Spring 1995

A Meta-Analysis of the Effect of Computer-Assisted Instruction on the Academic Achievement of Students in Grades 6 Through 12: A Comparison of Urban, Suburban, and Rural Educational Settings

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A Dissertation Submitted to the Faculty of Old Dominion University in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

Urban Education

Old Dominion University

April 1995

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Abstract

This meta-analysis analyzed grades 6 through 12 school students' academic achievement effect sizes from experimental, quasi-experimental, and correlational studies that examined the effects of microcomputer-based computer-assisted instruction (CAI) on the academic achievement of urban, suburban, and rural students across various subjects. Those studies compared secondary students who were exposed to CAI with those who were exposed to traditional instructional strategies.

A total of 3,476 students participated in 24 studies which resulted in 35 conclusions. The sample size ranged from 28 to 425; the mean sample size was 140 students.

The mean effect sizes of urban, suburban, and rural students uncovered differences in the effect of CAI on secondary students' academic achievement. CAI appears to have its strongest effects among urban students; its effects are weaker among suburban students and weakest among rural students. The mean effect size of the seven studies in urban areas was 0.362. In suburban areas, nine studies yielded a mean

effect size of 0.227, and a mean effect size of 0.148 was calculated across eight studies in rural educational settings.

From the 35 conclusions, an overall mean effect size was calculated to be 0.233. The overall mean effect size of this study indicates that the average student exposed to CAI showed academic achievement greater than 58.7% of the students exposed to traditional instruction.

The 35 effect sizes were categorized into seven academic subject areas. The mean effect size of CAI on science students' academic achievement was the largest effect size in the meta-analysis. In descending order, the mean effect sizes by subject area in science, reading, special education, music, math, vocational education, and English are as follows: 0.717, 0.262, 0.259, 0.230, 0.179, 0.168, and -0.420, respectively.

The 35 effect sizes were compared over time by calculating the mean effect size of the studies conducted within each year from 1984 to 1993. The mean effect of CAI on student academic achievement generally declined over time.

I shall be telling this with a sigh
Somewhere ages and ages hence:
Two roads diverged in a wood, and I -
I took the one less traveled by
And that made all the difference.

From "A Road Not Taken"
- Robert Frost

Dedication

I would like to dedicate this dissertation to my daughter, Lauren.

Acknowledgments

I would like to express sincere appreciation to Dr. Robert Lucking for his guidance in the preparation of this dissertation. As chair of my committee, his personal interest and support of my efforts in completing this study were invaluable. In addition, I wish to thank Dr. Steve Purcell and Dr. Jack Robinson for giving their time, insight, and valuable expertise in serving as members of my committee.

Without the influence of my family and friends, this dissertation would not have been completed. Special thanks to my brother, Jeff Christmann, whose unending friendship and influence has accompanied my journey toward this dream from the beginning.

To my parents, Nina and Ed Christmann, I offer my gratitude for your encouragement and support.

To my grandfather, Edwin A. Christmann, for being a great teacher and planting the idea for me to earn a doctorate.

Most importantly, I wish to thank my wife, Roxanne, whose sacrifices and dedication to our children gave me the opportunity to complete this project.

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CHAPTER 1

Introduction

Little doubt exists that throughout the last two decades the educational system in America has been beseiged with criticism. President Bush urged government officials to help develop a plan to solve the problems of America's educational system. A Nation at Risk: The Imperative for Educational Reform identified a severe crisis in American education, and it helped spawn America 2000--a plan created by the Bush administration to help our students compete internationally. More students are competing for college entrance, and parents want to make sure their children are prepared for the increased competition of the 21st century. According to the Carnegie Task Force (1986), further research is necessary on those educational efforts that are used to bolster student achievement. Various recommendations have been made to restore lagging student achievement; including increasing the length of the school year, increasing teachers' salaries, providing greater financial school support, and restructuring administrative practices through school empowerment and organizational change (Wilson & Harriot, 1990). Case (1987) suggests another alternative is to integrate microcomputer applications into schools. While it is true that microcomputers have been an integral part of American classrooms for nearly twenty years now, their roles have changed quite markedly.

During the 1970s, secondary schools implemented microcomputers primarily in laboratory settings; the focus of using computers was to develop computer literacy and programming skills (Case, 1987). Papert improved the early applications by integrating programming and learning through the development of LOGO as a mode of developing students' higher-order thinking skills (Clements, 1985). However, some teachers chose to utilize computers primarily to enhance academic achievement in various subject areas, such as mathematics, English, or science. Used that way, computer-assisted instruction (CAI) became a supplemental instructional method in schools across the United States (Kulick, Kulick, & Bangert-Drowns, 1985).

Lockard, Abrams, and Many (1994) report that the number of microcomputers in schools increased 600% from

1983 to 1991, and the average number of students per computer decreased from 125 to 19. This increased the number of microcomputers to approximately 2.5 million at a time when the U.S. teacher population was 3 million--less than one microcomputer per teacher. Furthermore, many of the microcomputers are too old to support modern software and hardware options. Ross (1988) explored which educational settings most frequently purchase and use microcomputers. He found that schools in rural settings use microcomputers less frequently than schools in urban settings. Rural principals surveyed stated that money was not available for microcomputers or for training teachers how to use them.

In a recent article, Labic (1992) asserts that Americans expect too little from their children. The author lists ten instructional areas that must be enhanced if American students are to remain competitive globally. One of the primary areas needing improvement is directly related to the use of CAI. Schwartz (1991) suggests that computers may provide a new mechanism for instruction and learning, thereby increasing students' potential for remaining competitive in a contemporary world. Computers provide students with enjoyable tools to learn and understand information, thereby improving academic performance (Kay, 1991).

Rationale

American education is at a crossroads; current trends must be examined and analyzed to cultivate the future global competitiveness of American students. The literature abounds with reports which explore the effectiveness of computers in education and provide evidence that computers are valuable aids to enhance student learning. Much of past research concentrates on software programs that were designed for specific disciplines. Subsequently, researchers generalized their findings in those disciplines to differing educational settings. The United States is entering a major period of transformation. Changes in the composition of our population, dramatic changes in the power of our economy, new technologies, and an emerging world order all suggest changes for our schools. Indeed, Mauriel's (1989) research suggests that students differ because of social, economic, demographic, and educational backgrounds.

Roblyer (1989) suggests that further research is necessary to determine whether CAI is more effective among certain kinds of students. Urban students encounter different learning conditions than suburban or rural students. For example, many urban students (one in nine) qualify for special education programs; and new trends, such as children born with drug dependence, make urban students a challenging task for educators (Mauriel, 1989). The purpose of this study was to determine whether CAI contributed to gains in students' academic achievement in differing educational settings, more specifically, urban, suburban, and rural. Also, this study reveals areas within education where CAI may be applied more effectively.

The microcomputers and software prevalent in today's schools were not used as the treatment in previous meta-analytic CAI research. Modern microcomputer-based CAI offers students more advanced technology, such as improved monitors, alternate input devices (e.g., mice, light pens, and touch screens), CD-ROMs, and faster and more efficient microprocessors. Also, contemporary software allows greater student interaction with greater stores of information. For example, a student can examine video clips, art, music, or conduct science experiments through multimedia activities. Mason (1984) asserts that as computers continually improve, academic achievement gains will increase.

Little research exists on the effectiveness of modern hardware and software that are present in today's secondary school settings. This investigation of the effectiveness of contemporary technology on academic achievement compared mainframe-and-microcomputer-CAI delivery on the academic achievement of secondary students. Additionally, this study compared the effectiveness of CAI to non-computer-based methods of instruction. Thus, new information was generated regarding the impact of contemporary technology on secondary students' academic achievement relative to traditional methods of instruction.

Despite research to date, little is known about the consequence of having introduced microcomputers in American public schools. As the number of microcomputers for instructional purposes increases, it will become more important to use them in the most effective and productive manner. This study exposed the areas of education where computers are impacting learning the most. Furthermore, the effectiveness of CAI on the academic achievement of secondary school students was explored. Subsequently, an agenda for researchers of educational technologies was developed.

Statement of the Problem

The necessity to improve academic achievement in American secondary schools has created the impetus for conducting a meta-analysis on all available research pertaining to computer-assisted instruction in Grades 6 through 12. This study focused on the following research question:

> *What differences exist in the academic achievement levels between urban, rural, and suburban secondary students who were exposed to computer-assisted instruction and those who were not?*

This research evaluated the effectiveness of CAI on urban, rural, and suburban student academic achievement. Prior meta-analytic research on Grades 6 through 12 examined the effects of mainframe computer-driven software. This study concentrated on research examining the effectiveness of microcomputer-based software on academic achievement. Thus, the mean effect size of data included in this study was compared with the overall mean effect size of prior research that concentrated on mainframe computer-driven software.

This study determined in which educational disciplines and in which settings--urban, suburban, or rural--microcomputers were most effective in enhancing academic achievement. In addition, calculated effect sizes compared the relative effectiveness of using microcomputers versus traditional instructional methods in urban, suburban, and rural schools.

Methodology

The data from the study were analyzed by using a meta-analysis. Meta-analysis is designed as a secondary statistical analysis or re-analysis of previous research to answer new questions using old data (Glass, McGraw, & Smith, 1981). The procedure is a quantitative statistical method for organizing and extracting information from large masses of data that would have been impossible to gather by any other means

(Borg & Gall, 1989).

The meta-analytic approach that was used in this study was similar to the method used by Glass et al. (1981). Their approach to meta-analysis required the following: (a) locating studies through unbiased and replicable data searches, (b) coding the studies for prominent features, (c) describing each study's outcomes and creating a common scale, and (d) using statistical methods to combine the studies from a mixed set of results and to quantify a specific conclusion.

The studies examined in this research were selected from the following sources: the Educational Resources Information Center, Dissertation Abstracts International, and Psychological Literature. The selection process was based on the following criteria:

1) The study was conducted in a secondary school;
2) The study included quantitative results on academic achievement as the dependent variable and microcomputer-provided computer-assisted instruction as the treatment;
3) The study was of a quasi-experimental, experimental, or correlational research design;

4) The study sample size had a combined minimum of 20 students in the experimental and control groups.

Over one thousand relevant publications were identified for selection and possible integration into this meta-analysis. Of these, twenty-four met the criteria to be included in this meta-analysis. Studies not included in this meta-analysis did not meet all four selection criteria for integration into this study. Interestingly, the majority of CAI publications not meeting the criteria for integration into this study (nearly one thousand) did not utilize the statistical manipulation of experimental data. Clearly, there is a need for more and better research on the outcomes of CAI in the instructional process.

Limitations. This meta-analysis relied on the accuracy of published and unpublished research to provide the data analyzed in this study. The treatment was the use of CAI as an instructional method. The independent variable that was used in this study was the educational setting--urban, suburban, or rural. The dependent variable was the measure of academic achievement through the use of teacher-assigned grades, commercially designed standardized tests, locally developed tests, teacher evaluation, and percentile rankings on standardized tests. Studies included in this meta-analysis were selected by choosing research that included CAI as the treatment variable and academic achievement as the dependent variable.

This meta-analysis relied on the author's ability to classify the educational setting of each study used as either urban, suburban, or rural. This research is limited by the original researchers' definitions of urban, suburban, and rural educational settings. Copies of the original manuscripts were obtained, and evidence was gathered to identify the original authors' classification of the educational setting. In most cases, specific demographics had been provided in the manuscripts to aid in this classification.

The educational setting used here was identified by one of two ways. First, many authors explicitly classified their research setting by specifically labeling the educational setting as either urban, suburban, or rural. In these instances, no further assessment was necessary to clarify the classification the article's setting for the purpose of this meta-analysis. However, if an author did not explicitly state whether the study was conducted in an urban, suburban, or rural setting, the original original was contacted to specify the setting. Therefore, the classification of the educational setting fell to the original authors.

As one examines the range of studies that is described in these chapters, it is clear that studies conducted in Chicago or Boston (metropolitan areas) are urban educational settings. It is also clear that a study conducted in Farmington, Iowa is a rural educational setting. The Bureau of the Census (1990) defines an urban setting as place with a minimum population density of 1,000 persons per square mile. Rural settings are defined as places with a population density lower than 1,000 persons per square mile (Census, 1990). Based on these definitions, the precision of the original author's judgements cannot be fully ascertained in every case.

The educational setting classification of some studies used in this meta-analysis may be considered questionable. For example, the study conducted by King (1988) referred to Urbana-Champagne as merged cities with a combined population of 100,000. Both Urbana and

Champagne have populations above 2,500 with population densities greater than 1,000 persons per square mile. Therefore, King's (1988) study meets the Census Bureau's definition of an urban setting, and therefore, meets the urban classification used in this meta-analysis. Another study included that may come under scrutiny is Mason's (1984) research on an Iowa school system. In this case, it became necessary to contact the Graduate College of The University of Iowa. In doing so, Dr. Harold Schoen, Mason's thesis supervisor was contacted in order to gain clarification of the setting of Mason's study. Schoen (personal communication, April 27, 1995) indicated that "Mason's (1984) study was conducted in the Cedar Rapids City Schools, an urban district with over 20,000 students."

While differences may be found among urban, suburban, and rural schools, it will be impossible to determine the causality of these differences. The effectiveness of computers among certain students and in specific academic disciplines has yet to be clearly defined by the community of academic scholars. Therefore, this study will help set forth a research agenda for others in the field of CAI.

