Order Number 8921291

A comparison of the effectiveness of computer-assisted instruction using microcomputers and classroom instruction on three selected topics in a college algebra course

Tilidetzke, Robert James, Ed.D.

The University of North Carolina at Greensboro, 1988

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

A COMPARISON OF THE EFFECTIVENESS OF COMPUTER-ASSISTED INSTRUCTION USING MICROCOMPUTERS AND CLASSROOM INSTRUCTION ON THREE SELECTED TOPICS IN A COLLEGE ALGEBRA COURSE

by

Robert Tilidetzke

A Dissertation Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements of the Degree
Doctor of Education

Greensboro
1988

Approved John VanHoose
Dissertation Adviser

APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of the Graduate School at the University of North Carolina at Greensboro.

Dissertation Advisor John VanHoose

Committee Members [signature]

[signature]

[signature]

Oct 24, 1988

Date of Acceptance by Committee

Oct. 24, 1988

Date of Final Oral Examination

TILIDETZKE, ROBERT JAMES, Ed.D. A Comparison of the Effectiveness of Computer-Assisted Instruction Using Microcomputers and Classroom Instruction on Three Selected Topics in a College Algebra Course. (1988) Directed by Dr. John Van Hoose. 154 pp.

The study compared four sections of the college algebra course at the University of North Carolina at Greensboro during the Spring 1988 semester. There were two instructors participating in the study. Each instructor taught one control class (using the usual classroom instruction) and one experimental class (using computer-assisted instruction by means of tutorials in three selected topics). Complete data were collected for 21 students in each class. A pretest was given to all sections prior to any instruction; a posttest immediately after completion of instruction; and a delayed posttest embedded in the final exam for the course.

The analysis of the pretest results established that the four classes were comparable in prior knowledge of the topics selected for the study. No significant difference in mean scores was found between the control and experimental classes for each instructor on either the posttest or the delayed posttest. Further, no significant difference in mean scores was found between the two control classes combined and the two experimental classes combined on either the posttest or the delayed posttest. Thus, the use of the software package was as effective as classroom instruction on the three topics used in the study.

ACKNOWLEDGMENTS

Throughout my doctoral studies I have been especially grateful to Dr. John Van Hoose, my advisor, for his support, guidance, and patience during the coursework and this study. I also extend appreciation to Dr. Rita O'Sullivan, Dr. David Strahan, and Dr. Richard Sher, for their advice, encouragement, and friendship as members of my committee. I also wish to extend appreciation to Dr. Kieth Wright for his assistance with the literature search.

To my wife I owe special thanks for her understanding and support during my pursuit of this degree and for her assistance in proofreading the manuscript.

Special thanks is also extended to the United Negro College Fund for the two-year grant that made the attainment of this degree possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION AND STATEMENT OF THE PROBLEM

A Brief History

Computer-Assisted Instruction (CAI) has been used in a variety of educational settings for nearly 30 years. However, as Vaughn (1977) pointed out, the emphasis of CAI is, "in reality, a rediscovery of the Socratic method of instruction" (p. 35-36) that was used thousands of years ago. Socrates is credited with using the question-and-answer method to teach his students to reason logically and with clarity. CAI works in a similar manner; through a series of questions the student progresses from the simple to the more complex. Though this study will focus on CAI in mathematics, a broad overview of the evolution of this approach and the technology that supports it needs to be provided as a basic foundation.

Early Teaching Machines

"Historically, the first attempt to utilize a machine for teaching was made by Maria Montessori (1870-1952) in Rome in 1907. Her work with teaching devices anticipated later concepts of programmed instruction" (Vaughn, 1977, p. 38). In the 1920's, Sidney Pressey devised a mechanical device to administer and score tests. Its design provided immediate feedback to the students and allowed for teaching drill material (Vaughn, 1977). If the student chose the correct answer to a multiple-choice question, the student would advance to the next question, thereby knowing immediately that a correct answer had been given. If, however, an incorrect answer had been chosen, the student could continue making alternative choices until the question was answered correctly (Skinner, 1986).

Both Skinner and Holland studied the use of teaching machines in college instruction in 1958. They pointed out a similarity between the machine and a human tutor:

> There is a constant interchange between program and student; the machine induces sustained activity; like a good tutor, the machine insists that a given point be understood before the student moves on; the machine presents just that material for which the student is ready; it helps the student to come up with the right answer; and, like the private tutor, the machine reinforces the student for every correct response. (Fine, p. 151)

Motivated by a desire to provide appropriate reinforcement for each student, B.F. Skinner developed his version of a teaching machine. A complex learning situation was divided into smaller objectives and successful responses were immediately reinforced (Vaughn, 1977). Skinner (1986) wrote that he had not yet heard of Pressey's work (described above) when he demonstrated a machine to teach arithmetic in 1954. While there were a number of similarities in Pressey's and Skinner's machines, there also were important differences. Students would use Skinner's teaching machine without prior study of any special material. Moreover, students using Skinner's machine had to compose their answers rather than just respond to the multiple-choice format used by Pressey. The third, and according to Skinner the most important, difference was that his machine presented the material in a hierarchical fashion. Each subsequent question built on what the student learned by doing the earlier problems, and the notion of programmed instruction was born (Skinner, 1986).

Much of current CAI tutorials reflect the style and intent of Skinner's teaching machine. Feldhausen (1969) saw computer-assisted instruction as an outgrowth of programmed instruction of the late 1950's and early 1960's. CAI can be viewed as a new format for programmed instruction, an electronic incarnation of the teaching machine.

Computers in Education

Members of the computer industry were among the first users of CAI in the late 1950's for the purpose of training their own personnel. The focus by educators on programmed instruction at about the same time made "educational CAI ... an almost natural combination of emerging computer technology and the programmed instruction movement" (Burns & Bozeman, 1981, p. 33). In 1959, the PLATO (Programmed Logic for

Automatic Teaching Operation) system was installed at the University of Illinois. This system has undergone several revisions over the intervening years (Vaughn, 1977).

Burns & Bozeman (1981) described the use of PLATO at the University of Illinois as follows.

> The powerful and relatively facile PLATO author language, TUTOR, accommodates simultaneous system time sharing by students and teacher-authors as lesson material continues to proliferate. Efforts at the elementary and secondary levels have been concentrated in the areas of mathematics and language arts. PLATO now services over 4,000 students per semester." (p. 33-34)

Most important, with the increase in the power of microcomputers, it has been possible to create versions of PLATO that can be run on personal computers.

Developmental projects have been conducted at various institutions of higher education from the early 1960's to the present time. Suppes directed at Stanford University one of the early important projects to develop CAI. The development of a small tutorial system was started in 1963 to provide instruction in elementary mathematics and language arts. The second phase of the project was aimed at developing CAI in initial reading and math for culturally disadvantaged students (Burns & Bozeman, 1981).

