earned the highest achievement scores, followed by high-ability and low-ability students' scores in that order. It may be that the influence of I.Q. becomes stronger for prediction of third grade computation achievement when it is in combination with the sex variable. I.Q. was also part of the interaction included in the full model predicting fifth grade concepts achievement. The interaction, however, narrowly missed the .05 level of significance.

Two studies (Adams II, Waldrop, Justen III, & McCrosky, 1987; Hativa & Shorer, 1989) reported that math achievement gains for students receiving CAI were significantly greater for high-ability students over low-ability students. The finding is supported at the .001 level by this study's analysis of variance results for fifth grade students on both independent measures.

Classroom Instructional Time and Achievement

Many researchers (Anderson, 1975; Bloom, 1974; Cooley & Leinhardt, 1982; Stallings & Kaskowitz, 1974) concluded that increased time on task in a specific subject correlated with higher achievement in that same subject. The correlations between classroom instructional time and the residual scores on the posttests, as reported in this study, were as follows:

Dependent Measures	Correlation Coefficients
Grade Three Computation and Classroom Instructional Time	.093
Grade Three Concepts and Classroom Instructional Time	.078
Grade Five Computation and Classroom Instructional Time	-.129
Grade Five Concepts and Classroom Instructional Time	-.040

The coefficients for fifth grade showed a negative correlation, and third grade scores were only marginally correlated with the time reported for classroom instruction in mathematics.

The results from analysis of variance reflected the pattern indicated by the correlational data. The scores on the third grade posttests increased as classroom instructional time increased; however, the scores were significantly different at less than the .05 level only for computation. In the fifth grade, computation achievement scores declined as instructional time increased and the differences were significant at the .001 level. Fifth grade concepts scores were highest for students who received low amounts of classroom instructional time, followed next by students who received large amounts of time. Average amounts of classroom time yielded the lowest concepts achievement scores for students in the fifth grade. The differences between scores were significant at less than the .05 level.

Suydam and Osborne (1977) reported that the number of minutes structured for mathematics learning increased with each higher grade level. The finding was substantiated in this study, with fifth grade students scheduled for more classroom instruction in mathematics than students in third grade.

The main variable of classroom instructional time qualified as a predictor in the full models for third grade computation, third grade concepts, and fifth grade computation. The variable was significant at less than the .05 level in both models for third grade and was significant at the .001 level for fifth grade computation. In addition to being a significant main variable in the full regression model for grade five comprehension, classroom instructional time in interaction with time in CAI was a significant predictor at the .001 level of significance. When the interaction was tested using analysis of variance, the mean scores were significantly different at the .001 level for the three levels of classroom instructional time. Achievement scores increased as amounts of class time decreased. In other words, students receiving the lowest amount of classroom instructional time earned the highest scores on the fifth grade computation test.

Time in CAI and Achievement

Time in CAI was reported in many studies (Bracey, 1982; C. L. Kulik, J. A. Kulik, & Bangert-Drowns, 1984; Pogrow, 1983) to help raise achievement scores. Findings from analysis of variance tests in this study support the assumption that more time in CAI would be associated with higher computation achievement scores for third graders. The differences between scores were significant at less than the .01 level. When achievement scores for grade three concepts, grade five computation, and grade five concepts were grouped by levels of time in CAI, no significant differences were found between the means.

The main variable of time in CAI qualified at the .001 level as a predictor in the full model for grade five computation. Time in CAI was also part of the interactions included in the full models for third grade computation, fifth grade computation, and fifth grade concepts. The interaction of time in CAI and I.Q. was a significant predictor of grade three computation at less than the .01 level. When the interaction was tested using analysis of variance, the mean scores for levels of time in CAI were significantly different at the .001 level. Grade three computation scores increased as the amount of time in CAI increased. Similarly, the interaction of time in CAI and classroom instructional time was significant at the .001 level in predicting grade five computation scores. When analysis of variance tests were performed on the interaction, the mean scores for the three levels of time in CAI were not significantly different.

Sex and Achievement

Research over the last decade reported that until age 10, either no differences were found (Callahan & Clements, 1984; Dossey, Mullis, Lindquist, & Chambers, 1988; McKay, 1979; Peterson and Fennema, 1985) or that the differences favored females (Brandon, Newton, & Hammond, 1985; Hawn, Ellet, & Des Jardines, 1981). Results from this study support these findings. Analysis of variance tests showed a difference favoring females in third grade concepts which was significant at the .001 level. A difference favoring females on fifth grade concepts achievement was significant at less than the .01 level.