Analysis

After all of the data were gathered, they were analyzed through a meta-analysis. Meta-analysis relies heavily on the calculation of an effect size to establish statistical meaning (Wolf, 1986). According to Glass et al. (1981), the effect size is the degree to which the phenomenon is present in the population of the study. In meta-analysis, an effect size is calculated to establish statistical difference in mean standard deviation units (SD_x) (Wolf, 1986). The calculation depends on the type of statistical method that was used for the research design. For example, a multivariate analysis yields an F ratio to determine the ratio between two or more groups to establish significance (Kachigan, 1986). In studies where two means are compared, a t-value is used to establish significance (Bruning & Kintz, 1987). An effect size can be calculated by substituting the t-value, the F ratio, or the correlation coefficient (r) into its effect size equations (See Table 1).

Table 1

Effect Size Formula Transformation

Statistic	Formula transformation to ES
t-value	$ES=\frac{2t}{\sqrt{df}}$
F ratio	$ES=\frac{2\sqrt{F}}{\sqrt{df}}$
r	$ES=\frac{2r}{\sqrt{1-r^2}}$

The effect size formula transformation was not necessary if the standard deviation of the control group and the means of the experimental group and of the control group were available within the data provided in the study. In this case, the effect size formula (definitional formula) was the following:

$$ES=\frac{\overline{x_c}-\overline{x_t}}{sd_t}$$

where x_c is the mean of the experimental group, x_t is the mean of the group that did not receive CAI, and SD_t is the standard deviation of the group that used traditional methods of instruction.

Holmes (1984) devised a formula to calculate the mean effect size when the size of each group is reported. In that case, the effect size formula was the following:

$$ES = \sqrt{F\frac{1}{n_c} + \frac{1}{n_t}}$$

where n_c is the size of the experimental group, n_t is the size of the control group, and F is the F ratio.

After all effect size calculations were computed, mean effect sizes for each study were calculated on the effect size scores and comparisons between groups were undertaken. A mean effect size was determined by summing all effect sizes and dividing by the number of effect size calculations. The following formula was used to calculate mean effect size:

$$ES_{\bar{x}} = \frac{\Sigma ES}{n}$$

where n is the number of effect size calculations and ΣES_x is the sum of the mean effect sizes.

Once the mean effect size was calculated, the relative statistical significance was determined through an effect size classification. The approach that was used in this study was similar to the method used by Cohen (1977). Cohen (1977) provides the following ranges for mean effect size interpretations: ES = 0.200 to 0.499 (small effect), ES = 0.500 to 0.799 (medium effect), and ES = 0.800 and above (large effect).

A comparison between the control group and experimental group distribution shows the average effect in standard deviation units (SD_x). Cohen (1977) provides a table for translating the ES_x scores into a graphical representation that shows the degree of overlap between control and experimental groups. This comparison was accomplished by taking the area of a standard deviation unit and calculating the percentage of the experimental group that exceeded the upper half of the control group. Wolf (1986) provides the following example:

> The area under a normal curve associated with ES_x = 0.320 is 0.625. This means that the average person receiving the exercise intervention would have a score greater than 62.5% of the people in the non-exercising group. Thus, exercise could be expected to move the typical person from the 50th to the

62.5th percentile of self-concept for the non-exercising population. (p.28)

Figure 1 is a graphical representation of Wolf's (1986) example of average effect size in $\underline{SD}_x$ units.

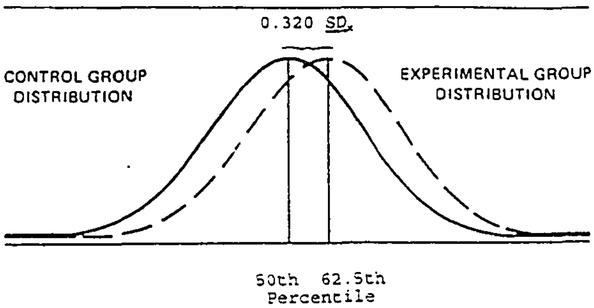

Figure 1. Average effect size in $\underline{SD}_x$ units

In this study, descriptions of the individual studies and information are presented in the order of sample, location and setting, methods, variables, findings, and effect sizes.

Definition of Terms

The following definitions are used in this study.

Achievement test. A numerical score that gives an indication of student learning that may have resulted from instructional treatment.

Computer-assisted instruction (CAI). The use of computers in education for such exercises as drill and practice, tutorials, instructional games, and simulations.

Drill and practice. A type of computer-assisted instruction that allows students to practice skills or study information with which they are familiar but not proficient.

Educational game. A motivational strategy used to achieve specific learning objectives using the unique capabilities of the microcomputer; requires a student to follow prescribed rules and includes some form of competition with herself, another student, or the computer.

Microcomputer. A general-purpose computer of small size and low cost that is capable of processing and manipulating data, graphics, and words and that has the ability to store and retreive information. This term refers to the computer, a disk drive, and monitor.

Simulation. Computer-assisted instruction that allows students to interact with models of reality that may otherwise be impossible, dangerous, or impractical.

Software. Programs that provide instruction to the computer and student.

Traditional instruction. Instructional method that does not utilize microcomputers as part of the educational process.

Treatment group. A group in which the normal curriculum is supplemented with computer-assisted instruction.

Tutorial. A computer program that presents a concept that a learner does not yet know in segmented, individual steps.

CHAPTER 2

Review of the Literature

Computer-assisted instruction (CAI) is a generic term that describes any instructional application of computers in educational settings. CAI software is available for language arts, mathematics, science, social studies, and vocational courses. Five subcategories exist within CAI including drill and practice, tutorial, simulations, problem solving, and educational games (Lloyd, 1986).

Researchers distinguished the CAI subcategories through early work that was completed by Atkinson, (1969) and Watson, (1972). Through drill and practice, the computer reinforces traditional instruction through relevant practice exercises to be completed by the student. The tutorial mode provides the student with an introduction to concepts and appropriate questioning strategies. Simulations allow students to assume a role that aspires to accomplish specific goals. In problem solving, students must make decisions, following logical steps, and find an answer to a problem by using the information provided. With educational games, students learn through entertaining or recreational activities. The teacher-authored format allows instructors to create an individualized program to meet the specific needs of students. CAI has been an effective instuctional method across several disciplines (Robyler, 1985).

Previous Meta-Analytic Findings

Ryan (1991) found that elementary-age students, when exposed to microcomputer applications in schools, gained three additional months of learning for every year they used microcomputer integrated instruction. This finding was determined after calculating a 0.309 effect size in a meta-analytic study of elementary school students. The effect size score was converted to an academic achievement unit because students normally gain 0.1 grade-equivalent unit per month, or 1.0 grade-equivalent unit per 10-month school year. Glass et al. (1981) states the following:

> ...it is also known, as an empirical--not a definitional--fact that the standard deviation of most achievement test scores in elementary school is 1.0 grade-equivalent units; hence the effect

> size of one year's instruction at the elementary school level is 1.0 grade-equivalent units. (p. 103)

Ryan's (1991) research focused on elementary school students in urban, suburban, and rural educational settings. Her study was similar to the meta-analytic research done by Kulick, Kulick, and Bangert-Drowns (1985) which analyzed the effect of CAI on academic achievement in elementary schools. Studies by Ryan (1991) and Kulick, Kulick and Bangert Drowns (1985a) utilized meta-analytic procedures to calculate the mean effect size of academic achievement on elementary school students. Kulick, Kulick, and Bangert-Drown's (1985b) study calculated a 0.470 mean effect size for elementary school students. Interestingly, the more contemporary study by Ryan (1991) calculated a 0.309 mean effect size which showed a decrease in the mean effect of computer-assisted instruction. Findings in both studies indicate that computer-assisted instruction improves students' academic achievement in elementary school settings. In addition, these findings lend evidence to support Manuel's (1987) study that showed computer-assisted instruction improved students' academic achievement. However, these findings contradict Mason's (1984) assertion that as computers continually improve, students' academic achievement gains will increase. Mason (1984) suggests that further research is necessary to determine why differences exist between the statistical results of these studies.

Kulick, Kulick, and Bangert-Drowns (1985a) examined the effectiveness of CAI on secondary students. They used meta-analysis techniques to calculate an effect size of CAI on academic achievement. The mean effect size calculated was .360. Again, computer-assisted instruction was found to be a more effective method of instruction than traditional instructional methods. The study also found that the higher effect sizes occurred in the most recent research. This finding is contrary to the decrease in academic achievement that occurred between the elementary school meta-analysis of Kulick, Kulick, and Banger-Drowns (1985b) and the meta-analysis of Ryan (1991). Kulick, Kulick, and Banger-Drowns' (1985b) research also found that when exposed to computers, lower aptitude students exhibited greater increases in their academic achievement than higher aptitude ones.

Eighty percent of the studies reviewed by Kulick, Kulick, and Bangert-Drowns (1985b) used mainframe-based software. Ryan's (1991) meta-analysis explored the effect of contemporary microcomuter-based software on the academic achievement of elementary school students. Based on prior meta-analytic research, a comparison of the effect of CAI on the academic achievement of secondary students using mainframe-based software and those that used microcomputer-based software could not be established.

CAI and Academic Achievement

Schools nationwide are adopting computer-assisted instruction for the primary purpose of enhancing student achievement. America's students have to be able to compete with the world's students. The implementation of computers coincides with the role of education to keep abreast with societal demands (Chira, 1990). Mechlinberger (1988) argues that education and the private sector must work together for America to remain competitive with other countries. The computer has developed as the fundamental tool for the successful operation of business and industry; school reformers suggest that technology may help link schools with the private sector (O'Malley, 1989).

Pogrow (1985) reported that CAI can produce learning gains similar to reducing the pupil-teacher ratio to 2-to-1. However, the findings indicated that students must work on a microcomputer for 15 to 20 minutes per day, four days per week. This finding concurred with the Computer Curriculum Corporation's CAI research that revealed students need exposure to CAI for a minimum of 10 to 15 minutes daily to improve their academic achievement (Suppes, 1980).

Hartley (1977) also suggests that CAI is effective in increasing academic achievement. He reports that students exposed to CAI gain an average effect size in mathematics achievement of 0.410. This is equivalent to an increase from the 50th to the 66th percentile in mathematics achievement. Hartley further determined that CAI was less effective than peer tutoring and more effective than individualized learning strategies.

Edwards (1975) found that traditional instruction supplemented with CAI is more effective than traditional instruction alone. Burns and Bozeman

(1981) concurred with Edwards when they found CAI to be significantly more effective in increasing student academic achievement than traditional methods of instruction. Furthermore, Roblyer's (1985) review of the research found that CAI was effective as an additional instructional method at both elementary and secondary school levels.

Easterling (1982) examined the effects of CAI on fifth-grade mathematics achievement. Students were exposed to computers twice a week for 15 minutes each class session; there was no significant difference between the academic achievement of the CAI group and the non-CAI control group. As a result, Easterling recommends additional CAI sessions of up to four or five per week to increase academic achievement.

Jamison, Suppes, and Wells (1974) established that CAI was more effective for elementary students than for secondary or college students. Roblyer's (1985) review of the literature also reports larger academic achievment gains for elementary students than secondary students. This finding concurs with the Kulick, Kulick, and Bangert-Drowns (1985a; 1985b) meta-analysis of studies on elementary and secondary students.

Burns and Bozeman also (1981) found that CAI significantly improved academic achievement among disadvantaged elementary and secondary students. Their results indicate that drill and practice was more effective in increasing academic achievement with disadvantaged elementary and secondary students than high-achieving students. However, average students experienced no gains in academic achievement when exposed to CAI drill and practice.

A four-year study by the Educational Testing Service on the effects of computer-assisted instruction in the Los Angeles Unified School District found that students who had been performing at below-average levels improved their basic skills through drill and practice activities. In that particular study, academic achievement gains in mathematics were cited as the most significant (Ragosta, Holland, & Jamison, 1982).

Becker (1986) compared students by achievement level and discovered that higher achieving students are exposed to CAI more often than below-average students. Becker's survey was completed by elementary and secondary teachers who worked directly with students of both levels. Becker's results contrast with those of Burns and Bozeman (1981) and Edwards (1975).

Learning disabled students using CAI mathematics software were compared to a control group that used traditional instructional methods. Both groups received 40 minutes of instruction each day of the 180-day school year. The grade-equivalent gain for the group using CAI was 0.8 years, whereas the control group gained only 0.3 years (Trifiletti, Grith, & Armstron, 1984).

Other studies established that CAI can increase the rate of student learning. Kulick, Bangert, and Williams (1983) found that students' exposed to CAI increased their academic achievement ranking from the 39th to the 88th percentile. Valdez's (1986) research concurred with this; students learned 10 to 40 percent more information in a given time frame through the use of microcomputers. To increase the rate of learning, those students used the computer for at least 12 to 20 minutes per day, four times per week. Also, proper learning objectives that corresponded to the curriculum and appropriate software were utilized to increase the rate of learning.

Many of these studies established differences between between males and females in the effectiveness of CAI. Burns and Bozeman (1981) report that the drill-and-practice method of CAI was significantly more effective in increasing academic achievement gains among middle-school boys than traditional instructional methods alone. However, the girls did not show a significant increase in academic achievement; traditional methods of instruction were as effective as drill and practice for middle school females.

Cole and Hannafin (1983) report that girls were reluctant to use microcomputers. The research indicates that girls expressing an interest in computers experienced negative peer pressure. However, boys were encouraged to use computers by peers, teachers, and parents (Lipkin & McCormick, 1986).

Becker (1986) found that boys and girls occupied computer labs for equal amounts of time over the course of a school day. However, boys used computers more often before and after school. Becker reports that when teachers were asked which students were most affected by computers, 62% responded that boys were impacted to a higher degree than girls. These boys reportedly had improved self-esteem, self-discipline, and motivation. However, the 38% of teachers who identified a greater impact for girls suggested that computers did help female academic achievement.