There were other pioneer CAI efforts in addition to the Stanford Project. The Individual Communication (INDICOM) system was launched in Waterford, Michigan, in 1967 for grades K through 12, in 11 content areas. In the late 1960's the University of Pittsburgh developed Project Solo and subsequently, the Soloworks Lab Project. Burns & Bozeman (1981) wrote that the intent of these projects was

> to test the feasibility of deliberately reorganizing a segment of secondary school mathematics around computer-based laboratories intended to preserve the best features of both student-controlled computing and modern math curricula and to integrate mathematics and other disciplines. (p. 34)

In the early 1970's the TURTLE CAI project was developed at the Massachusetts Institute of Technology. This project stressed creative functions as opposed to rote aspects of subject matter. The TURTLE system provides a learning environment in which students can experientially deal with mental models (Burns & Bozeman, 1981).

To conclude this historical discussion it is appropriate to look at the present and the future of computers in instruction. The field of artificial intelligence (AI) holds great promise for creating much more effective computer-delivered instruction. When compared to a human tutor, most CAI programs are very limited. O'Shea (1982) pointed out that some of the limitations include

> (1) the inability to conduct dialogues with students in natural language;
> (2) the inability to understand the subject being taught, in the sense that the program cannot accept unanticipated responses;
> (3) the inability to understand the nature of the student's mistakes or misconceptions;
> (4) the inability to profit from experience with students or to experiment with the teaching strategy. (p. 309)

Intelligent Tutoring Systems (ITS), Computer-based Learning Environments, and Expert Systems are products of AI research. They are on the cutting edge of research into educational uses of computers. A brief overview of each of these will be provided.

Expert Systems have been in existence for about 15 years and "have become the most commercially successful progeny of artificial intelligence" (Cromie, 1988, p. 10). Cromie further pointed out that, nonetheless, "they remain severely restricted because of difficulties in modeling knowledge and its use" (Cromie, 1988, p. 10). In the field of medicine, expert systems began with MYCIN in the mid-1970's. Since that time several other medical expert systems have been developed such as ONCOCIN, which is a cancer treatment consultant, and PUFF, which interprets the results of physiological tests of patients suffering from lung disease. Each of these expert systems specializes in a narrow area of medicine. Expert systems with much more extensive data-bases that will allow for diagnoses across a large range of diseases as well as prescribe appropriate treatments for a patient suffering from two or more concurrent illnesses are still things of the future. Cromie indicates that more limited systems of this type of Expert System product are being developed for use both in medical practice and medical education. A major challange in this area is to design expert systems that can be run on the more powerful personal computers. At present either an expensive mainframe computer or a minicomputer is needed to run these expert systems.

Intelligent Tutoring Systems aim at solving specific shortcomings identified with earlier CAI systems. "By its very nature, research in Intelligent Tutoring Systems is an interdisciplinary activity which includes the fields of cognitive science, artificial intelligence, human-computer interface design, educational evaluation, etc" (Sleeman, 1987, p. 239). Perhaps the greatest advance of ITS is the use of techniques of knowledge representation that had been pioneered within the "knowledge engineering" community (Yazdani, 1987). The central objective of ITS is the communication of "some knowledge through computer facilities which may employ domain-specific expertise, error analysis, and user modelling" (Yazdani, 1987, p. ix). The main strengths of ITS are a well-articulated curriculum and an explicit theory of instruction. Its weakness is an inadequate complexity in the models of what the users presently know, how they learn new knowledge, and how they determine what might be an appropriate instructional theory (Yazdani, 1987).

The underlying principles of ITS packages make them capable of rich interaction with the student, with the capabilities of knowing who and what they are teaching as well as how to teach persons of differing ability and learning styles. Yazdani (1987) felt that while CAI can be considered a mature technology, having a three-decade history, ITS approaches are currently at a pre-technology phase.

Ohlsson (1987) summarized the matter in the following way:

> In summary, the main promise of computer tutors, I claim, lies in their potential for moment-by-moment adaptation of instructional content and form to the changing cognitive needs of the individual learner, and our task, as I see it, is to find principles which can guide the construction of tutors which fulfill that promise." (p. 204).

It remains to be seen whether the promise offered by ITS will be fulfilled.

Computer-based learning environments aim to lead students to powerful authentic knowledge. This approach is in part a response to Piaget's view that active discovery of reality is superior to merely providing youngsters with a ready-made reality. This emphasis on discovering reality leads to a focus on the activity of the learner. For it is the learner's internal actions that integrate new knowledge with old knowledge and express that integration creatively. Observations of outward behavior provide only a partial understanding of the thought processes that the student may have used. There are some fundamental limitations in these learning environments. It is difficult to determine the learning environments' impact because of the nature of the effects being sought and the complexity of the human minds within which those effects take place (Yazdani, 1987).

This brief history has focused on the development of automated-instruction machines that has led to the present uses of computers for instructional purposes. The evolution from huge mainframe computers filling complete rooms to small, extremely powerful, desktop personal computers is fairly well-known. The first computers were too expensive to be used in "ordinary" classrooms. The small, powerful microcomputer has become inexpensive enough to be accessible to most classrooms. It should be pointed out that this evolution of computers was and is a driving force behind the course of development of instructional applications of computers.

CAI: Problems and Issues

Computer-assisted instruction has not been free from criticism. A major criticism of CAI has been its cost. For example, the initial versions of PLATO required a main-frame computer, costing many thousands of dollars. Such costs would surely give one pause before investing in something that was then very experimental. Fortunately, this situation has changed dramatically in the past decade. The quality of CAI software has improved greatly in recent years. In particular, good CAI software packages are now available for introductory-level college mathematics courses for less than $50.

The effectiveness of computers in education has been questioned since the first time they were used in teaching. Over the past 25 or 30 years there have been many studies of computer effectiveness in various disciplines, utilizing different computer methods, across all grade levels, from elementary to college to adult education. The diversity of studies has made it difficult to synthesize the results. In the mid 1970's a method of analyzing a body of research was developed by Glass (1976). Glass' method of meta-analysis provided the means to synthesize the research that had been done on computer effectiveness in educational settings. A number of researchers have done meta-analyses on the use of computers at specific grade levels. The weight of evidence from these studies indicates that the use of computers in education is effective. Work in this area has been done by Kulik, J. A., Kulik, C-L., & Cogen, P. A. (1980), Kulik, C-L., & Kulik, J. A. (1986), Kulik, J. A., & Kulik, C-L. (1987), and by Suppes and Fortune (1985).

A detailed review of the various meta-analyses of CAI and mathematics that have been done since 1980 is provided in Chapter II. Some of the results of these meta-analyses have been called into question by Clark (1985). Clark's objections as well as a response to them by the three primary authors of meta-analyses are also discussed in Chapter II.

There is no shortage of other problems of varying degrees of complexity related to computer-assisted instruction. A brief overview of the most serious problems associated with the use of computers in education follows. Though many of the problems are presented in the context of public education, most of the concerns carry over to higher education.

Merrill & Tolman (1986) have identified a major problem that is not going to go away, but will grow more severe; namely, the pace of change in the social and ethical issues associated with the introduction of computers:

> Social and ethical issues are usually complex, but the consideration of computers in education is further complicated by an unparalleled and increasing rate of change. Just as we feel we have an understanding of a given issue, the issue may change or no longer exists. Unfortunately, predictions of even the near future often prove to be wrong, due to the mercurial nature of social and ethical issues concerning computers. (p. 281)

For example, a few years ago microcomputers were considerably more expensive than they are now. The prices for microcomputers are now about one-third to one-fourth of what they were about five years ago. With the substantial reduction in their cost there has also been an extensive increase in the capabilities of microcomputers. Formerly, there were questions of whether the high cost of microcomputers and their limited capability made them worth the investment. These questions are less pertinent today.