Sex, as a main variable, qualified only as a predictor in the full model for fifth grade computation. It was significant at less than the .05 level. In the full model for grade three computation, the interaction of sex and I.Q. was significant at the .001 level. Further investigation of the interaction using analysis of variance showed a significant difference at less than the .05 level between scores for males and females. The females scored higher than the males.

Instructional Organization and Achievement

Studies by Evertson (1982), Oakes (1985), and Veldman and Sanford (1984) supported heterogeneous grouping for instruction. Using analysis of variance tests, the only significant difference between contained or heterogeneous classes and non-contained classrooms occurred in relation to fifth grade computation scores. Students in non-contained situations outscored their heterogeneously-grouped counterparts at less than a .01 level of significance.

Instructional organization, as a main variable, did not qualify for inclusion in any of the regression models used for predicting achievement. As part of the interaction between instructional organization and sex, it was included in the full model for grade three concepts; however, the interaction was not a significant predictor.

I.Q. and Time in CAI

The interaction of I.Q. and time in CAI was a significant predictor in the regression model for third grade computation at less than the .01 level. Through analysis of variance, it was determined that when computation scores were grouped by levels of I.Q., no significant differences were found between the means. A significant difference was reported at the .001 level between the scores when grouped by time in CAI. Grade three computation scores increased as the amount of time in CAI increased.

When the interaction of I.Q. and time in CAI was tested using analysis of variance, the differences were not significant. In other words, the achievement scores were uniformly higher with regard to increasing CAI time, regardless of which level of I.Q. was being studied.

I.Q. and Sex

The interaction of I.Q. and sex was included in the full model for predicting third grade achievement in mathematics computation. The interaction was significant at the .001 level. Through analysis of variance it was determined that when scores were grouped by sex, the difference was significant at less than the .05 level. Females scored higher than males. When scores were grouped by levels of

I.Q., the differences were significant at the .001 level. Average-ability students earned the highest scores, followed by high-ability and low-ability students respectively.

In the analysis of variance test, the interaction of I.Q. and sex was not significant in explaining the variance in grade three concepts scores. This means that achievement scores were uniformly higher for females, regardless of which I.Q. level was under consideration.

Classroom Instructional Time and Time in CAI

The interaction of classroom instructional time and time in CAI was a significant predictor in the regression model for fifth grade computation at the .001 level. Through analysis of variance, significant differences at the .001 level were found between scores grouped by levels of classroom time. Computation scores increased as amounts of classroom instructional time decreased. When the fifth grade computation scores were grouped by amounts of time in CAI, no significant differences were observed.

The interaction of classroom instructional time and time in CAI was not significant in explaining the variance in the computation scores. This means that achievement scores were uniformly higher with regard to decreasing class time, regardless of which level of time in CAI was under consideration.

Conclusions

Based on the findings and subject to the limitations of this study, the following conclusions can be drawn.

1. I.Q. had less predictive ability for achievement gain than suggested by earlier research. When the posttest scores in this study were adjusted to control for differing levels of achievement on the pretest, the resulting gain scores reflected what the change in test scores would have been over a seven-month period if all subjects had entered with the same level of knowledge. Under the assumption that the pretest and I.Q. were highly correlated, it is suggested that the residual gain score negated most of the effect that I.Q. had exerted on achievement over the time period prior to this study. This statistical approach was used to isolate the achievement gain exclusive of prior knowledge in order to investigate some of the manipulatable variables under the control of educators. The result was that I.Q. explained less than 6% of the variance in all models tested. Findings suggest that students' I.Q. levels have little predictive value for the variation in achievement gains over instructional time periods of approximately seven months and that other variables have far greater impact on mathematics achievement.

I.Q. qualified as a main variable in the prediction of computation and concepts achievement for grade five.

I.Q. was not a main variable in the predictive models for third grade achievement. These findings indicate that I.Q. is more positively associated with the mathematics achievement of fifth grade students than third grade students.

In the predictive model for third grade achievement on the computation component, I.Q., as it interacted with time in CAI, was a significant predictor. Although the total explained variance was less than 3%, achievement scores increased at all I.Q. levels when students spent more time in CAI. This finding obviously suggests that all third grade students can benefit in mathematics computation from increased time in CAI.

When the I.Q. variable was analyzed as a single factor for explaining differences in achievement, the patterns were different for grades three and five. For both dependent measures at grade three, average-ability students outperformed the high- and low-ability students who ranked second and third respectively. For both dependent measures at grade five, high-ability students ranked first in achievement, followed by average- and low-ability students in that order. These findings suggest that factors other than I.Q. are impacting the achievement of third grade students and that the traditionally assumed influence of I.Q. is less associated with achievement at grade three than grade five.