The Arkansas Commission on Microcomputer Instruction found that students using computer-assisted instruction gained an additional 24% to 29% of a year's growth in reading, mathematics, and language arts compared to a control group with a similar background (Bittner, 1983). The University of Oregon's Center for Advanced Technology in Education (CATE) selected elementary school students to utilize the Milliken Math software sequence for 10 minutes per day for 71 days. Compared with a control group which did not use microcomputers, those students using CAI scored significantly higher when tested in math concepts and problem solving skills (Hawley, Fletcher, & Piele, 1986).

Review of the Literature Summary

Research substantiates that computer-assisted instruction is effective in improving academic achievement when utilized as a form of supplemental instruction at both the elementary and secondary school levels. CAI instructional methods have been successful in enhancing achievement in various subject areas. Furthermore, CAI has shown to be more effective in raising the academic achievement among younger students, lower ability students, and disadvantaged students. Research suggests that boys have greater confidence and a higher level of interest in using computers than girls. Academic achievement gains were higher among boys than girls when CAI drill-and-practice was used as an instructional method. Research also indicates academic achievement gains can be realized when traditional instruction is supplemented with CAI for 15 to 20 minutes per day, four days per week.

The importance of CAI's effect on academic achievement in all school learning has been established in the research literature. Research regarding the effect of CAI on the academic achievement levels between urban, rural, and suburban secondary students had not been thoroughly evaluated at the inception of this study. This meta-analysis will initiate a line of CAI research by providing a better understanding of the effects of CAI on students in differing educational settings.

Chapter 3

Methodology

The research design used in this study was a meta-analysis. This chapter provides a description of the studies included and also includes the calculation of effect sizes. Table 2 lists the researchers, publication dates, and locations of the studies included in this meta-analysis. Descriptions of each individual study will follow, showing sample, location and setting, methods, variables, findings, and effect sizes.

Table 2

Studies Included in the Meta-Analysis

Author(s)	Date	Location
Bailey, T. E.	1991	Urban, VA
Bass, et al.	1986	Suburban, VA
Battista, et al.	1987	Urban, OH
Birkenholtz, et al.	1987	Rural, MO
Carnes, et al.	1987	Suburban, OH

Table 2 (Continued)

Studies Included in the Meta-Analysis

Author(s)	Date	Location
Christie, et al.	1989	Urban, AZ
Davidson, R. L.	1985	Urban, TN
Dupnin, R.	1985	Rural, MI
Dunn, S. M.	1985	Rural, AL
Elliot, E. L.	1985	Rural, MI
Ferrell, B. G.	1986	Urban, TX
Hounshell, et al.	1989	Rural, NC
Hunter, et al.	1992	Rural, PA
King, R. V.	1988	Urban, IL
Klein, et al.	1987	Suburban, FL
Landry, S. A.	1987	Suburban, CT
Lewis, et al.	1993	Suburban, CA
Manuel, S. Q.	1987	Rural, NE
Marty, J. E.	1986	Suburban, WI
Mason, M. M.	1984	Urban, IA
McCaskey, et al.	1989	Rural, MO
St. Pierre, K. A.	1992	Suburban, OH
Wohgehagen, K. S.	1992	Suburban, TX
Wood, J. B.	1991	Rural, IN

Review of Studies and Calculation of Effect Sizes

Bailey, T. (1991). The effect of computer-assisted instruction in improving mathematics performance of low achieving ninth-grade students (Doctoral dissertation, The College of William and Mary, 1991). Dissertation Abstracts International, 52, 11-A.

Sample

The sample consisted of 46 ninth grade students. All of the students were low-ability students whose eighth-grade Iowa Test of Basic Skills scores ranked between the 1st and 30th national percentile(s).

Location and Setting

The study was conducted on four classes of students registered for a course entitled Mathematics Nine. The research site for this study was an urban high school in the Hampton City School Division of Hampton, Virginia.

Method

Identified students were randomly assigned to 1 of 4 instructors and 1 of 2 instructional groups (computer-assisted instruction or traditional instruction). Students in the treatment group used 16

Apple IIe microcomputers and were exposed to CAI for 50 minutes daily. A pretest/posttest comparison group design was used to compare CAI to traditional instructional methods. A repeated measures analysis of variance was used to analyze the data.

Variable

The dependent variable of interest in this study was the Iowa Test of Basic Skills (ITBS). The ITBS was used as the pretest and posttest measure. The treatment variable in this study was CAI through the use of drill and practice, simulation, and games.

Findings

The study found a significant difference ($p < .05$) in total mathematics achievement between students receiving CAI and those that received only traditional instruction. Students receiving CAI exhibited an increased mean ITBS score from the 11th percentile to the 30th percentile.

Effect Size

One effect size will be calculated from this study using the definitional formula. The CAI group had a mean ITBS score of 159.76 while the group exposed to traditional instruction had a mean of 149.96 with a standard deviation of 12.65.

$$\underline{ES}=\frac{159.76-149.96}{12.65}=0.775$$

The effect size of 0.775 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a medium effect.

Bass, G., Ries, R., & Sharpe, W. (1986). Teaching basic skills through microcomputer instruction. Journal of Educational Computing Research, 2(2), 207-219.

Sample

The sample in this study consisted of intact, low achieving, Chapter I, sixth-grade reading and math classes containing boys and girls. The math group had a total of 121 students (n = 61 in the treatment group and n = 60 in the control group). The reading group contained 85 students (n = 42 in the treatment group and n = 43 in the comparison group).

Location and Setting

The study took place among four teachers at a suburban middle school. The school was a component of the James City County School System in Williamsburg, Virginia.

Method

Students' performance was assessed with a pretest/posttest nonequivalent comparison group design that used standardized tests to measure reading and math achievement. Students in math classes were assigned either to a treatment group which utilized CAI or to a comparison group which exposed students to traditional methods of instruction. Students in reading classes were also assigned to either a treatment group (CAI) or to a comparison group (traditional instruction). The treatment and comparison group in each subject area received regular instruction, but students in the treatment groups received supplemental CAI over a 30-week period. The reading treatment group averaged a total of 14.89 hours of CAI over the 30-week period. The math treatment group averaged 8.72 hours over 30 weeks. Each treatment classroom contained four Apple microcomputers, each used by a pair of students while the remaining students worked on regular class assignments. All treatment students were scheduled for computer time during each week.

Variable

The dependent variables in this study were mathematics and reading achievement as measured by the SRA Achievement Series and the Virginia Basic Learning Skills Test (VBLS). The treatment variable in this study was CAI through the use of microcomputer-based drill and practice, simulation, and game software.

Findings

The study found significant differences ($p < .05$) among students exposed to CAI in reading and mathematics on the SRA Achievement test. An analysis of the VBLS test also indicated that the CAI groups had positive achievement gains ($p < .05$).

Effect Sizes

Four different effect sizes will be calculated using the Holmes method from the data available in this study and are as follows: the mathematics group SRA Achievement Series, the mathematics group VBLS

Achievement Series, the reading group SRA Achievement Series, and the reading group VBLS test.

Mathematics group SRA achievement series. For the CAI group, n = 61; and for the group exposed to traditional instruction, n = 60. The F value was calculated to be 5.196.

$$ES=\sqrt{5.196\left(\frac{1}{61}+\frac{1}{60}\right)}=0.414$$

The effect size of 0.414 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Mathematics group VBLS test. The CAI group had an n of 61, and the group exposed to traditional instruction had an n of 60. The F value was calculated to be 0.130.

$$ES=\sqrt{.130\left(\frac{1}{61}+\frac{1}{60}\right)}=0.066$$

The effect size of 0.066 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Reading SRA achievement series. The CAI group had an *n* of 42 and the group exposed to traditional instruction had an *n* of 43. The *F* value was calculated to be 8.35.

$$ES=\sqrt{8.35\left(\frac{1}{42}+\frac{1}{43}\right)}=0.626$$

The effect size of 0.626 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a medium effect.

Reading VBLS test. The CAI group had an *n* of 42 and the group exposed to traditional instruction had an *n* of 43. The *F* value was calculated to be 3.77.

$$ES=\sqrt{3.77\left(\frac{1}{42}+\frac{1}{43}\right)}=0.421$$

The effect size of 0.421 is positive because higher scores were attained by the group that received CAI. Cohen's (1977) vote table interprets this effect size as a small effect.

Battista, M. T., & Clements, D. H. (1986). The effects of LOGO and CAI problem-solving abilities and mathematics achievement. Computers and Human Behavior, 2, 183-292.

Sample

The study consisted of 48 sixth-grade students who volunteered to be subjects in this study. The subjects were divided between two schools into a CAI treatment group and a comparison group.

Location and Setting

The participants in this study were from an urban middle school. The school was a part of the Kent City Schools in Ohio.

Method

Two middle school mathematics classes were divided into a treatment group (CAI) and a comparison group (traditional instruction). Students were randomly assigned to the CAI and comparison group. Students' academic achievement was assessed with a pretest/posttest comparison group design that used standardized tests to measure mathematics achievement. Students in the CAI group used microcomputers twice each week for 40 minutes over a 21-week period. Students worked in pairs on the microcomputers using CAI and Logo problem solving software.

Variable

The dependent variable for this study was mathematics achievement as measured by a locally-designed problem solving test. That test was used as the pretest and posttest measure of achievement.

Findings

This study found no statistically significant differences ($p < .05$) for academic achievement in mathematics between the treatment and comparison groups.

Effect Size

One effect size will be calculated from this study using the definitional formula. The CAI group had a mean problem solving test score of 5.11 while the comparison group had a mean problem solving test score of 4.67 with a standard deviation of 2.33.

$$\underline{ES}=\frac{5.11-4.67}{2.33}=0.189$$

The effect size of 0.189 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Birkenholtz, R. (1989). Using microcomputers in education assessment of three teaching strategies. Journal of Agricultural Education, 30(1), 45-52.

Sample

A total of 312 students from 11th- and 12th-grade classes enrolled in agricultural education provided the data for analysis in this study.

Location and Setting

The study was conducted in 31 classes of 11th- and 12-grade agricultural education students. The classes were selected from rural schools in Missouri.

Method

A pretest/posttest quasi-experimental design was used to assess the effect of microcomputer-based software on secondary agriculture classes. Thirty-one intact classes were randomly selected, and 75% (234 students) of those students were placed into one of the following CAI treatment groups: 1) tutorial, 2) simulation, or 3) drill and practice. The software programs were written by a graduate student at the University of Missouri-Columbia. Only Apple II and Apple IIe microcomputers were used in this study. The remaining 78 students comprised a comparison group which was exposed solely to traditional methods of instruction. The study required five consecutive class periods in each selected classroom. Students in the CAI groups used microcomputers for 20 minutes during the five class periods. Students in the comparison group received traditional methods of instruction through the use of lesson plans provided by the researchers. An analysis of covariance was used to analyze the data.

Variable

The dependent variable of interest in this study was the level of academic achievement relative to a 5-day lesson on soil management. An objective test was developed at the University of Missouri-Columbia to assess the achievement level of this variable.

Findings

Analysis of the data indicated that there were no significant differences between the CAI groups and the comparison group in this study.

Effect Size

The effect size will be calculated from this study using Holmes' method. The CAI group had an n of 234, and the group exposed to traditional instruction had an n of 78. The F value was calculated to be 1.20.

$$ES=\sqrt{1.20\left(\frac{1}{234}+\frac{1}{78}\right)}=0.143$$

The effect size of 0.143 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Carnes, E., Lindbeck, J., & Griffin, C. (1987). Effects of group size and advance organizers on learning parameters when using microcomputer tutorials in kinematics. Journal of Research in Science Teaching, 24(9), 781-789.

Sample

The 100 subjects for this study were 100 11th and 12th-grade physics students from five separate, intact classes.

Location and Setting

The study was conducted at a comprehensive suburban Ohio high school. Sixty percent of the students studied were male. The socioeconomic structure of the community from which the population came was middle class to upper middle class.

Method

A four-by-two (4 X 2) factorial design was used on five classes of physics students taught by the same teacher. The classes were divided into two groups: treatment and comparison. The treatment group had a total of 50 students, and the comparison group also had 50 students. The treatment group received CAI tutorials on kinematics, and the comparison group was exposed to traditional methods of instruction. The tutorials consisted of four microcomputer programs that covered information related to kinematics. Students in the treatment group used the microcomputers for a total of 250 minutes over a 5-day period.

Variable

The dependent variable of interest in this study was physics achievement in the area of kinematics. This variable was measured by individually administered paper-and-pencil teacher-made tests.

Findings

The 4 X 2 analysis of variance revealed group size as the only significant result ($p > .05$) in this study.

No significant difference was found between the treatment and comparison group relative to academic achievement. However, the results suggested that students working on CAI in groups of three or four may have a faster rate of learning than those individuals working on CAI by themselves.

Effect Size

The effect size will be calculated from this study using Holmes' method. The CAI group had an n of 50, and the group exposed to traditional instruction had an n of 50. The F value was calculated to be 1.96.

$$ES=\sqrt{1.96\left(\frac{1}{50}+\frac{1}{50}\right)}=0.280$$

The effect size of 0.280 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Christie, N., & Sabres, D. (1989, March). Using microcomputers to implement mastery learning with high-risk and minority adolescents. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Sample

The sample of 265 consisted of 9th-, 10th-, 11th-, 12th-grade high-risk minority students whose ages ranged from 14 to 18. Students included in this study were selected to participate in a summer instructional program that focused on reading/language arts and mathematics.

Location and Setting

The study was conducted on 265 urban high school students at four different sites located within a large school system in Arizona.