The computer has a tremendous capacity to individualize instruction. As yet this potential has not been fully realized. Artificial intelligence (AI) may possibly exploit this potential fully. If it does, a host of related questions arise. Should there be a more flexible curriculum? With some students finishing a course, largely provided by computer instruction, in a fraction of the time needed by others, "How will students be scheduled into discrete classes, receive grades, and move on to the next class when they are all completing class curricula at different times? (Merrill & Tolman (1986)). Who will have the power to decide on how far and under what constraints a student learns? There is the sensitive question of equal access to computer education. Will the gap between the "haves" and the "have-nots" be widened?

Coburn, Kelman, Roberts, Snyder, Watt & Weiner (1985), echoed the concern mentioned earlier for the impact of CAI on scheduling, grades, and access:

> How can educators begin to make use of the genuinely new learning potential of computers?...Considering all that may be possible to do educationally with computers someday it is likely that the realization of this potential will require significant changes in patterns of teaching and learning.
> (pp. 245-246).

Coburn et al. (1985) devoted an entire chapter to issues in educational computing, and the choices that will have to be made:

> How will teachers get the training they need?...Schools investing tens of thousands of dollars each year for computer hardware are only just beginning to spend as much on teacher training. (p. 244)

In a recent interview, Weizenbaum (1987) also expressed a variety of concerns. His view is pessimistic in that he sees the failure of faculties to utilize computers more fully as a real obstacle to future improvement in use.

> They (computers) are used for individual classes for homework and that sort of thing, but the dream or the vision that computers would actively participate in classroom teaching ... well, that hasn't happened and I don't think it's about to happen. (p. 4)

The participants at the symposium of the International Commission on Mathematical Instruction (ICMI)

> Seemed to feel that the computer offers a potential for dramatic improvement in mathematics instruction. However, its potential for failure is also great. (p. 51).

Kinds of CAI Software

There are basically four kinds of CAI software. One type of software is used for drill and practice. A package of this type can be effective for providing students with additional practice after a topic or concept has been taught in class. Another type of software, known as a utility package, contains programs that do all of the laborious calculations associated with a variety of math problems. For example, the task of graphing a function in the coordinate plane is very time-consuming if done by hand. So much effort is spent on the computations that the student never seems to have the time or energy to look for the "big picture", the overall structure and the relationships between the component parts. A utility package for graphing functions provides an environment in which students are freed from the tedious computations and allowed to expore the consequences of changing the parameters of a function.

A third type of software uses simulations. The flight simulators used by pilots and astronauts are sophisticated applications of simulation software. Simulations can be used in a variety of subject areas from economics to sociology.

A fourth type of software is a tutorial program designed to actually teach a concept in an interactive environment. Examples are presented and then the student is given similar problems and is expected to work them. The computer provides feedback to the student, so the student can measure progress. The extent of the feedback varies from one tutorial to another. Some tutorial packages have very elaborate responses to student errors, as well as positive feedback for correct answers. Other tutorial packages are more modest in the feedback provided. A careful review of the literature reveals that systematic studies to determine the value of using tutorial packages in college algebra have not been conducted.

CAI and Mathematics

A dozen tutorial software packages in algebra were reviewed prior to selecting one for this study. The criteria for selection were a) that it presented instruction on several topics contained in the syllabus for the College Algebra course that would require no supplemental classroom instruction; b) that it provided options to allow the students to have some control over the presentation; c) that it provided appropriate feedback and help when requested; that it was available at a reasonable cost; and e) that it was sound pedagogically.

Statement of the Problem

This study investigates the use of a tutorial package in a course of instruction in Math 119, College Algebra, taught at the University of North Carolina at Greensboro (UNCG) in the Spring 1988 semester. This course serves as a precalculus course for those students planning to take calculus eventually. A tutorial software package published by Addison-Wesley was used and its effect evaluated.

The syllabus for a typical College Algebra/Precalculus course is lengthy, and the length poses a dilemma. On the one hand, since this course is a prerequisite for a subsequent course, there is a need to cover the required topics. On the other hand, it is extremely difficult to cover all topics in the syllabus while still attending to the learning needs of the students. This dilemma has led to the consideration of a computer tutorial package as a possible solution. However, the value of this approach has not been determined. The major impetus to conduct this study is thus provided.

Mathematics is hierarchical in nature. The prerequisite topics for a particular course are well established. The remedy, thus, does not lie in an attempt to delete topics from the syllabus. Fortunately, there is a certain amount of review material covered at the beginning of the College Algebra/Precalculus course. Moreover, some of the "new" material is fairly straightforward and not too complicated. Therefore, it seems reasonable that some of the less complex topics may be taught by means of computer-assisted instruction rather than in class. It may be that additional time in class may be used to attend to students' questions, as well as provide more time to present more thoroughly the more complex topics. However, before questions related to the use of additional class time due to the use of C.A.I. are addressed, it is essential to determine whether the C.A.I. coverage of topics is at least as effective as in-class coverage of the same topics. This determination is the focus of this study.

Approach and Hypotheses of the Study

Students in two sections of College Algebra studied three topics by means of CAI in an Apple Computer lab: 1) the multiplication and division of complex numbers, 2) completing the square, and 3) solving linear equations. These topics are discussed in Chapter 3 in the Pilot Test of Software section. Two additional sections of College Algebra served as control groups. Two instructors participated in the study, each teaching a CAI section and a control section of College Algebra. The primary research question was to determine whether the students using CAI in selected topical areas would do as well as or better than the students receiving classroom instruction on a posttest and on a delayed posttest. The research hypotheses were the following:

Hypothesis 1. For each of two instructors, the students in their CAI class will do as well as or better than those in their control class on a posttest covering the topics in this study.

Hypothesis 2. As a group, the two CAI classes will do as well or better than the two control classes as a group on the posttest.

Hypothesis 3. For each of two instructors, the students in their CAI class will do as well as or better than those in their control class on a delayed posttest, embedded in the final exam, covering the topics in this study.

Hypothesis 4. As a group, the two CAI classes will do as well or better than the two control classes as a group on the delayed posttest, embedded in the final exam, covering the topics of this study.

Definition of Terms

Arithmetic of complex numbers: The multiplication and division of two complex numbers, subsuming the processes of the addition and subtraction of complex numbers, and the concepts of the imaginary unit and complex conjugates.

Completing the square: (1) adding the necessary third term to an x-squared term and an x-term to form a perfect trinomial square; (2) factoring a perfect trinomial square: (3) adding and subtracting the appropriate amount within a trinomial expression to convert a part of the expression into a perfect trinomial square.

Solving linear equations: Includes both elementary linear equations and equations with parentheses on at least one side of the equation.

Interactive: A type of computer software package in which the student answers questions posed by the computer and receives feedback on the correctness of the answers.