2. Classroom instructional time qualified as a significant main variable in the predictive models for third grade computation, third grade concepts, and fifth grade computation. While a significant predictor, the amount of variance in achievement accounted for by the amount of classroom instructional time was relatively small since no model explained more than 7% of the variance. Classroom instructional time was not included in the model for fifth grade concepts. These findings indicate that the amount of classroom instructional time is not significantly associated with achievement among fifth grade students on the concepts component. Results further suggest that other variables have far more impact on mathematics achievement.

The predictive model for grade five computation included as a significant variable the interaction of classroom instructional time and time in CAI. Analysis showed that achievement gains increased as the amount of classroom instructional time decreased and that this pattern held true regardless of the time in CAI. These findings suggest that fifth grade computation is not improved by increasing classroom instructional time and that students might benefit more from an alternative use of class time.

When the classroom instructional time variable was tested as a single factor for explaining differences in achievement, the results for third grade computation differed from fifth grade results. Scores on the grade three computation test increased as amounts of classroom instructional time increased. The opposite pattern was found for grade five computation. On the fifth grade concepts test, students with low amounts of classroom instructional time ranked first in achievement, followed by students who received high amounts of time and average amounts of time respectively. These findings suggest that third grade students need and benefit from high levels of classroom instructional time dedicated to mathematics computation. The findings do not provide a clear path for time allocation decisions concerning instruction related to mathematics concepts for either grade level.

3. Time in CAI qualified as a significant main variable in the model for predicting grade five computation achievement. Analysis of variance showed no significant differences between the scores when grouped by amounts of time in CAI. Again, the actual amount of variance accounted for by this variable was small due to the fact that the full model had an adjusted R square of .060. Time in CAI was not included in the models for grade three computation, grade three concepts, or grade five concepts. These findings indicate that the amount of time in CAI, as a main variable, is not significantly associated with achievement by third grade students on both dependent measures and by fifth grade

students on mathematics concepts. The data also suggest that time in CAI is a significant predictor of achievement in fifth grade computation; however, no pattern was discovered to tell the amount of time in CAI which is most beneficial.

The interaction of time in CAI and I.Q. was a variable in the predictive model for third grade computation. As noted earlier, scores improved for all students, regardless of I.Q., as time in CAI increased. While the predictive ability of the interaction was limited, the finding implies that all third grade students benefit from high levels of time in CAI on computation measures.

4. Sex as a main variable had predictive value only for grade five computation. Since the full model had an adjusted R square of .060, the amount of variance accounted for by sex was limited. Analysis of variance findings did not reveal a significant difference between the scores of males and females on the fifth grade computation measure. While it appears that sex is a significant predictor of fifth grade computation achievement, no conclusion can be inferred as to which sex has higher achievement.

The interaction of sex and I.Q. was a variable in the predictive model for grade three computation. Females scored higher than males, regardless of I.Q. This finding indicates that instructional intervention may be advisable to help males with computation in grade three. No evidence suggests that time in CAI or classroom instructional time interacts with sex to the advantage or disadvantage of males or females.

When sex was analyzed as a single factor for explaining differences in achievement, females scored significantly higher than males on the concepts measures for both third and fifth grades. These findings suggest that males may need additional instructional help with mathematical concepts.

5. Instructional organization was not a significant predictor, as a main variable or as part of an interaction, for any of the four dependent measures. When instructional organization was analyzed as a single factor for explaining differences in achievement, it was significant only for grade five computation. Students in non-contained classroom settings scored higher than students in contained settings. While the data suggest that fifth grade students perform better if grouped in non-heterogeneous classroom settings, the small amount of explained variance in all of the models dictates caution in concluding that achievement is significantly affected by instructional organization.

Recommendations

The following recommendations are based on the findings and conclusions of this study and the review of related literature.

1. An item analysis of the ITBS dependent measures should be compared with the mathematics curriculum and the instructional objectives of the computer software to determine the degree of alignment between that which students are taught and that over which they are tested. Curriculum revision should occur as indicated by the comparison.

2. This study should be replicated with the following changes: (a) an added variable to designate the teacher of each student; (b) a different procedure for determining classroom instructional time; and (c) an added variable to designate the socio-economic status of each student.

3. Further study of the time variables should be undertaken. The differing results found between grade levels and dependent measures suggest there are differences in terms of the interaction of these variables.

4. Instructional strategies should be developed to close the achievement gap between males and females on mathematics concepts.

5. Professional educators should move away from basing mathematics achievement gain expectations predominantly on student I.Q.

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