Method

Students were randomly placed in either a treatment group that utilized CAI or a comparison group that used traditional methods of instruction for the subjects of reading/language arts and mathematics. A pretest/posttest, pre-experimental design with a comparison group was used. Quantitative assessment of the experimental program was provided by comparing the effect sizes of the treatment group with the effect size of the comparison group. Students in the experimental setting received CAI related to reading/language arts and to mathematics as an enrichment exercise after the teacher finished lecturing. There were one treatment and three comparison groups included in this study.

Variable(s)

The two academic achievement dependent variables of interest for this study were reading/language arts and mathematics. The tests to measure these variables were locally-developed tests that measured the course curriculum objectives for the school district in reading/language arts and in mathematics.

Findings

The study found that the students in the treatment CAI groups posttest scores surpassed 93% of their pretest scores in mathematics and reading/language arts. The author reported an average effect size of 1.50 in both mathematics and reading/language arts relative to gains from the pretest to the posttest.

Effect Sizes

Two effect sizes will be calculated from the data available in this study using the definitional formula. Effect sizes for mathematics achievement and for reading/language arts achievement between the treatment CAI group and the comparison groups will be calculated.

Reading/language arts achievement. The CAI treatment group had a mean test score of 42.60 while the groups exposed to traditional instruction had a mean of 42.23 with a standard deviation of 8.40.

$$\underline{ES}=\frac{42.60-42.23}{8.40}=0.044$$

The effect size of 0.044 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect as a small effect.

Mathematics achievement. The CAI treatment group had a mean test score of 29.50 while the groups exposed to traditional instruction had a mean of 28.83 with a standard deviation of 6.50.

$$\underline{ES}=\frac{29.50-28.83}{6.50}=0.103$$

The effect size of 0.103 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Davidson, R. (1985). The effectiveness of computer-assisted instruction of Chapter I students in secondary schools (CAI) (Doctoral dissertation, The University of Tennessee, 1985). Dissertation Abstracts International, 47, 02-A.

Sample

The subjects for this study were Chapter I students from grades 9, 10, 11, and 12. A total of 54 students volunteered to be included in this study. These students had either failed to achieve 80% of grade-level objectives on the Knoxville Basic Skills Test (grades 1-9) or had failed to demonstrate proficiency on the Tennessee State Proficiency Test (grades 10-12).

Location and Setting

The participants in this study were from an urban high school. The study took place at Fulton High School in Knoxville, Tennessee.

Method

The design utilized in this study was the pretest/posttest control group design. The classes were randomly divided into two groups: treatment and comparison. The treatment group had 18 students, and the comparison group had a total of 36 students. The treatment group received CAI drill and practice related to the area of mathematics by using commercial and noncommercial microcomputer-driven software. Students were introduced to a different software package each week for 13 weeks. The treatment group had use of 11 Apple IIe, 3 TRS-80 Model IV, and 3 TRS-80 Model III microcomputers. The comparison group received only traditional instructional methods. The scores of the treatment and comparison group were compared by using an analysis of covariance.

Variable

The dependent variable of interest in this study was mathematics achievement as measured by the Metropolitan Instructional Mathematics Test.

Findings

The analysis of covariance indicated that computer-assisted instruction did not result in significant (p >.05) gains in mathematics achievement of Chapter I students.

Effect Size

The effect size will be calculated from this study using Holmes' method. The CAI group had an n of 18 and the group exposed to traditional instruction had an n of 36. The F value was calculated to be 0.369.

$$\underline{ES}=\sqrt{.369\left(\frac{1}{18}+\frac{1}{36}\right)}=0.175$$

The effect size of 0.175 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Dunn, S. (1985). Effects of experience in computer programming on the cognitive level of secondary school students (Doctoral Dissertation, Auburn University, 1985). Dissertation Abstracts International, 46, 10-A.

Sample

The sample in this study consisted of heterogeneously intact classes of 11th- and 12th-grade students. A total of 96 students participated in the study. The treatment group consisted of 48 students who volunteered to use CAI. The comparison group consisted of 48 students who utilized traditional methods of instruction.

Location and Setting

The study took place at T. R. Miller High School in Brewton, Alabama. T. R. Miller High School is a rural school situated in a small community.

Method

A pre-experimental posttest only, control group design was used in this study. Students were placed into either the treatment CAI group or the comparison group. The comparison group used only traditional methods of instruction. Random assignment to groups was not possible in this particular study because the treatment group was composed of students whc chose to take the microcomputer-based course. The CAI treatment attempted to use software that improved mathematics and problem solving skills. Students in the treatment group used the microcomputers five days per week for a total of 50 minutes over a 30-week period. Students worked individually in a self-directed manner.

Variable

The dependent variable for this study was mathematics and problem solving achievement. The instrument to measure the dependent variable was the

Test of Logical Thinking. The test was administered as a posttest after 30 weeks of instruction.

Findings

The results of the study showed that the treatment group, which received CAI as a treament, outscored the comparison group on the Test of Logical Thinking. This difference was found to be significant ($p <.05$). The results further indicated that there was no significant difference between males and females relative to scores on the test. However, there was a significant difference ($p <.05$) between black and white students on the Test of Logical Thinking.

Effect Size

One effect size will be calculated from this study using the definitional formula. The CAI group had a mean test score of 26.42 while the comparison group had a mean test score of 24.13 with a standard deviation of 5.54.

$$ES=\frac{26.42-24.13}{5.54}=0.413$$

The effect size of 0.413 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Durnin, R. (1985). Computer-based education: a study of student interactions and achievement in small group and individual settings (Doctoral dissertation, Claremont Graduate School, 1985). Dissertation Abstracts International, 45, 12-A.

Sample

The 154 subjects for this study were seventh- and eighth-grade students enrolled in intact general science classes.

Location and Setting

The study was conducted on two groups of science students attending Sierra Vista Middle School, a suburban middle school in the Irvine Unified School District in California. The majority of the students came from upper-middle-class homes and were caucasian. The students included in this study scored above the national median on standardized test scores, and approximately 30% of the students scored at the 80th percentile or above.

Method

This research examined the academic achievement of middle school students working in groups of one, two, three, and four with CAI science software that was developed at the University of California-Irvine. Students were randomly placed in either a treatment group that utilized CAI or in a comparison group that used only traditional methods of instruction related to science. Students in the treatment CAI group engaged in CAI software-driven instruction for 95% of the time over a three month period. A pretest/posttest comparison group design was used to compare CAI to traditional instructional methods. Descriptive statistics were calculated with SPSS followed by an analysis of variance.

Variable

The dependent variable of interest in this study was posttest scores on a locally-designed objective test which measured scientific achievement. An eight-item electronics test constructed by the researcher was used as the testing instrument.

Findings

The study found that group size had no significant (p <.05) impact on academic achievement. However, students using computers had significant gains over students exposed to traditional instructional methods. Additionally, the study suggested that the use of CAI should not be restricted to individuals working alone. Many benefits appeared by having pairs or groups of three working together.

Effect Size

Four effect sizes will be calculated from the data available in this study using the definitional formula. Effect sizes for science academic achievement in each group size of one, two, three, and four was calculated by comparing the mean posttest scores of the treatment group to the mean posttest scores of students exposed to traditional instructional methods.

Individual achievement. The CAI treatment group had a mean test score of 5.80 while the groups exposed to traditional instruction had a mean of 4.50 with a standard deviation of 1.40.

$$\underline{ES}=\frac{5.80-4.50}{1.40}=0.928$$

The effect size of 0.928 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a large effect.

<u>Group-of-two achievement</u>. The CAI treatment group had a mean test score of 6.40 while the groups exposed to traditional instruction had a mean of 4.50 with a standard deviation of 1.40.

$$\underline{ES}=\frac{6.40-4.50}{1.40}=1.36$$

The effect size of 1.36 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a large effect.

<u>Group-of-three achievement</u>. The CAI treatment group had a mean test score of 5.90 while the groups exposed to traditional instruction had a mean of 4.50 with a standard deviation of 1.40.

$$\underline{ES}=\frac{5.90-4.50}{1.40}=1.00$$

The effect size of 1.00 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a large effect.

<u>Group-of-four achievement</u>. The CAI treatment group had a mean test score of 5.70 while the groups exposed to traditional instruction had a mean of 4.50 with a standard deviation of 1.40.

$$\underline{ES}=\frac{5.70-4.50}{1.40}=0.857$$

The effect size of 0.857 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a large effect.

Elliot, E. (1985). The effects of computer-assisted instruction upon basic skill proficiencies of secondary vocational education students (Doctoral dissertation, The University of Michigan, 1985). <u>Dissertation Abstracts International, 46,</u> 11-A.

<u>Sample</u>

The 191 students in this study consisted of 11thand 12th-grade vocational education students, 106 of whom were male and 85 of whom were female. The treatment group consisted of 96 students (49 males and 47 females), and the comparison group consisted of 95 students (57 males and 38 females).

Location and Setting

The study was conducted on students residing in rural southeastern Michigan's Lenawee County. The students attended Lenawee Intermediate School District Vocational Technical Education Center in Adrian, Michigan during the 1984-85 school year.

Method

A pretest/posttest quasi-experimental design was used to assess the effect of microcomputer-based software on secondary students' agriculture classes. One hundred ninety-three students were randomly selected and placed into either a CAI treatment group or a comparison group that utilized only traditional instructional methods. The treatment program used in this study was the Control Data Corporation's Microcomputer, Programmed Logic for Automatic Teaching Operators (PLATO) Basic Skills Program. PLATO CAI software-based tutorial lessons assumed the direct instructional task, followed by generated drill-and-practice exercises provided the treatment for this study. Students used CAI for one hour per week over an 18-week period. The system automatically logged each student's progress. The comparison group remained in the vocational laboratory and received regular classroom instruction. An analysis of covariance was used to analyze the data.

Variable

The three dependent variables of interest in this study are the achievement calculations for the subjects of reading, language, and mathematics. The 3-R's Standardized Achievement Test was used as the instrument to assess student achievement in this study.

Findings

The study did not find significant differences ($p < .01$) in the reading scores or in the mathematics scores of the two groups studied. However, there was a significant difference between the language scores of the treatment group and comparison group. Pearson product-moment correlations were calculated between the number of CAI hours on task and subjects' gain scores. The correlation showed a relationship with the amount of CAI time on task and gain scores. This finding suggested that additional time on task may have produced a more desirable effect.

Effect Sizes

Three effect sizes will be calculated from the data available in this study using the definitional formula. Each effect size for reading, language, and mathematics academic achievement will be calculated by comparing the mean posttest scores of the treatment group to the mean posttest scores of students exposed only to traditional instructional methods.

Reading academic achievement. The CAI treatment group had a mean test score of 26.26 while the groups exposed to traditional instruction had a mean of 26.61 with a standard deviation of 8.27.

$$\underline{ES}=\frac{26.26-26.61}{8.27}=-0.042$$

The effect size of -0.042 is negative because lower scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a negative effect.

Language academic achievement. The CAI treatment group had a mean test score of 25.18 while the groups exposed to traditional instruction had a mean of 20.92 with a standard deviation of 6.58.

$$\underline{ES}=\frac{25.18-20.92}{6.58}=0.647$$

The effect size of 0.647 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a medium effect.

Mathematics academic achievement. The CAI treatment group had a mean test score of 18.79 while the groups exposed to traditional instruction had a mean of 18.13 with a standard deviation of 5.79.

$$\underline{ES}=\frac{18.79-18.13}{5.79}=0.114$$

The effect size of 0.114 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Ferrell, B. (1986). Evaluating the impact of CAI on mathematics learning: Computer immersion project. Journal of Educational Computing Research, 2(3), 327-336.

Sample

The sample for this study consisted of 91 sixth-grade students. The subjects, 46 girls and 45 boys, were from an ethnically mixed predominantly Hispanic population.

Location and Setting

The study took place in four intact sixth-grade mathematics classes at a middle school in a large urban school district in Texas during the 1983-84 school year.

Method

One school was selected on the basis of willingness to participate in the study. Teachers were then assigned to a treatment group (n = 50) which exposed students to CAI or to a comparison group (n = 41) which used only traditional methods of instruction. A pretest/posttest quasi-experimental design was used to assess the effectiveness of CAI on academic achievement in mathematics.

Students in the treatment CAI group consisted of two randomly selected classes that used one classroom equipped with 26 Apple II microcomputers. Therefore the students in the treatment group experienced a 1:1

computer-to-pupil ratio. The treatment was introduced in early September and continued at 40 minutes per day until early March. Students used commercially and teacher-developed microcomputer-driven drill-and-practice software which addressed relevant topics in the area of mathematics. An analysis of covariance was used to analyze the data.

Variable

The dependent variable of interest in this study was the Iowa Test of Basic Skills (ITBS). The ITBS Level 12, Test M (Mathematics Skills) was used to assess mathematics computation, concepts, and problem solving. The ITBS was used as the pretest and posttest measure of academic achievement.

Findings

The analysis of covariance yielded a significant (p <.05) difference between the treatment CAI group and the comparison group. The CAI group exceeded the comparison group in academic achievement.

Effect Size

The effect size will be calculated from this study using Holmes' method. The CAI group had an n of 50, and the group exposed to traditional instruction had an $\underline{n}$ of 41. The $\underline{F}$ value was calculated to be 5.357.

$$\underline{ES}=\sqrt{5.357\left(\frac{1}{50}+\frac{1}{41}\right)}=0.488$$

The effect size of 0.488 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Hounshell, P., & Hill, S. (1989). The microcomputer and achievement and attitudes in high school biology. Journal of Research in Science Teaching, 26(6), 543-549.

Sample

A total of 202 student enrolled in 10th-grade biology classes provided the data for this study. The treatment group consisted of 76 students who volunteered to use CAI. The comparison group consisted of 126 students who utilized traditional methods of instruction.