Computer-assisted instruction (CAI): In this study, refers to the use of an interactive tutorial software package; in the literature, refers to the use of drill and practice software.

Mainframe computer: a very large, complex computer (Initially, all computers were mainframe, the first of which filled an entire room).

Minicomputer: Still a fairly large computer compared to a desktop computer, but substantially smaller than a mainframe computer; typically small enough to fit in a good sized walk-in closet.

Microcomputer: The small desktop or the more compact portable computer now having as much computing power as the first huge mainframe computers in the late 1950's.

AI: Artificial Intelligence, the study of ways to make computers function more like human beings; on the cutting edge of both computer and educational research.

ITS: Intelligent Tutoring System, a tutorial software package that more closely emulates a human tutor than the earlier tutorials did.

CBE: Computer-Based Education, an umbrella term that includes all of the various uses of computers for instruction such as CAI, CMI, and CEI.

CMI: Computer-Managed Instruction, the use of computers to administer and score exams, as well as to maintain student records.

CEI: Computer-Enriched Instruction, the use of the computer as a calculating device, programming tool, and simulator.

Computer-Based Learning Environment: Software package designed to provide an environment in which the students may explore, experiment, and discover facts and relationships on their own, rather than having a predetermined "truth" handed to them.

Significance of the Study

More knowledge is needed about how well students in a freshman-level College Algebra course learn introductory topics by means of computer-assisted instruction. Presently, student needs cannot be fully attended to by instructors who have to press ahead to meet a demanding syllabus. If students were to study a portion of the more elementary topics by means of CAI outside of the classroom, the class time available to present, explain, and assist students with the more difficult topics would be increased. This study is an attempt to determine the comparative effectiveness of CAI and the usual classroom instruction. It is intended to contribute to an understanding of how CAI on microcomputers may be used in place of classroom instruction in a college algebra course. There is a need for further study of the educational uses of microcomputers. Manion (1985) pointed out:

> Where microcomputer-assisted instruction is already being employed, it is a relatively new practice, highly innovative, and currently experimental in both nature and design. Because of the recency of the microcomputer revolution in education, problems and uncertainties surrounding the practice of computer-assisted instruction, or CAI, still exist. (p. 25)

Limitations

A number of factors limit the generalizability of this study. The topics used in this study represent only a small portion of the introductory material in the college algebra course. The students spent only two hours (approximately) in the lab. Thus, one can not determine the consequences of using a greater number of topics and a longer period of exposure to CAI.

Furthermore, since the students in the CAI sections (to equate instruction time for treatment and control groups) were excused from two class periods, this study cannot be generalized to a setting in which students simultaneously study topics by means of CAI while receiving classroom instruction on other topics. Another limiting factor is the specific nature of the sample of students participating in the study. These students are assumed to typify College Algebra students in colleges and universities in the United

States, although they were not randomly selected. A further limiting factor is the physical setting in which the CAI tutorial interaction occurred. Student access was limited by the number of computers available and the limited number of days set aside for the use of the lab.

Summary

Computers have been used in instruction for over 30years. However, the use of microcomputers in a college algebra course has not been adequately researched. In this study the effectiveness of a CAI tutorial was compared with the usual classroom instruction on three introductory level topics. Two instructors each taught a control section and an experimental, CAI, section. A pretest was given before instruction, a posttest was given the first class day after treatment, and a delayed posttest was embedded in the final exam for the course. The next chapter presents a search of the literature to acquaint the reader with the body of research extant.

Chapter II

OVERVIEW

The first computer-assisted instruction (CAI) was designed and put into use in 1958 (Austin, 1978). At that time, of course, computers were in the "Dark Ages" when compared to the present. There were no interactive terminals for students to use, and microcomputers were just a faint gleam in someone's eye. The mechanics of using a computer in 1958, as well as for a number of years thereafter, were archaic. The use of punched cards and batch processing, plus a wait possibly as long as a day or more for a reply, made the whole process tedious and time-consuming. Thus, it is clear that the initial studies of the use of CAI are not germane to this study, except perhaps for their historical interest.

While this study deals specifically with the use of a tutorial in College Algebra, a broader review is necessary to place this study in perspective. A review of the literature is structured across several dimensions: 1) types of CAI, 2) modes of use, 3) duration of use, 4) the grade level at which the CAI is used, and 5) the subject or content area.

Next in this chapter, several meta-analyses of computer-based instruction in various subject areas are discussed. Selected studies in these areas are presented. Then, studies in calculus and college algebra and precalculus are covered extensively since this is the content area of this study.

Types of CAI

Drill and Practice

Drill-and-practice software was the first type of CAI to be developed Culp & Castleberry, 1971; Kulik, Kulik, and Schwalb, 1986; Nelson and Irwin, 1986; Ries and Granell, 1985; Vaughn, 1977; Vinsonhaler & Bass, 1972, are studies of the use of drill-and-practice CAI. It was quite literally an electronic substitute for the workbook and did not take full advantage of the unique capabilities of computers. Drill-and-practice CAI was used after the desired skills and concepts were presented by the instructor. Thus this type of CAI was used for reinforcement, rather than for the initial instruction.

Tutorials

CAI tutorials are designed to provide the instruction (Diem, 1982; Fortune, 1985; Liu, 1975; Ries and Granell, 1985; Spock, 1987; Vaughn, 1977). It is not assumed that the students have previously been exposed to the skills and concepts presented in the tutorial. The essence of a math tutorial is to present the material by means of narrative and worked-out examples, followed by similar problems to be solved by the student.

The first math/arithmetic tutorials were really modified drill-and-practice software. They were stark and followed a linear format of presentation in which every student encountered precisely the same sequence of materials. The tutorials now available are more sophisticated. The use of a menu allows the student a measure of control over sequencing. For example, a student may choose to review a lesson previously studied, to study a new lesson, or to take a lesson test. Each choice may be selected with a single keystroke. In addition to a menu of choices, many software packages list several options at the bottom or the top of the screen. The user may select from among the available options to exercise some control over the flow of the lesson. Typically, these options allow the student to back up one screen at a time, skim through the lesson by advancing one screen at a time, or terminate the lesson.

By the use of a random number generator, a greater variety of problems can be presented, and each student encounters a unique set of examples and problems to solve. This is accomplished by structuring the form a question should have, but leaving the choice of the numbers to be used in the question up to the computer. For example, question 1 might have the form "a+b=?". When one student encounters this problem, it may be "34 + 73 = ?", while for another student this same question may be "51 + 29 = ?". Some of the more sophisticated tutorials have some branching capabilities, which allow the software to choose from among alternate paths based on the student's responses. At present, these branching processes are not elaborate enough to allow the software to act as a human tutor would. However, this may soon change. An area of computer research known as "artifical intelligence (AI) may provide the means of designing tutorial software capable of acting like a human tutor.

Utilities

Utilities provide an environment in which the student can discover concepts and relationships while being freed from the computational work associated with many mathematical concepts (Brown and Cutlip, 1987; Byers, 1973; Hundhausen, 1980; McCall and Holton, 1982; Sterrett and Karian, 1978). Utilities for the graphing of functions were mentioned in Chapter I. The geometric figures of circles, ellipses, parabolas, and hyperbolas are all members of a family of functions known as conic sections. A utility designed to graph these kinds of functions will not only allow but also encourage a student to experiment by changing certain parameters in an equation to see how the corresponding graphs are modified or transformed from one type into another. They may, for example, be transforming the equation of an ellipse into the equation of a hyperbola. What would otherwise require hours of work can be accomplished in minutes, and the students are enabled to explore and learn in a discovery mode that otherwise would not be available to them.

Simulations

In addition to flight simulators mentioned in Chapter I, which have obvious value in the military and the airline industry, this category of software includes simulations in ecology, business, and statistics, as well as certain kinds of games such as text adventures. Some simulations teach skills in a manner similar to flight simulators. Others allow one to explore "what if...?"-type questions for better understanding of complex systems. For example, if a lake area is developed for recreation, what will be the impact on the eco-system? Text adventures can promote and polish problem-solving skills (Sheriff, 1988). There are a number of additional studies of simulations (Culp & Castleberry, 1971; Gray, 1988; Hollen, Bunderson, & Dunham, 1971; Kulik, Kulik, & Schwaub, 1986; Ries & Granell, 1985).

Modes of Use

There are three modes of use of CAI: 1) as a supplement to classroom instruction; 2) as a substitute to classroom instruction; and 3) as instruction on its own. These three modes are described below.

The first use is as a supplement to classroom instruction (Byers, 1973; Liu, 1975; and Smith, 1976). A drill and practice package may be used for homework or made available as a resource for students to review as extensively as they wish. A utility package may also be used as a resource. It may also be incorporated into a guided exploration of relationships and concepts by the students outside of class, or it may be used by the instructor in a presentation before the class in which the instructor enters student-suggested changes into the computer.

The second mode of use is as a substitute for classroom instruction (Meyer and Beaton, 1974; Ries and Granell, 1985; Smith, 1980). Instead of being presented in the usual way, the material is presented by the computer. Clearly, a CAI tutorial is well suited to this task. It is the primary type of CAI used to substitute for classroom instruction. However, a drill-and-practice package covering review topics might be used outside of class to refresh the student's memory in place of taking class time to cover these topics.

The third mode of use of CAI is as an instructional mode of its own. That is, CAI may be used on its own to explore various aspects of a discipline to understand better the way the major elements of the discipline fit together. Simulations provide a means for accomplishing this. Judah Schwartz is a prominent proponent of this use of CAI. However, it seems that all of his work in this area is in the form of computer files in data bases, which were therefore unavailable to the writer.

Duration of Use

Essentially, CAI is used either for an entire course or for only a few selected topics. Examples of studies in which CAI was used for an entire course may be found in the following works: Bell, 1970; Buckley and Rauch, 1979; Daughdrill, 1978; Vaughn, 1977. Examples of studies in which CAI is used for only a portion of the material covered in a course can be found in Deigman and Duncan, 1978; Diem, 1982; Ries and Granell, 1985; Sheriff, 1988.

Grade Level

Initial CAI studies focused on the elementary level Vinsonhaler & Bass, 1972). Later studies were done at the middle and secondary levels (Bostron, Cole, Hartly, Lovelly and Tait, 1982; Fortune, 1985; Gallego, 1985; Koohang, 1984; Romero, 1979; Vaughn, 1977). Most recently, studies in higher education have appeared (Abraham and Slotnick, 1985; Hundhausen, 1980; Nelson & Erwin, 1986; Spock, 1987; Sterrett & Karian, 1978).

Subject Areas

Sciences

CAI has been widely used in physics, chemistry, engineering, and mathematics, because these subject areas are well suited for CAI instruction. However, CAI is not used frequently in other content areas. CAI studies in math may be found in Byers, 1973; Cooke, 1986; Fortune, 1985; Romero, 1979. CAI studies in physics may be found in Liu, 1975 and Oberem, 1987. CAI studies in chemistry may be found in Culp and Castleberry, 1971 and Hollen et al., 1981. CAI studies in engineering may be found in Brown and Cutlip, 1987 and Hundhausen, 1980.

English

Tutorials to teach grammar, punctuation, and other aspects of English have also been used (Duin, 1988; Fortune, 1985; Jeger and Slotnick, 1985; Vinsonhaler and Bass, 1972). A word-processor is used as a utility in English composition courses. Drill-and-practice CAI is used to reinforce rules of grammar and punctuation.

Less extensive use of CAI is found in other disciplines. Moreover, the uses of computers in other disciplines do not differ from their uses in the sciences and English. The next portion of this chapter reviews several meta-analyses on the effectiveness of computer-based instruction (CBI).

Meta-Analyses

Over the past eight years a number of meta-analyses have been conducted on the effectiveness of CBI in a variety of areas (Kulik and Kulik, 1986; Kulik and Kulik, 1987; Kulik, Kulik, and Cohen, 1980; Kulik, Kulik, and Schwalb, 1986). The term "computer-based instruction" is used to encompass a wider range of instructional uses of computers. CBI includes CAI as well as computer-managed instruction (CMI) and computer-enriched instruction (CEI). Before discussing each of these papers, it is necessary to describe a meta-analysis and to convey some of the common features of all of these meta-analyses.

A meta-analysis (Glass, 1976) involves a systematic search of the literature to identify studies that have been done in an area of interest. In particular, Kulik et al. identified the studies that compared computer-based instruction with regular classroom instruction. A number of criteria were used to sift through the located studies. First, only studies that took place in the desired environment were retained; i.e., only studies that took place in actual college classrooms would be included in a meta-analysis of studies at the postsecondary level. Second, studies had to report quantitatively measured outcomes in both experimental and control classes to remain in the meta-analysis. Third, studies had to be well-designed and free of crippling methodological flaws.

Once a subset of the original set of studies located in the search was identified as meeting these three criteria, the studies in this subset were categorized across a number of features. Some of these features could be year of the study, whether the study was published or unpublished, methodological features such as random assignment of comparison groups or control for instructor effect, ecological conditions such as duration of treatment, course level, and university setting.

Due to the diversity in the studies it is necessary to quantify the outcomes to allow for comparisons across studies. This is accomplished by using a measure of effect size. In a meta-analysis of a set of studies the metric of the dependent variable is not consistent across studies. Effect size is a measure to convey the magnitude of a difference (say, between group means) that is not effected by the metric used for the dependent variable. Thus, the effects produced in two studies using different metrics may be compared. In some of the meta-analyses the effect size was computed to be the difference between the means of the two groups (the computer-based group and the control group) divided by the standard deviation common to the two populations. In other meta-analyses, the difference was divided by the standard deviation of the control group. As each meta-analysis is discussed below, the method used for computing effect size is explicitly stated.

CBE and College Teaching

In a chronological review the first study to be summarized is the meta-analysis by Kulik et al. (1980) of 59 independent evaluations of computer-based college teaching. Computer-based instruction (CBI) is an umbrella term that includes the use of tutorials, simulations, the teaching of programming, and computer-managed instruction. Computer-managed instruction (CMI) refers to the use of the computer to administer and score tests, as well as to manage student records. The authors pointed out that in the tutoring studies they analyzed the computer instruction was presented directly to students (Kulik et al. 1980).