Location and Setting

The study was conducted using five classes of

10th-grade biology students. The classes were selected from a rural high school in North Carolina. The school was part of the Winston-Salem/Forsyth County Schools, Winston-Salem, North Carolina.

Method

The 76 students from a total population of 202 who had volunteered for the treatment group were randomly selected from a total students and were placed in five classes with class size limited to 16. This procedure allowed a computer-to-pupil ratio of 1:2. The classroom was equipped with eight Apple IIe microcomputers and one printer. Students in the comparison group used only traditional methods of instruction. Both groups were involved in the research project for a total of 27 weeks. Academic achievement was assessed by using a posttest-only control group design with a standardized test at the end of the 27 weeks of treatment. A *t*-test was used to analyze the data.

Variable

The dependent variable of interest for this study was biology achievement as measured by the *Comprehension Test of Basic Skills*.

Findings

The t-test indicated that CAI resulted in significant (p >.05) gains in biology achievement in comparison to using only traditional instructional methods.

Effect Size

One effect size will be calculated from this study using the definitional formula. The CAI group had a mean test score of 20.29 while the comparison group had a mean test score of 17.46 with a standard deviation of 6.46.

$$ES = \frac{20.29 - 17.46}{6.46} = 0.438$$

The effect size of 0.438 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Hunter, M., & Chen, A. (1992). A microcomputer-networked information system for daily academic activity by low achieving students. Journal of Special Education, 11(4), 178-188.

Sample

The sample in this study consisted of intact low-achieving Chapter I seventh-grade reading and mathematics classes containing 23 boys and 9 girls.

Location and Setting

Participating students attended a large, regional high school in central Pennsylvania. The school was located in a rural, small-town setting with a minority population of approximately 1%. Approximately 20% of the secondary school population was identified as low income based on entitlement for subsidized lunches.

Method

Thirty-two low achieving seventh-grade students participated in a microcomputer software-based CAI project over the final 27 weeks of the 1990-91 school year. Five Macintosh SE microcomputers were used to deliver Fourth Dimension software to students. Students used these microcomputers on an individual basis for approximately 50 minutes each week. A pre-experimental one-shot case study was used in this study, and a Pearson correlation matrix was used to analyze the data.

Variable

The criterion (dependent) variable in this study was academic achievement as measured by the teacher-assigned final grade for the course.

Findings

There was not a significant ($p > .05$) relationship found between academic achievement and any of the variables included in the correlation matrix.

Effect Size

One effect size will be calculated from this study using the formula transformation for the r value. The value reported for the relationship between the number of log-ins and mean final grade was a -0.18.

$$ES = \frac{2(-.18)}{\sqrt{1-(-.18)^2}} = -0.366$$

The effect size of -0.366 is negative because lower scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a negative effect.

King, R. (1988) The effects of computer-assisted music instruction on achievement of seventh-grade students (Doctoral dissertation, University of

Illinois at Urbana-Champaign, 1988). Dissertation Abstracts International, 49, 09-A.

Sample

A total of 342 students from seventh-grade classes enrolled in music provided the data for analysis in this study. The treatment group consisted of 64 students who were randomly selected to use CAI. The comparison group consisted of 278 students who utilized traditional methods of instruction.

Location and Setting

The study was conducted at Urbana Junior High School in Urbana, Illinois, an urban setting with a population of approximately 37,000. Urbana neighbors the city of Champaign, whose population is 63,000. The median effective annual income in Urbana is $21,945.

Method

The 64 students in the treatment CAI group were randomly selected from a population of 342 students and placed in four classes of 16 music students each. The two classrooms used were equipped with Apple II computers. The software used was designed at the University of Illincis and consisted to be drill-and-practice and tutorial CAI. The research design used to assess academic achievement was a pretest-postest control group design. The students were exposed to CAI for 20 minutes each day, four times per week over an eight-week period. An analysis of variance was used to analyze the data.

Variable

The dependent variable of interest in this study was music achievement. The instrument used to measure music achievement was the Music Achievement Test (MAT). This standardized test was used as a pretest and as a posttest at the end of the eight-week study.

Findings

The results of the study showed that the treatment group outscored the comparison group on the Music Achievement Test. This difference was found to be significant ($p < .05$).

Effect Size

One effect size will be calculated from this study using the definitional formula based on scores from the MAT in general music classes. The CAI group had a mean test score of 3.60 while the comparison group had a mean test score of 1.68 with a standard deviation of 8.35.

$$\underline{ES}=\frac{3.60-1.68}{8.35}=0.230$$

The effect size of 0.230 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Klein, J., & Salisbury, D. (1987, February). A comparison of a microcomputer progressive state drill and flashcards for learning paired associates. Paper presented at the annual Convention of the Association for Educational Communications and Technology, Atlanta, GA.

Sample

A total of 96 students from 10th-grade classes enrolled in the Development Research School at Florida State University provided data for analysis in this study.

Location and Setting

The study was conducted on two groups of students enrolled in the Development Research School at Florida State University. The groups were selected from suburban schools in Florida.

Method

A sequential analysis was used to assess the effect of microcomputer software-based CAI on 10th-grade students. The students were randomly placed in either a CAI group or a group that used flashcards. The treatment in each group consisted of three 20-minute sessions, one session each day for three consecutive days. Subjects in the flashcard group were allowed to use flashcards in any manner but were required to work alone. Subjects in the microcomputer group used drill-and-practice software to learn the same material as the group that utilized flashcards. For this study, the alpha level was set at 0.05, and the beta at 0.20.

Variable

The dependent variable of interest in this study was mathematics achievement. This variable was measured by the Object-Number Test (ONT) developed by the Educational Testing Service.

Findings

The sequential analysis did not reveal a significant (p >.05) difference in posttest ONT scores between the CAI group or the group that used flashcards. However, the study found that students in the microcomputer group demonstrated a more positive attitude.

Effect Size

One effect size will be calculated from this study using the definitional formula based on scores from the Object-Number Test. The CAI group had a mean test score of 21.90 while the flashcard group had a mean test score of 22.80 with a standard deviation of 14.80.

$$\underline{ES}=\frac{21.90-22.80}{14.80}=-0.061$$

The effect size of -0.061 is negative because lower scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a negative effect.

Landry, S. (1987). A comparison of the effects of computer-based and non-computer-based revision comments on the writing of low-motivated ninth grade

students (Doctoral dissertation, The University of Connecticut, 1987). Dissertation Abstracts International, 48, 11-A.

Sample

The sample consisted of 29 students enrolled in ninth grade English. The treatment group consisted of 15 students exposed to CAI, and the comparison group contained 14 students who were subjected to traditional methods of instruction.

Location and Setting

The study was conducted in a small, suburban college preparatory boarding school for boys in southeastern Connecticut. The school program was designed to provide the structure necessary to help make these students more successful. Mandatory, supervised study halls, a dress code, and a strict behavior code were among the restrictions placed upon the students in an effort to provide the support system necessary to help them be more successful in school.

Method

The classes that were used in this study were taught by the researcher as part of his responsibilities at the school. Each class met for 40 minutes, five days a week for a period of ten weeks. A coin toss at the beginning of the first day of classes determined which class would be the treatment (CAI) and which would be the comparison group. The treatment class met during the second period of each day, and the comparison group met during the third period each day. The lesson planning was identical for both classes except the treatment group used Apple II microcomputers to supplement regular instruction with CAI. The research design used was a posttest-only control group design. An analysis of covariance and a *t*-test were used to analyze the data.

Variable

The dependent variable of interest in this study was English achievement relative to writing ability. The instrument used to measure English achievement was the *California Achievement Writing Assessment* measure.

Findings

The results of this study showed that the comparison group, which received only traditional instruction, outscored the treatment group on the *California Achievement Writing Assessment*. This difference was found to be significant ($p < .05$).

Effect Size

One effect size will be calculated from this study using the definitional formula based on scores from the California Achievement Writing Assessment. The CAI group had a mean test score of 4.53 while the comparison group had a mean test score of 6.00 with a standard deviation of 1.18.

$$\underline{ES}=\frac{4.53-6.00}{1.18}=-1.25$$

The effect size of -1.25 is negative because lower scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a negative effect.

Lewis, E. L., Stern, J. L., & Linn, M. C. (1993). The effect of computer simulations on introductory thermodynamics understanding. Educational Technology, 1, 45-58.

Sample

A total of 290 students from eighth-grade enrolled in middle school physical science classes provided the data for analysis in this study.

Location and Setting

The study was conducted in a suburban middle school that was located in California. The students came from ethnically diverse middle-class families.

Method

This study was conducted on 10 classes of science students in 1988 and 1989. During the 1988 academic year, five classes (n = 142) that utilized only traditional methods of instruction were included as data for this research investigation. During the 1989 school year, five classes (n = 148) utilized CAI to complete the data for analysis in this study. Each class contained between 29 and 33 students. Each CAI classroom was equipped with 16 Apple II microcomputers and microcomputer-based software simulations and laboratory activities that covered topics related to thermodynamics. An analysis of variance was used to analyze the data.

Variable

The dependent variable of interest in this study was science achievement relative to thermodynamics. The instrument used to measure science achievement was a locally developed test.

Findings

The results of this study showed that the CAI group outscored the group that was exposed to traditional instruction. This difference was found to be significant (p <.02).

Effect Size

The effect size will be calculated from this study using Holmes' method. The CAI group had an n of 148 and the group exposed to traditional instruction had an n of 142. The F value was calculated to be 1.765.

$$ES=\sqrt{1.765\left(\frac{1}{142}+\frac{1}{148}\right)}=0.156$$

The effect size of 0.156 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Manuel, S. (1987). The relationship between supplemental computer-assisted mathematic instruction and student achievement (Doctoral dissertation, University of Nebraska, Lincoln, 1987). Dissertation Abstracts International, 48, 1643A.

Sample

The sample consisted of 28 sixth-grade students enrolled in mathematics classes. The subjects were divided into a CAI treatment group (n = 6) and a comparison group (n = 22).

Location and Setting

The participants in this study were from a rural school in the Westside Community School District in Nebraska. The school was selected because of the availability of computer stations in classroom settings.

Method

Two mathematics classes were divided into a treatment group (CAI) and a comparison group (traditional instruction). Students were randomly selected from the sixth-grade population and assigned to either the CAI group or to the comparison group. Students' achievement was assessed with a pretest/posttest control group design that used a standardized test to measure academic achievement. Students in the CAI group received supplementary mathematics instruction using Apple II microcomputers and selected software. The CAI group used the microcomputers for 10 minutes each day for 12 weeks. An analysis of variance was used to analyze the data.

Variable

The dependent variable of interest in this study was mathematics achievement as measured by the California Test of Basic Skills (CTBS). The test was used as the pretest and also as the posttest.

Findings

The results of the study showed that the comparison group, outscored the treatment group on the CTBS. This difference was not found to be significant ($p < .05$).

Effect Size

One effect size will be calculated from this study using the definitional formula based on scores from the California Test of Basic Skills. The CAI group had a mean test score in grade level equivalency units of 2.05 while the comparison group had a mean test score in grade equivalency units of 2.14 with a standard deviation of 1.23.

$$ES = \frac{2.05 - 2.14}{1.23} = -0.073$$

The effect size of -0.073 is negative because lower scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a negative effect.

Marty, J. (1985). Selected effects of a computer game on achievement, attitude, and graphing ability in secondary school algebra (Doctoral dissertation, Oregon State University, 1985). Dissertation Abstracts International, 47, 01-A.

Sample

The sample in this study consisted of intact classes of high school algebra students. A total of 425 students participated in the study. The treatment group consisted of 213 students who utilized CAI. The comparison group consisted of 212 students who utilized traditional methods of instruction.

Location and Setting

The study involved 11 teachers at seven suburban high schools in eastern Wisconsin. The school district served mainly middle-class students.

Method

The experimental design used was the non-equivalent control group design. Students were placed into the treatment CAI group or the comparison group. The CAI treatment used microcomputer software (Algebra Arcade) in lieu of doing in-class problems. Both classes groups did the same out-of-class homework problems. The software was incorporated into the Quadratic Functions unit. The experiment lasted four weeks. An analysis of variance was used to analyze the data.

Variable

The dependent variable for this study was mathematics achievement. The instrument to measure this dependent variable was the Descriptive Test of Mathematics Skills. The test was administered as a pretest and posttest after four weeks of instruction.

Findings

The results of the study showed that the experimental group, which received CAI, outscored the comparison group on the Descriptive Test of Mathematics Skills. However, this difference was not found to be significant ($p < .05$).

Effect Size

The effect size will be calculated from this study using Holmes' method. The CAI group had an n of 213, and the group exposed to traditional instruction had an n of 212. The F value was calculated to be 9.10.

$$ES=\sqrt{9.10\left(\frac{1}{213}\right)+\left(\frac{1}{212}\right)}=0.293$$

The effect size of 0.293 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

Mason, M. (1984). A longitudinal study of the effects of computer-assisted instruction on mathematics achievement of the learning disabled and educable mentally retarded (Doctoral dissertation, University of Iowa City, 1984). Dissertation Abstracts International, 45, 2791A.

Sample

The sample of 49 consisted of 11th-grade students enrolled in special education. The treatment group consisted of 19 students who were exposed to CAI, and the comparison group contained 30 students who only used traditional methods of instruction.

Location and Setting

The study was conducted in an urban school system located in Cedar Rapids, Iowa.

Method

This study was conducted on two classes of special education students at two separate high schools located within the same school district. Students' mathematics achievement was assessed with a pretest/posttest control group design that used a standardized test to measure academic achievement. The treatment CAI group was placed in a classroom that was equipped with 10 Apple II microcomputers. Students in the CAI group used microcomputers for a minimum of three 15-minute sessions each week for an entire school year. An analysis of variance was used to analyze the data.

Variable

The dependent variable of interest in this study was mathematics achievement as measured by the Iowa Test of Basic Skills (ITBS). The test was used as the pretest and posttest.

Findings

The analysis of variance indicated that there was a significant (p <.05) difference in mathematics achievement between the CAI and comparison groups with the CAI group showing higher gains.

Effect Size

The effect size will be calculated from this study using Holmes' method. The CAI group had an n of 30, and the group exposed to traditional instruction had an n of 19. The F value was calculated to be 9.09.

$$ES=\sqrt{9.09\left(\frac{1}{30}\right)+\left(\frac{1}{19}\right)}=0.884$$

The effect size of 0.884 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a large effect.

McCaskey, M., Birkenholtz, R., & Stewart, B. (1989). Assessing the effect of computer-assisted instruction. Journal of Studies in Technical Careers, 11(2), 119-130.

Sample

A total of 144 secondary students from all Missouri vocational agriculture programs provided the data for analysis in this study.

Location and Setting

The study was conducted in 31 classes of 11th- and 12th-grade vocational agriculture students. The classes were selected from rural schools in Missouri.

Method

A pretest/posttest quasi-experimental design was used to assess the effect of CAI on secondary vocational agriculture students. The classes were divided into two groups, treatment (CAI) and comparison (lecture/discussion). The treatment group received a CAI simulation on soil management, and the comparison group was only exposed to traditional methods of instruction like lecture and discussion. Software used in the microcomputer simulation was created specifically for this study by agriculture education personnel at the University of Missouri-Columbia. Students in the treatment group used the microcomputers for 20 minutes each day over a two-day period. An analysis of covariance was used to analyze the data.

Variable

The dependent variable of interest in this study was the level of academic achievement relative to a two-day lesson on soil management. An objective 17-item test was developed at the University of Missouri-Columbia to assess the achievement level of this variable.

Findings

Analysis of the data indicated that there were no significant differences in academic achievement between the CAI group and the comparison group in this study.

Effect Size

One effect size will be calculated from this study using the definitional formula. The CAI group had a mean test score of 12.86 while the comparison group had a mean test score of 12.18 with a standard deviation of 3.52.

$$\underline{ES}=\frac{12.86-12.18}{3.52}=0.193$$

The effect size of 0.193 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a large effect.

St. Pierre, K. (1992). The effect of computer-assisted instruction and traditional instruction on ninth-grade English composition and academic self-concept (Doctoral dissertation, Miami University, 1992). Dissertation Abstracts International, 53, 08-A.

Sample

A total of 72 students from ninth-grade classes enrolled in high school English provided the data for analysis in this study.

Location and Setting

The study was conducted at Trotwood Madison High School in Dayton, Ohio. The school is located in a suburban setting with a very diverse student population. The community is primarily low-to middle-class composition with an even mixture of caucasian and black students.

Method

There were 18 students in the comparison group who received traditional instruction and 18 students in the treatment group who received traditional instruction plus CAI for three hours each week for fourteen weeks. A pretest/posttest nonequivalent control group design with matching was utilized. The groups were matched on the basis of academic ability, language ability, and gender. Students were selected as subjects for the study by nonrandom assignment. A two-tailed *t*-test was used to determine if there was a statistically significant difference between the two groups.

Variable

The dependent variable of interest in this study was English achievement as measured by the *California Achievement Test* (CAT). This test, measuring expository and narrative writing, was used as the pretest and as the posttest.

Findings

The results of the study showed that the comparison group, which received traditional instruction, outscored the treatment group on the CAT. This difference was not found to be significant ($p < .05$).

Effect Sizes

Two effect sizes will be calculated from the data available in this study using the definitional formula. Effect sizes for both the expository and the narrative English academic achievement will be calculated by comparing the mean posttest scores of the treatment group to the mean posttest scores of students exposed to traditional instructional methods.

Expository academic achievement. The CAI treatment group had a mean test score of 2.44 while the groups exposed to traditional instruction had a mean of 2.83 with a standard deviation of 0.70.

$$ES=\frac{2.44-2.83}{.70}=-0.557$$

The effect size of -0.520 is negative because lower scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a negative effect.

Narrative Academic Achievement. The CAI treatment group had a mean test score of 2.33 while the groups exposed to traditional instruction had a mean of 2.72 with a standard deviation of 0.75.

$$ES=\frac{2.33-2.72}{.75}=-0.520$$

The effect size of -0.520 is negative because lower scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a negative effect.

Wohlgehagen, K. (1992). A comparison of the attitude and achievement in mathematics of Algebra 1 students using computer-based instruction and traditional instructional methods (Doctoral dissertation, University of North Texas, 1992). Dissertation Abstracts International, 52, 06-A.

Sample

A total of 242 students from 9th- and 10th-grade classes enrolled in Algebra 1 at two different high schools provided the data for analysis in this study.

Location and Setting

The school district selected for this study was located in North Texas and had approximately 31,984 students. The ethnic composition of this suburban school district was 89.5% Caucasian, 4.0% African-American, 3.1% Hispanic, and 3.4% other nationalities. About 60% of teachers in the school district held masters degrees, and 82% of the students are college bound.

Method

This study used a pretest/posttest nonequivalent control group design. All of the students were taught the units from the regular curriculum covering first semester Algebra 1. The treatment group (n = 106) supplementally used the microcomputer lab daily for 55 minutes over an entire semester. These students used Learning Logic software to complete self-paced drill-and-practice exercises that covered the Algebra 1 curriculum. The comparison group (n = 136) followed the district Algebra 1 curriculum through traditional methods of classroom instruction. An analysis of covariance was used to analyze the data.

Variable

The dependent variable of interest in this study was mathematics achievement as measured by the Texas Essential Skills Test for Algebra 1. The test was used as the pretest and posttest.

Findings

The analysis of covariance showed that there was a significant (p <.05) difference in mathematics achievement between the CAI and comparison groups with the comparison group showing showing higher gains.

Effect Size

One effect size will be calculated from this study using the definitional formula. The CAI group had a mean test score of 8.99 while the comparison group had a mean test score of 10.49 with a standard deviation of 3.96.

$$\underline{ES}=\frac{8.99-10.49}{3.96}=-0.378$$

The effect size of -0.378 is negative because lower scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a negative effect.

Wood, J. (1991). An investigation of the effects of tutorial on tool applications of computer-based education on achievement and attitude in secondary mathematics (Doctoral dissertation, Purdue University, 1991). Dissertation Abstracts International, 52, 06-A.

Sample

A total of 104 second-year high school students enrolled in algebra provided the data for analysis in this study.

Location and Setting

The school selected for this study was a rural high school located in Indiana. This school was one of two public secondary schools in a county school system. Approxamitely 80% of the graduating class continued beyond high school with some form of post-secondary education. This study was conducted in a public secondary school over three weeks during May of 1989.

Method

Six classes of second-year algebra students participated in this study. Three groups of two classes were formed--the CAI tutorial group (n = 39), the CAI tool group (n = 28), and the comparison group (n = 37). Two teachers were each assigned one class in each of the three groups. The research design utilized was a nonequivalent control group design with a pretest and a posttest. The treatment groups received daily CAI instruction in a 30 station microcomputer laboratory using IBM PS/2 hardware with software designed by WICAT. An analysis of variance was used to analyze the data.

Variable

The dependent variable of interest in this study was mathematics achievement as measured by a locally-developed 20-item, multiple choice test. The test was used as the pretest and posttest.

Findings

The analysis of variance showed that there were no significant ($p < .05$) differences between CAI or traditional methods of instruction. However, the study showed that CAI is at least as effective as traditional instruction in overall academic achievement effects. The two CAI groups performed no better nor worse than the comparison group on the achievement posttest in this study.

Effect Sizes

Two effect sizes will be calculated from the data available in this study using the definitional formula. Effect sizes for CAI tool and CAI tutorial academic achievement will be calculated by comparing the mean posttest scores of the treatment groups to the mean posttest scores of students exposed to traditional instructional methods.

CAI tool academic achievement. The CAI treatment group had a mean test score of 14.43 while the group exposed to traditional instruction had a mean of 14.16 with a standard deviation of 3.47.

$$\underline{ES}=\frac{14.43-14.16}{3.47}=0.077$$

The effect size of 0.077 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

CAI tutorial academic achievement. The CAI treatment group had a mean test score of 14.44 while the group exposed to traditional instruction had a mean of 14.16 with a standard deviation of 3.47.

$$\underline{ES}=\frac{14.44-14.16}{3.47}=0.081$$

The effect size of 0.081 is positive because higher scores were attained by the group that received CAI. Cohen (1977) interprets this effect size as a small effect.

This chapter has provided a description of the criteria used for selecting studies, brief summaries of studies included in the meta-analysis, and the relative academic achievement effect of CAI when compared to traditional methods of instruction.

CHAPTER 4

Analysis of Data

Each study included in this research was reviewed using a design which consists of the sample, location and setting, method, variables, findings, and effect size. All studies included in this meta-analysis yielded enough information to calculate an effect size. All studies reviewed in Chapter 3 were analyzed through the use of a statistical significance comparison (Table 3).

Statistical Significance Comparison

The 24 studies and the 35 conclusions generated by the original authors are broken down into a statistical significance comparison. The studies' findings are separated into three categories: (a) significant positive, where the CAI group achieved statistically significant higher gains than the group exposed to traditional methods of instructon; (b) significant negative, where the group exposed to traditional methods of instruction achieved statistically significant gains over the group exposed to CAI; and (C) no significant difference, where neither the group exposed to CAI nor the group exposed to traditional instruction achieved statistically higher gains.

Of the conclusions reviewed, 54% showed significant positive, 11% showed significant negative, and 34% revealed nonsignificant gains when comparing gains in academic achievement between the CAI group and the group exposed to traditional instruction.

Table 3

Statistical Significance Comparison

	Significance		
Author	Positive	None	Negative
Bailey, T. E.	X		
Bass, et al.	X		
Bass, et al.	X		
Bass, et al.	X		
Bass, et al.	X		
Battista, et al.		X(0)	
Birkenholtz, et al.		X(0)	
Carnes, et al.		X(0)	
Christie, et al.	X		

Table 3 (Continued)

	Significance		
Author	Positive	None	Negative
Christie, et al.	X		
Davidson, R. L.		X(0)	
Dunn, S. M.	X		
Dupnin, R.	X		
Dupnin, R.	X		
Dupnin, R.	X		
Dupnin, R.	X		
Elliot, E. L.		X(0)	
Elliot, E. L.	X		
Elliot, E. L.		X(0)	
Ferrell, B. G.	X		
Hounshell, et al.	X		
Hunter, et al.		X(0)	
King, R. V.	X		
Klein, et al.		X(0)	
Landry, S. A.			X
Lewis, et al.	X		
Manuel, S. Q.	X		

Table 3 (Continued)

	Significance		
Author	Positive	None	Negative
Marty, J. E.		X(+)	
Mason, M. M.	X		
McCaskey, et al.		X(0)	
St. Pierre, K. A.		X(-)	
St. Pierre, K. A.		X(-)	
Wohlegahagen, K. S.			X
Wood, J. B.			X
Wood, J. B.			X

Note. (+) denotes nonsignificant gains by the CAI group. (-) denotes nonsignificant gains by the group exposed to traditional methods of instruction. (0) denotes a non-distinguishable difference in gains by either group.

Meta-analysis

Twenty-four of over 1,000 studies were identified and accepted for this meta-analysis. Table 4 presents the location, sample size, and mean effect size for each study. A total of 3,476 students participated in 24 studies which resulted in 35 conclusions. The sample size ranged from 28 to 425; the mean sample size was 140 students.

Table 4

Location, Sample Size, and Effect Size of Each Study

Author(s)	Setting	n	ES
Bailey, T. E.	Urban, VA	46	0.775
Bass, et al.	Suburban, VA	121	0.414
Bass, et al.	Suburban, VA	121	0.066
Bass, et al.	Suburban, VA	85	0.626
Bass, et al.	Suburban, VA	85	0.421
Battista, et al.	Urban, OH	48	0.189
Birkenholtz, et al.	Rural, MO	312	0.143
Carnes, et al.	Suburban, OH	100	0.280
Christie, et al.	Urban, AZ	265	0.044
Christie, et al.	Urban, AZ	265	0.108
Davidson, R. L.	Urban, TN	54	0.175
Dunn, S. M.	Rural, AL	96	0.413
Dupnin, R.	Suburban, CA	154	0.928
Dupnin, R.	Suburban, CA	154	1.360

Table 4 (Continued)

Author(s)	Location	n	ES
Dupnin, R.	Suburban, CA	154	1.000
Dupnin, R.	Suburban, CA	154	0.857
Elliot, E. L.	Rural, MI	191	-0.042
Elliot, E. L.	Rural, MI	191	0.647
Elliot, E. L.	Rural, MI	191	0.114
Ferrell, B. G.	Urban, TX	91	0.488
Hounshell, et al.	Rural, NC	202	0.438
Hunter, et al.	Rural, PA	32	-0.366
King, R. V.	Urban, IL	342	0.230
Klein, et al.	Suburban, FL	96	-0.061
Landry, S. A.	Suburban, CT	29	-1.250
Lewis, et al.	Suburban, CA	148	0.156
Manuel, S. Q.	Rural, NE	28	-0.073
Marty, J. E.	Suburban, WI	425	0.293
Mason, M. M.	Urban, IA	49	0.884
McCaskey, et al.	Rural, MO	144	0.193
St. Pierre, K. A.	Suburban, OH	72	-0.557
St. Pierre, K. A.	Suburban, OH	72	-0.520
Wohlegahagen, K. S.	Suburban, TX	242	-0.378
Wood, J. B.	Rural, IN	104	0.081

Table 4 (Continued)

Author(s)	Location	n	ES
Wood, J. B.	Rural, IN	104	0.077

Note. N = 3,476, 895 urban students, 1,472 suburban students, and 1,109 rural students.