In addition to variation in the type of application of the computer to instruction, the 59 studies also varied along two other dimensions. One of these dimensions was the way in which the computer was used, either as a substitute for instruction for the usual classroom teaching or as a supplement to the classroom instruction. The other dimension was the extent of usage, either for the full duration of the course or for only a unit of instruction lasting about one to two weeks (Kulik et al. 1980).

The authors found the following:

> A total of 54 of the 59 studies located for this meta-analysis looked at examination performance of students in CBI and conventional classes. In 37 of the 54 studies CBI examination performance was superior to examination performance in a conventional class; 17 studies favored conventional instruction. Fourteen of the 54 comparisons reported statistically significant differences between teaching methods. Results of 13 of these studies favored CBI, and results of one study favored conventional instruction. If no overall generalization about the effect of CBI was possible, one would expect about half the cases to favor CBI and half to favor conventional teaching. Instead, a clear majority of studies favored CBI. We were therefore able to reject the null hypothesis of no effect of CBI on student achievement. (p. 534)

The authors also found that CBI raised exam scores by about 3 percentage points which is approximately one-quarter of a standard deviation (Kulik et al. 1980). Moreover, this boost in scores was "about as noticeable in high- and low-aptitude students as it was in in average students" (p. 538). It should be noted that in this study the effect size was computed by dividing the difference of the means by the standard deviation common to the two populations. It was also found that, in every study in which CBI was used in place of conventional instruction, CBI required only about two-thirds of the time required by conventional teaching methods. Thus, computers could reduce the time spent in instruction while functioning effectively in college courses.

There seemed to be little relationship between the design features of the experiments and experimental outcomes. "Quasi-experimental and true experiments produced similar effects" (p. 538). The authors found that there was just one design variable that predicted study outcomes.

> Only one variable predicted study outcomes in our meta-analysis, and that was use of a design that controlled for instructor effects. In studies in which different teachers taught computer-based and conventional sections of a course, examination differences were more clear-cut and favored computer-based teaching. In studies in which a single teacher taught both experimental and control classes, differences were less pronounced. (p. 539)

In 1986 Kulik & Kulik undertook a new meta-analysis of studies on the effectiveness of computer-based education at the college level. This time there were 101 studies included in the meta-analysis. In this meta-analysis the effect size was computed by dividing the difference of the means by the standard deviation of the control group. They found that examination scores were an average of .26 standard deviations higher across the 101 studies for the computer-based group.

This is very nearly equal to the average effect size of .25 reported in the 1980 meta-analysis. A total of 99 out of the 101 studies reviewed reported results for both a computer-based education (CBE) group and a control group. There were 77 of these 99 studies that reported higher scores for the CBE group and 22 that reported higher scores for the control group. The difference in exam scores between CBE and control groups was significant in 22 studies, and it was significant in favor of the CBE group in 21 out of these 22 studies.

Kulik & Kulik (1986) found the following:

> The strongest positive result reported was an effect size of 2.17 standard deviations (Cartwright, Cartwright, & Robine, 1972); the strongest negative result was an effect size of -1.20 standard deviations (Diem, 1982). (pp. 88-93)

The authors felt that this variation in study outcome might be systematic. They made further analyses to determine whether different types of studies were actually producing different results. Three design features were found to be significantly related to the effect size reported. These features were (a) source of publication, (b) the extent to which the discipline studied emphasized scientific methodology, and (c) the extent to which the discipline emphasized life versus nonlife processes. This differs from what was found in the 1980 meta-analysis of computer-based college teaching in that the 1980 meta-analysis only found one variable predicted study outcome: the use of a design that controlled for teacher effects.

Regarding publication sources, it was found that the difference in effect sizes for professional journal versus dissertations and technical documents was significant at the .05 level. In the 41 journal studies reviewed the average effect size was .42, with a standard error of .08. For 46 dissertation studies the average effect size was .16 with a standard error of .07. For 12 technical reports the average effect size was .11 with a standard error of .14. However, it was found that the difference between dissertations and technical documents was not significant.

The average effect size from courses in the "hard" sciences was significantly lower than the average effect size for courses in the "soft" disciplines ($p<.04$). The authors found the following:

> The average ES in the 44 studies of CBE applications in the hard scientific disciplines was 0.15; it was 0.35 for the 55 studies of applications in the social sciences and humanities. The average ES from courses emphasizing life processes was also significantly higher than was the average ES from courses emphasizing nonlife content, $F(1,97) = 9.15$, $p<.01$. The average ES in the 22 studies of life courses was 0.54; it was 0.18 in the 77 studies of nonlife courses. The coding on these two dimensions of course content, however, was significantly correlated, $r=.29$, $p<.01$. (p.93)

To conclude the discussion of this meta-analysis, some additional observations made by Kulik et al. (1986) are provided. They did not find any significant difference in effectiveness across types of CBE implications. "CAI, CMI, and CEI [computer-enriched instruction] programs all made small, positive contributions to student learning" (p. 98). They noted that this differs strikingly from precollege findings on CBE. At the elementary level, CAI tutorials and drill-and-practice programs almost always produced good results, while CMI programs produce findings that are weaker. On the other hand, in high schools both CAI and CMI produced favorable results, while CEI programs seemed to contribute little to student achievement.

Clearly, not all postsecondary education takes place in colleges and universities with the traditional college cohort. Much postsecondary education occurs in nontraditional settings. This is also true for computer-based education. Thus, a natural extension of the meta-analyses done for CBE in colleges is the 1986 meta-analysis of computer-based adult education by Kulik, Kulik and Schwalb.

CBE Use in Adult Education

The same approach was used to screen studies for inclusion in the meta-analysis, and ultimately 24 studies were obtained for inclusion. These researchers again computed the effect sizes by dividing the difference between means by the standard deviation of the control group. They found that in 19 of 23 studies that reported examination scores for both a CBE and control group, the CBE group had the higher average. In only four of these 23 studies did the conventionally taught class have the higher average. Of the studies reviewed, the average effect size was .42 standard deviations (an average ES of 0.29 for CAI, 0.72 for CMI, and 1.13 for CEI). Thus, a typical learner in the CBE class would perform at the 66th percentile on an achievement test, while a typical learner in the conventionally taught class would perform at the 50th percentile on the same examination. This is a more positive improvement than found for college students in either the 1980 or 1986 meta-analyses (J. Kulik, et al. (1980); C.-L. Kulik et al. 1986).

As in the 1986 meta-analysis for college students, but to a lesser extent, there was quite a bit of variation in the effect sizes among the studies. The highest positive result was an effect size of 1.53 and the most negative result was an effect size of -.68. Thus, the authors did further analyses to determine whether this variation was systematic.

This time none of the study features were found to be significantly related to achievement effect size.

In their 1987 article, Kulik & Kulik reviewed the various meta-analyses of CBE. In one sense the Kulik & Kulik (1987) article is a review of reviews. In another sense, it is an attempt to obtain a broader perspective by not only looking back but by looking ahead to future questions and issues to resolve. Table 1 is taken from Kulik & Kulik's 1987 review. The table indicates that most of the studies reported that computer-based instruction had positive effects on students.

Table 1
Average Effect of CBE on Students in 199 Studies

Outcome measures	Number of studies	Average effect*
Final examination	199	0.31
Attitude towards instruction	17	0.28
Attitude towards computers	17	0.33
Attitude towards subject	29	0.05
Instructional time	28	68%

* The average effect is measured by the statistic ES for the following variables: final examination, attitudes towards computers, instruction, and subject matter. Savings in instructional time are measured in percentage of time saved (x/c).

The following excerpts from Kulik and Kulik (1987) convey a sense of past, present, and futur directions of CBE.

> The history of education is largely a story of gradual evolution, but education has also had it revolutions. The first use of writing as a tool in teaching transformed education many centuries ago when it freed teachers from the constraints of oral tradition. The invention of printing in the 15th century made books widely available and had a similarly dramatic effect on the history of education. Now, in the 20th century, the invention of the computer may have an equally profound impact on education. (p.222)

> Until recently the cost of computer-based teaching systems was too high for most schools. With the development of small, quick, inexpensive microcomputers during the last decade, computing costs have dropped dramatically, and a computer revolution in education now seems a real possibility. (p.222)
>
> Will such a revolution have a beneficial effect on education...or will it have negative effects? Most researchers believe that there is one straightforward way to answer this question. And that is to compare the performance of students who have learned with or without computer assistance. (p.222)
>
> The earlier revolutions in education ran their courses without the benefit of such studies. ...Earlier educational revolutions just happened-without measurement, prediction, or control. The computer revolution is different. It is occurring at a time when educators have tools for evaluating programs and tools for drawing general conclusions from a collection of evaluations. (p. 223)

The educational challenges presented by computers need to be and can be met with a thorough evaluation of CBE programs. The tools to make the necessary evaluations are available. The use of computers is an educational revolution that will not be allowed to just happen.

A finding reported by Kulik and Kulik (1987) in their review of the meta-analyses of research on computer-based instruction that has important consequences for future research is that random experiments and quasi-experiments produced the same results. Thus, if it is not possible to use random assignment of subjects to treatments, one may use intact classes without assuming that the validity has been compromised. Also, the effects of computer-enriched instruction (CEI) were found to be much greater in college and adult settings (moderate-sized effects) than for precollege settings (effects near zero). Computer-assisted instruction (CAI) has been a good deal more successful at the elementary and secondary levels, whereas CEI has been less successful at these levels. All forms of CBE: CAI, CMI, and CEI have been moderately successful at the college and adult levels.

In the various meta-analyses conducted since 1980, the evidence of the effectiveness has been consistent. The students using CBE have not only learned more, but they have done so in less time. Kulik and Kulik (1987) suggested that perhaps the findings of studies of computer-based instruction should be taken at face value. Doing so would not make the use of computers in education a closed matter. Rather, the authors suggested quite a number of research questions that would need to be addressed. For example, they suggested investigation of the question, "Are computer lessons equally effective when presented without electronic technology?" (p. 229). That is, if printed copies of computer lessons were used in place of having the lessons presented by the computer, would they be equally effective? What role does having control over the CAI lesson have on the effectiveness of the instruction? Gray (1988) studied this question. She compared the effects of sequence selection menus availiable to students who had control over their own sequence of instruction in a CAI program: Breadth/depth of menus and meaningfulness of menu category names. She found that meaningfulness affected comprehension. Groups with broad menus performed better on a retention measure, but not on a comprehension measure. Another question suggested by Kulik and Kulik focuses on the immediacy of the computer's response as the primary reason for the computer's effectiveness? Or in broader terms, "why has the computer helped students to the extent it has?" (p. 229). To answer such questions it is necessary to use process rather than outcome studies. What is exciting about these questions is that the tools exist to answer them. At the conclusion of this discussion of the meta-analyses that have been done to measure the effectiveness of CBE, it is necessary to consider Clark's 1985 critique of meta-analyses as well as the reply to Clark made by Kulik, Kulik and Bangert-Drowns (1985).

Possible Confounding of Meta-Analytic Results

The findings reported in the meta-analyses discussed above have been challenged. Clark (1985) took a 30% sample (the method of selection was not reported) of the computer-based instruction (CBI) studies that were meta-analyzed by Kulik et al. This sample was examined for evidence of confounding of the results of the meta-analyses. There are competing claims about the real contribution of the computer in CBI studies. "Some of these claims propose that the CBI effects are overestimated and others argue that CBI effects are underestimated" (Clark, 1985, p. 249). From his examination of his sample of studies, Clark concluded:

> The result of the analysis strongly suggests that achievement gains found in these CBI studies are overestimated and are actually due to the uncontrolled but robust instructional methods embedded in CBI treatments. It is argued that these methods may be delivered by other media with achievement gains comparable to those reported for computers. (p.249)

Thus, there is possible confounding of medium and method of instruction. But what is the nature of this confounding? Some argue that methods such as using examples and matched non-examples, individualized pacing, corrective feedback after response, etc. tend to be used in CBI lessons but not used in the classrooms in the comparison treatments. Therefore, one could argue that CBI effects are not as great as they appear. On the other hand, others argue that the confounding may be caused by teachers competing with the computers due to a sense of rivalry with a new technology. Thus, one could argue that true CBI effects are actually greater than they appear. Clark (1985) pointed out that at the college level, when the same instructor designs both the CBI and traditional treatments, the effect sizes are reduced to insignificant levels. Clark concluded that the evidence (from studies that used the same teacher for both control and CBI groups) in the meta-analysis reviews is only one indication of the primacy of instructional methods over media in influencing student achievement. That is, the apparent superiority of CBI over classroom instruction may be due to the considerable instructional design and development effort (compared to the development of typical classroom instruction) that goes into the creation of CBI programs, rather than to any intrinsic characteristics of the computer itself.

The effect on the validity of the meta-analyses depends on the nature of the confounding. The external validity of the meta-analyses is threatened by confounding due to method. On the other hand, their internal validity is threatened by confounding due to compensatory rivalry. Clark (1985) contended that it is not a question of whether or not the CBI research is confounded, but that "the disagreement involves the nature of the confounding" (p. 251). It was Clark's intention to determine the nature of the confounding. He selected a sample (in a manner not explained) of studies from among those included in the various meta-analyses by having two experienced researchers code the manifest features of each study. Clark was one of the two researchers. A meta-analysis was made of this selected sample. Clark concluded the following:

1. The effect size was estimated to be .49 which was similar to Kulik's.

2. In over half of the studies CBI groups received more instruction than the control groups.

3. In about 40% of the studies the same teacher taught both CBI and control groups. In these studies the revised effect size of CBI was .09 of a standard deviation.

4. "Instructional method was controlled in only half of the 30 studies analyzed. The revised CBI effect size in these more adequately controlled studies was an insignificant -.01" (p. 259).

5. The sample of 30 studies implies that only 5% of the meta-analytic studies have important achievement data favoring CBI instruction.

6. There is meager but compelling evidence for the "John Henry Effect" (compensatory rivalry) based on one study in which a control school having been sensitized by pretest scores and having done extra noncomputer drill-and-practice exercises, outperformed the CBI schools.