Mean Effect Sizes

From the 35 effect sizes calculated, an overall mean effect size of the meta-analysis was calculated using the formula to calculate mean effect size. The sum of effect sizes was calculated to be 8.155 with an effect size n of 35.

$$ES_{\bar{x}} = \frac{8.155}{35} = 0.233$$

The mean effect size of 0.233 is positive because higher scores were attained by the groups that received CAI. Cohen (1977) classifies this effect as a small effect. Wolf's (1986) graphical interpretation shows the average effect in SD_x units for the comparison between the traditional instruction group and the CAI group. The overall mean effect size of this meta-analysis indicates that the average student exposed to CAI showed academic achievement greater than 58.7% of the students exposed to traditional instruction. Figure 2 displays that the typical student moves from the 50th percentile to the 58.7th percentile when exposed to CAI.

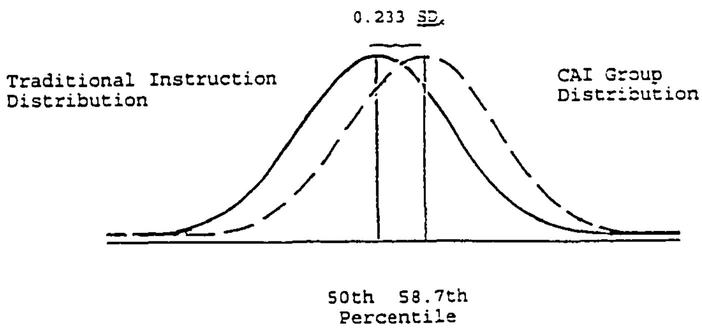

Figure 2. Overall Average ES in SD_x Units

Table 5 compares the results across the urban, suburban, and rural educational settings with regard to conclusions, significance, and mean effect size. The mean effect size of the seven studies in urban areas resulted in a mean effect size of 0.362. In suburban areas, nine studies yielded a mean effect size of 0.227; and a mean effect size of 0.148 was calculated across eight studies in rural educational

Table 5

Comparisons Across Different Educational Settings

Comparison Categories	Urban	Suburban	Rural
No. of studies	7	9	8
No. of effect sizes	8	16	11
Positive results			
Number	6	9	4
Percentage	32%	47%	21%
Negative results			
Number	0	2	3
Percentage	0%	40%	60%
Nonsignificant results			
Number	2	5	4
Percentage	18%	45%	36%
Mean effect size	0.362	0.227	0.148

Note. Percentage refers to result relative to 35 effect sizes.

settings. These results indicate a positive mean effect size of CAI on academic achievement in each educational setting. CAI appears to be most effective in urban educational settings, moderately effective in suburban settings, and least effective in rural settings. Cohen (1977) classifies the mean effect size in each educational setting as a small effect.

Urban Studies.

From the eight urban setting effect sizes calculated, a mean effect size was calculated using the formula to calculate mean effect size. The sum of all effect sizes was calculated to be 2.896 with an effect size $\underline{n}$ of 8.

$$ES_{\bar{x}} = \frac{2.896}{8} = 0.362$$

The mean urban-setting effect size of 0.362 is positive because higher scores were attained by the group that received CAI. Cohen (1977) classifies this effect as a small effect. Wolf's (1986) graphical interpretation shows the average effect in $\underline{SD}_x$ units for the comparison between the traditional instruction group and the CAI group. In urban educational settings, the average student exposed to CAI showed academic achievement greater than 64.1% of the students exposed to traditional instruction. Figure 3 displays that the typical urban student moves from the 50th percentile to the 64.1st percentile if the student received CAI.

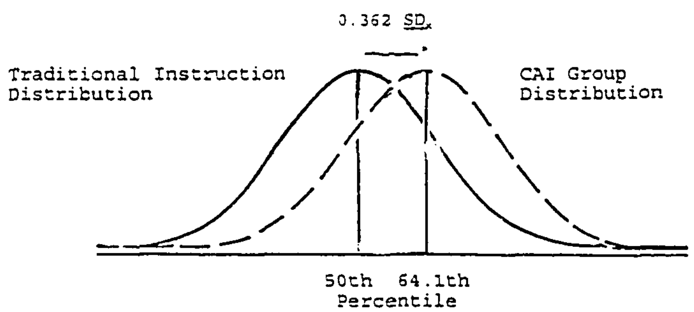

Figure 3. Average Urban ES in SD_x Units

Suburban Studies.

From the sixteen suburban setting effect sizes calculated, a mean effect size was calculated using the formula to calculate mean effect size. The sum of all effect sizes was calculated to be 3.632 with an effect size n of 16.

$$ES_{\bar{x}} = \frac{3.632}{16} = 0.227$$

The mean suburban-setting effect size of 0.227 is positive because higher scores were attained by the group that received CAI. Cohen (1977) classifies this effect as a small effect. Wolf's (1986) graphical interpretation shows the average effect in SD_x units for the comparison between the traditional instruction group and the CAI group. In suburban educational settings, the average student exposed to CAI showed academic achievement greater than 59.1% of the students exposed to traditional instruction. Figure 4 demonstrates that the typical suburban student moves from the 50th percentile to the 59.1st percentile if the student received CAI.

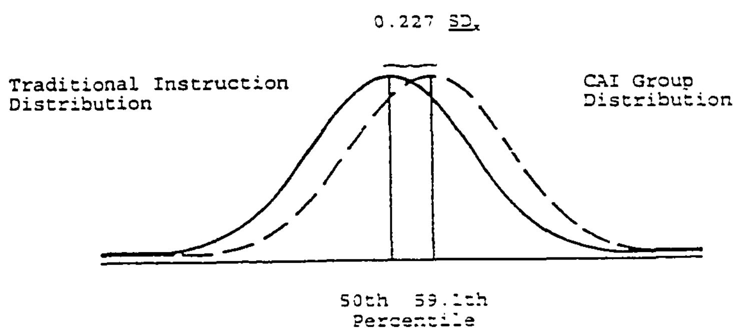

Figure 4. Average Suburban ES in SD_x Units

Rural Studies

From the eleven rural-setting effect sizes calculated, an overall mean effect size was calculated using the formula to calculate mean effect size. The sum of all effect sizes was calculated to be 1.628 with an effect size n of 11.

$$ES_{\bar{x}} = \frac{1.628}{11} = 0.148$$

The mean rural-setting effect size of 0.148 is positive because higher scores were attained by the group that received CAI. Cohen (1977) classifies this effect as a small effect. Wolf's (1986) graphical interpretation shows the average effect in SD_x units for the comparison between the traditional instruction group and the CAI group. In rural educational settings, the average student exposed to CAI showed academic achievement greater than 55.8% of the students exposed to traditional instruction. Figure 5 shows that the typical rural student moves from the 50th percentile to the 55.8th percentile if the student receives CAI.

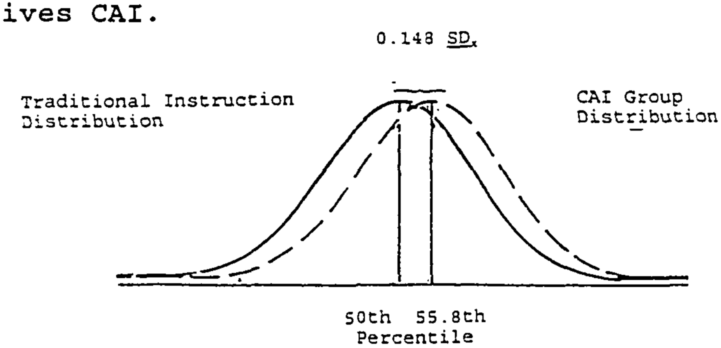

Figure 5. Average Rural ES in SD_x Units

Table 6

Mean Effect Size in Subject Areas

Subject Area	No of ES	Mean ES
English	4	-0.420
Math	15	0.179
Music	1	0.230
Reading	4	0.262
Science	7	0.717
Special education	2	0.259
Vocational education	2	0.168
Total	35	0.233

The mean effect sizes across the differing subject areas are compared (see Table 6). The 35 effect sizes were catagorized into the seven academic subject areas. The mean effect size was calculated for each subject area where academic achievement and the effects of CAI were studied. The mean effect size of CAI on science students' academic achievement was the largest effect size in the meta-analysis. The only negative mean effect size was on English students' academic

Table 7

Mean Effect Size by Differing Years

Year	No of ES	Mean ES
1984	1	0.884
1985	9	0.606
1986	6	0.385
1987	5	-0.183
1988	1	0.230
1989	5	0.185
1991	3	0.311
1992	4	-0.455
1993	1	0.156

achievement when comparing CAI and traditional methods of instruction. In descending order, the mean effect sizes by subject area in: science, reading, special education, music, math, vocational education, and English are as follows: 0.717, 0.262, 0.259, 0.230, 0.179, 0.168, and -0.420, respectively

Figure 7 shows a graphic representation of the mean effect sizes yielded by students over the ten years of studies included. The overall yearly effect of CAI on academic achievement decreases from 1984 to 1993. Of the 35 effect sizes examined, they ranged from a low of -0.455 to a high of 0.884.

The 35 effect sizes are compared over time by calculating the mean effect size of the studies conducted within each year from 1984 to 1993 (See Table 7 and Figure 6). The mean effect of CAI on student

Figure 6

Mean Effect Sizes by Year

achievement generally declined over time, and the percentage of change generally decreased over time. An increase in the mean effect size from year to year occurred in 1988, 1991, and 1993; however 1988 and 1991 were increases from negative mean effects in 1987 and 1989.

CHAPTER 5

Conclusions and Recommendations

The purpose of this study was to evaluate the effectiveness of CAI on students' academic achievement in differing educational settings. The specific objectives of the study were to: (a) select studies which utilized CAI as a supplement to traditional methods of instruction, (b) analyze statistically the studies using meta-analysis techniques, and (c) determine where CAI is effective in bolstering academic achievement.

The literature abounds with controversies on the effectiveness of CAI in secondary school settings. Some previous research showed that there are no differences in the academic achievement between students using traditional methods of instruction versus traditional methods of instruction supplemented with CAI. Other researchers concluded that CAI improves achievement in both elementary and secondary educational settings.

Researchers are continuing to assess the effectiveness of CAI in various settings, on different types of students, and across subject areas. Urban students encounter different learning conditions than suburban or rural students. CAI may provide an at-risk student who is exposed to a hostile urban environment with a means to improve academic achievement. Teachers of at-risk students can tailor software to meet disadvantaged students' learning needs. Interaction and flexability are key elements of meeting the diverse learning needs of individual students. Not all students learn at the same rate or in the same way. As in one-to-one tutoring, students can set their own pace through the material, taking as little or as much time necessary to achieve mastery of subject matter. Based on student responses, microcomputer-based software can provide remediation and advance learners to more difficult topics. In addition, CAI appeals to various learning modalities by offering text, graphics, and sound.

Research Question

The research question posed in this meta-analysis was the following:

What were the differences in the academic achievement levels between urban, rural, and *suburban secondary students who were exposed to computer-assisted instruction and students who were not?*

In this meta-analysis, individual studies on CAI constituted the data for statistical integration of the literature.

Discussion of Meta-analysis Results

Statistical significance comparison. Studies listed in Table 4 show results categorized as either (a) significant positive, where the CAI group achieved statistically significant higher gains than the group exposed to traditional methods of instruction; (b) significant negative, where the group exposed to traditional methods of instruction achieved statistically significant gains over the group exposed to CAI; or (c) no significant difference, where neither the group exposed to CAI nor the group exposed to traditional instruction achieved statistically higher gains. CAI is more effective in raising academic achievement than traditional instruction. Using the statistical significance comparison; 54% of the conclusions showed significant positive; 11% showed significant negative; and 34% revealed nonsignificant gains in academic achievement.

Effect sizes. Cohen (1977) provides the following ranges for effect size interpretations: ES = 0.200 to 0.499 (small effect), ES = 0.500 to 0.799 (medium effect), and ES = 0.800 and above (large effect). Tallmadge (1977) reports that an effect size difference of 0.250 or more is considered to be educationally significant. Effect sizes (ES_x) in standard deviation units (SD_x) show the degree of overlap between control and experimental groups (see Figure 1). This representation depicts what percentage of the experimental group exceeds the upper half of the control group; this technique helps to show the impact of the CAI treatment on academic achievement.

Mean effect size. The mean effect size calculation across the 24 studies and the 35 conclusions generated by the original authors was 0.233. Cohen (1977) interprets this effect size as a small effect. The difference in academic achievement resulting from CAI was an improvement of 8.70 percentile ranks from the central region of the distribution. Using this measure, it can be concluded that CAI is more effective than traditional methods of instruction in raising overall academic achievement in Grades 6 through 12. This finding supports Kulick, Kulick, & Bangert Drowns' (1985) research that showed a positive effect of CAI on academic achievement in secondary schools. However, Kulick et al. calculated a higher average effect size of 0.360, demonstrating that the students exposed to mainframe-based CAI improved academic achievement from the 50th to the 64th percentile. In comparison to the average effect size in this meta-analysis, the research of Kulick et al. indicated that students exposed to mainframe-based CAI achieved academically greater than 55.3% of the students exposed to microcomputer-based CAI.

The exhibited decrease in the effect of CAI on learning since 1985 contradicts Mason's (1984) assertion that as computers continually improve, academic achievement gains will increase. The difference in academic achievement resulting from older studies is larger than 5.0 percentile ranks in the central region of the distribution. Therefore, more was learned among students that utilized mainframe-based software. However, it is possible that the novelty of using software increased students' academic achievement.

Mainframe-based CAI was utilized prior to the popularity of microcomputers in American homes. Today, children are surrounded by computers both at home and school. The routine use of microcomputers by today's students may be less exciting than the novelty students experienced previously with mainframe-based software. Therefore, educational researchers should use caution when interpreting the results of older CAI studies.

Comparing mean effect size by educational setting. The mean effect size from the seven studies conducted in urban settings was 0.362. Cohen (1977) interprets this effect size as a small effect. This effect size indicates that the group exposed to CAI in urban settings achieved academically greater than 64.1% of the students in urban settings exposed to traditional instruction. Thirty-two percent of the conclusions calculated on studies in urban settings were classified as significant positive.

The mean effect size from the nine studies conducted in suburban settings was 0.227. Cohen (1977) interprets this effect size as a small effect. This effect size indicates that the group exposed to CAI in suburban settings achieved academically greater than 59.1% of the students in suburban settings exposed to traditional instruction. Forty-seven percent of the conclusions calculated on studies in suburban settings were classified as significant positive. Studies conducted in suburban settings had a higher percentage of significant positive results than studies conducted in urban settings. A smaller effect size with a higher percentage of significant positive results may indicate that there is variation in the effectiveness of certain treatments.

The mean effect size from the eight studies conducted in rural settings was 0.148. Cohen (1977) interprets this effect size as a small effect. This effect size indicates that the group exposed to CAI in rural settings achieved academically greater than 55.8% of the students in rural settings exposed to traditional instruction. Only 21% of the conclusions from studies in rural settings were classified as significant positive.

The results indicate that the mean effect sizes calculated on studies in urban, suburban, and rural educational settings are small relative to Cohen's (1977) effect size interpretation. The mean effect size calculations show that CAI is most effective in urban educational settings, moderately effective in suburban educational settings, and least effective in rural educational settings. Relatively, urban-setting CAI is more effective than rural-setting CAI and suburban-setting CAI.

Tallmadge (1977) considers the difference in mean effect sizes calculated on studies in urban and suburban educational settings to be educationally significant. The findings here support Roblyer's (1989) suggestion that CAI may be more effective in increasing academic achievement among certain kinds of students. However, the effectiveness of CAI may vary in differing educational settings because the software may not meet the needs of the students.

The urban-area mean effect size (0.362) achieved by students who utilized microcomputer-based software is almost identical to the mean effect size (0.360) calculated by Kulick, Kulick, & Bangert-Drowns (1985) in their meta-analysis on secondary students using mainframe-based software. The findings suggest that urban students using microcomputer-based software improve academic achievement at nearly the same level as those students who utilized mainframe-based software. However, the difference between effect sizes is too small to be considered educationally significant.

Comparing mean effect sizes by subject areas. Mean effect sizes by subject areas were tallied, showing that the majority of conclusions (15) were calculated in mathematics, seven in science, four in reading, four in English, two in special education, two in vocational education, and one in music. The mean effect size among science students' academic achievement showed the largest mean effect size (0.707) when comparing CAI to traditional instruction. The mean effect size of 0.707 was the largest mean effect size calculated. This effect size indicates that the average science student exposed to CAI achieved academically greater than 78% of the science students exposed to traditional instruction. This finding supports the findings of Roblyer (1985) whose research indicates that CAI appears to have the greatest effect in science. Roblyer (1985) also found that effects of

CAI among mathematics and science students were higher than the effects of CAI on English students' academic achievement. This may occur because both science and mathematics lend themselves to the discrete and objective steps that CAI offers students. The use of microcomputer simulations can enable students to learn science through their experiences rather than just reading about experiments. Students can conduct experiments normally considered dangerous, impossible, or impractical. For example, simulations can allow for an analysis of genetic characteristics of many generations during a single laboratory session. Other examples, such as experiments on diffusion, osmosis, mitotic division, and population problems, can be simulated by microcomputers in a very short period of time at a nominal expense. The simulations free students from time-consuming procedures so they can concentrate on the comprehension and mastery of the material (Christmann, 1995). On the other hand, English involves a more holistic approach to learning that may not necessitate the use of microcomputers to bolster academic achievement.

The findings included in this study also concur with Roblyer's (1985) conclusion that mathematics and science students utilizing CAI have higher academic achievement gains than English students exposed to CAI. This finding is important because Roblyer (1985) cautioned that the study did not contain enough results to ascertain an accurate estimate of the mean effect size in mathematics, science, or English. This study provided cell sizes of fifteen in mathematics, seven in science, and four in English. No science effect size conclusions were reported from urban educational settings. Further research is needed to determine if CAI is effective in bolstering academic achievement among science students in urban educational settings.

Comparing mean effect sizes by differing years. Studies included in this meta-analysis were conducted between 1984 and 1993. Of the 35 effect sizes examined, they ranged from a low of -0.455 to a high of 0.884. Over the ten-year span, the overall mean effect size by year decreased from 0.884 to 0.156 (See Table 7 and Figure 6). This finding contradicts Mason's (1984) assertion that as technology improves, academic achievement gains will increase. Perhaps this effect size decrease is because advances in hardware have outpaced progress in software development. The software utilized between 1984 and 1993 may have not utilized the capabilities of high performance hardware.

From 1984 to 1993, microcomputers have rapidly improved through the development of more advanced microprocessors. The most drastic downward trend of effect sizes occurred from 1990 to 1992. Between 1990 and 1993, only one effect size result was included in this meta-analysis that examined the effect of CAI on academic achievement in an urban educational setting. Further research is needed to determine if microcomputer-based CAI is effective in increasing academic achievement among students in urban educational settings.

Reliability and Literature Searches

Some biases, such as publication bias may have increased the effect sizes found in this meta-analysis. Research journals generally select and publish studies showing positive results. Furthermore, certain methods of statistical analysis can provide results that do not reflect the actual effect size (Wolf, 1986). Kulick, Kulick, & Bangert-Drowns (1985) identified two distinct purposes of meta-analysis: 1) to describe the current research literature, and 2) to attempt to uncover the "true" effect sizes of a treatment. This meta-analysis has focused on the first purpose, describing research results to date. Determining the true effect size of a treatment is very difficult. The data reported was inadequate to utilize the definitional formula for every effect size calculation in this meta-analysis. Means and standard deviations are essential for the most accurate estimate of the effect size. Cohen (1977) recommends that effect sizes appear in every report. Only one published article that was included in this meta-analysis included an effect size.

Questions of External Validity

The findings were limited by the studies that have been conducted to date and those that were possible to retrieve. It is not clear to what extent the search strategy may have failed to uncover research. The search strategy certainly missed research studies that may have never been published or presented. The findings were limited by the studies that have been published and those that were possible to retrieve. Problems of validity can be addressed by carefully reading and coding the studies included in the meta-analysis (Glass, 1981).

Glass (1981) reports that using only published research in a meta-analysis can inflate the mean effect size. The thirteen dissertations (ES_x= 0.251) and two unpublished papers (ES_x= 0.030) included in this meta-analysis may have helped reduce the inflation of effect size due to publication bias.

Recommendations for Future Research

CAI has consistently been found to have a positive effect on the academic achievement of students in Grades 6 through 12. Overall, CAI is beneficial in increasing academic achievement among students in secondary schools. However, the effect of CAI varies among certain students. Thus, four directions for future research seem most important. One is to further investigate the effect of CAI in both urban and rural educational settings. Although this study's findings suggest that CAI is most effective among urban students, this meta-analysis did not include any studies among science students in urban educational settings. Given the high success of CAI among science students, further research among urban science students would be worthwhile. Also, CAI was least effective in rural educational settings. It would be beneficial to further study why CAI has such a small effect on students in rural educational settings. The rural studies included in this meta-analysis were conducted among vocational agriculture students. Perhaps vocational agriculture students prefer to actually engage in authentic activities (such as participating in farm activities) rather than simulating activities on the computer. CAI may be an unnatural teaching tool within certain subject areas. Research uncovering effective applications of CAI among rural students may further increase rural students' potential for remaining competitive in the 21st century.

A second direction for more research would be to investigate why modern microcomputer-based software is less effective than mainframe-based software. To accomplish this task, more studies are needed to compare differing hardware and to evaluate types of software. Additional studies seeking to understand differences in the effectiveness of certain types of software may help provide students with the best and most effective technology available. This research is important because it may provide additional evidence that contemporary software is no more effective than older, less sophisticated software. Additional research or replication studies comparing older and newer software may show how extensively the "novelty effect" altered the findings of previous CAI research.

A third direction is to further determine the effect of CAI across differing subject areas, like mathematics and English. The effect of CAI appears to be decreasing in secondary mathematics. This study found that mathematics ranked fifth among the seven subject areas, with a mean effect size of 0.179. The search located only four studies that explored the effect of CAI on English academic achievement. Further research that determines what applications of CAI are most effective among English students may allow educational planners to integrate CAI into English instruction with more success.

A fourth direction is to examine differences in the effect of CAI on academic achievement by gender or by race. This meta-analysis found only one study that reported the effect of CAI by gender and one study that discussed the effect of CAI by differing ethnic groups. Additional studies exploring the benefits of CAI by gender or by race will provide a deeper understanding of where microcomputer-based software works best with differing learners. Under the right circumstances, CAI may allow different students to enhance learning and develop a more positive attitude toward the learning process.

The results of this meta-analysis lend support to the notion that CAI effects vary among students in differing educational settings. For example, CAI appears to have its strongest effects among urban students; its effects are weaker among suburban students and weakest among rural students. The higher effects among urban students may have resulted because CAI improved classroom management in urban educational settings. Microcomputer-based software provides teachers with additional instructional support for at-risk students. Improved classroom management may have improved urban students' academic achievement by providing an atmosphere that was more conducive to learning than previous instructional methods.

Suburban and rural students may have less need for the highly structured and reactive instruction provided by microcomputer-based software. These students may be able to acquire information through the use of textbooks without the prompting and feedback that a microcomputer-based CAI system would provide.

Implications for conducting future research. This study focused on a comparison between the academic achievement effects of CAI and traditional methods of instruction. This meta-analysis shows that CAI is an effective intervention for improving students' academic achievement. Further research is needed to predict and explain how CAI can be utilized as a more effective instructional tool. Today, there are many instructional factors that effect students' learning outcomes. Borg and Gall (1989) show the relative effect sizes of several instructional factors that improve students' performance on various measures of academic achievement (see Table 8).

Future researchers should generate research on why CAI helps some students learn more than others. Therefore, research that explains how CAI can enhance learning would contribute valuable knowledge to the field. Educational researchers should conduct research that explains how CAI compliments other educational interventions. For example, how does cooperative

Table 8

Instructional Factors that Influence Learning

Instructional Factor	Effect Size
Cooperative learning	0.760
Instructional time	0.380
Home environment	0.370
Higher-order questions	0.340
Individualized instruction	0.320
Socioeconomic status	0.250
Sequenced lessons	0.240
Class size	0.090

learning supplimented with CAI effect the academic achievement of students? Educational researchers need to determine the best instructional strategies available for students to remain competitive into the twenty-first century.

Educational researchers must develop ways to measure patterns and make approximations of how students best learn through the use of computers. CAI research restricted to controlled environments may not adequately explain what happens in natural settings. Qualitive research methods, such as ethnography, can help researchers determine when students grasp information or become confused during CAI activities.

Computers can provide opportunities for students to engage themselves in self-directed learning activities. As a result, students may become more motivated to participate in learning activities. Becker (1986) shows a relationship between students' attitudes toward using computers and academic achievement. Future research can determine how students' attitudes toward learning are influenced through the use of CAI. Many opportunities exist for researchers to extract meaningful patterns of affective learning through CAI teaching strategies. For example, dynamic gestalts permitting the flexibility, change, and excitement of students' learning can be measured using modern computer technology. The microcomputer can be programmed to measure changes in students' brain impulses, their pulse rate, and other areas of interest at specified intervals. Through further analysis of this data, perhaps researchers will be able to pinpoint how and why students using CAI learn most effectively.

In conclusion. Educators and researchers should keep in mind that a meta-analysis is a method of reviewing research. This study cannot forecast future developments in CAI. It should not be concluded, for example, that CAI will never be effective in raising the academic achievement among students in rural educational settings or among students in certain subject areas.

The research agenda that has been proposed will help educational planners determine reasons why CAI is more or less effective among certain kinds of students. Such research can lead to an increase in the number of students who will benefit from using CAI. Additional research is needed to prevent microcomputer-based CAI from evolving into a highly useful educational tool that is misunderstood, over-bought, under-used, and eventually largely discarded (Ryan, 1991).

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Autobiographical Statement

Edwin Patrick Christmann was born in Buffalo, New York, March 17, 1966. He earned a college preparatory diploma in 1984 from Manheim Township High School in Lancaster, Pennsylvania. He graduated in 1988 from California University of Pennsylvania with a Bachelor of Science degree in Education. He recieved his Master of Education degree in 1989 from The Pennsylvania State University in the area of Educational Administration. Mr. Christmann is currently teaching physics and chairman of the science department at Norview High School in Norfolk, Virginia. He has accepted a position as an assistant professor in the Department of Secondary Education at Slippery Rock University. Mr. Christmann has a wife, Roxanne Christmann, and two children, Lauren Ashley Christmann and Edwin Forrest Christmann.