In their reply to Clark (1985), Kulik et al. (1985) made a number of points in defense of the findings on the effectiveness of computer-based instruction (CBI) reported in their meta-analyses. Kulik et al. asserted that "outcome studies are commonly understood to be the basic way of determining whether instructional innovations help or hurt students" (p. 381). Whatever shortcomings outcome studies may have, they are widely recognized as an appropriate means for determining the effects of instructional innovations.

The authors specifically responded to four criticisms by Clark: 1) confounding due to experimental expectations, 2) confounding due to novelty effects, 3) confounding due to editorial gatekeeping, and 4) experimental design influences. These points will be briefly presented here.

first, Clark's assertion that the positive effects of CBI may be due to experimental expectations conflicts with the great diversity of effects found in the meta-analyses. Wide variation in effect sizes were found for different types of CBI at various instructional levels. For example, CAI drill and practice and tutorials in elementary schools almost always produced good results, whereas computer-managed instruction (CMI) produced much weaker results at this level. On the other hand, it was found that at the high school or college level CMI had the most to contribute to instructional effectiveness from among CAI, BMI, and computer-enriched instruction (CEI). Experimental expectation refers to the possible unconscious effort on the part of the subjects in a study to strive to make the experiment work. Kulik et al. concluded that the variation in the findings indicates that factors other than experimental expectations are involved.

Second, the issue of novelty effects is present in any research setting. Clark suggested that much of the apparent effectiveness of CBI may be due to a novelty effect. Kulik et al. argued that the evidence of differential effectiveness of CAI, CMI, and CEI also conflicts with Clark's novelty hypothesis. While there is a reduction in the average effect size for long-term studies compared to short-term studies (decreasing from .34 standard deviations for short-term evaluations to .26 standard deviations for long-term evaluations), Kulik et al. found this difference was not statistically significant.

Third, Clark claimed that editorial gatekeeping results in the publication of journal articles that primarily report higher average effect sizes than those reported in dissertations. There is a significant difference between the average effect size for journal articles and average effect size for dissertations. However, this occurs in evaluation studies in many areas in addition to studies of CBI. There are alternatives to editorial gatekeeping to explain this difference. For example, journal studies are usually conducted by persons with more research experience than authors of dissertations. Authors of journal articles often have access to different resources than are available to dissertation authors. The authors of journal and dissertation studies also differ in their relationship to instructional developers. It is difficult to support Clark's hypothesis of editorial gatekeeping in face of these competing explainations.

Fourth, differences are found between one-instructor and two-instructor studies (there are smaller effect sizes when one teacher teaches both the experimental and control groups than when one teacher teaches the experimental group and another teaches the control group). Kulik et al. feel it is not at all obvious why this difference exists. They have offered some possible explanations. Perhaps the poorer instructor is usually assigned to teach the control group, and the better teacher assigned to teach the experimental group. If this is the case, then the difference between groups is magnified due to these teacher assignments. Thus, the conclusion would be that the one-teacher studies are more accurate. On the other hand, it may be that in a one-teacher design there is a diffusion of the innovative approach to the control condition. That is, due to involvement in the experimental instruction, the teacher teaches the control class better than otherwise would have been the case. If this is what happens, then the observed differences may be less than the true differences, and hence, the two-teacher design may provide the better basis for estimating the effect size.

Individual Studies

A number of individual studies have particular relevance to this study. Ortiz and MacGregor (1988) investigated whether there were significant differences in understanding the concept of variable among sixth-grade students (N = 89). LOGO graphics is a software package that uses a small triangular figure referred to as a turtle and programming commands that cause the turtle to move around the screen to draw figures. One group of students used a LOGO graphics approach while a second group used a textbook-based approach. A third group of students received no instruction on the concept of variable and served as a control group. An interesting result was that while there was no significant difference between computer and textbook-based groups on an immediate posttest, there was a significant difference ($p < .01$) between these two groups, favoring the LOGO group on a test three weeks after the treatment ceased. Ortiz and MacGregor (1988) feel that this may be due to

> the strength of the effect Logo computer programming activities have on students' understanding of the concept. The computer programming approach provided a mental model for teaching the concept of variable and one that appears more effective than the textbook-based approach used in this study. Logo graphics

> provided a way to visualize how changing the values of a variable in a procedure affects the graphic design drawn by the turtle. (p.20)

Liu (1975) used volunteers (N = 36 in Winter quarter and N = 14 in Spring quarter) from among the students enrolled in a college physics course to investigate opinions on each of the eight CAI lessons by means of a questionnaire. The students were asked for ways they felt the lessons could be improved or modified. Liu found that "an analysis of student comments and the responses to the questionnaires indicated that students, in general, reacted positively to the project" (p. 45). He also found that the more able students benefited more than the less able because the former group tended to study the CAI lessons more carefully. Similar results of better students benefiting more from CAI were reported in Hatfield (1969), Goodsen (1977), and Clark (1985). Clark pointed out that two of the studies included in his survey, Hatfield (1969) and Lang (1976), also found that "high-ability students profited from computer programming of math or physics principles whereas low-ability students had their learning depressed by the computer programming activity" (p. 257). On the other hand, Jamison, Suppes, and Wells (1974) and Deignan (1980) found just the opposite, namely, that the less able students benefited more. Thus it appears that who might benefit more depends on factors other than or in addition to a student's ability. Kulik et al. (1980) found that students of all ability levels benefited about equally from CBI. It appears that the question of who benefits the most according to ability level is not yet clearly understood.

Calculus Studies

In 1970, Holoien's dissertation study compared the effectiveness of using computer programming in a calculus course. Computer programming problems were assigned to the experimental group for homework. This early study operated under what may now appear to be very primitive conditions. Students had to submit their computer programs in handwritten form on paper. A professional keypunch operator would then punch the student's programs onto cards. The programs would be run and computer printouts containing the student program commands as well as the generated output would be returned to the students the day after the programs were submitted!

Holoien used an interesting research design. There were four classes participating in his study. Two of them met at eight o'clock in the morning and the other two met at noon. Two instructors participated in the study, each teaching an experimental class and a control class. Teacher A taught the morning experimental class and taught the noon control class, while the order was reversed for teacher B. Holoien found no significant differences between the two morning classes (one experimental, the other control) nor between the two noon classes. However, there was a significant difference between the morning control class and noon experimental class (taught by teacher B). Using a t test, an observed t value of 1.72 was found. The corresponding critical t value was 1.70. However, for teacher A (morning experimental class and noon control) the observed t value was negative ($t = -1.04$). This appears to be an indication of a teacher effect.

Another early comparative study in calculus was done by DeBoer (1973). The computer was used to supplement the instruction in an introductory calculus course for engineering students at Vanderbilt University (N=22 in experimental group and N=22 in control group). The experimental treatment consisted of assigning six computer programs to be created, run, and submitted by the students. DeBoer points out that pre-registration materials made students aware that the experimental section was to be computer oriented. Thus, there is a possibility that results may be confounded due to self-selection by the students. DeBoer reported no significant differences between groups on outcome measures.

Marshman (1985) studied the use of interactive computerized teaching in advanced calculus, (i.e., the second year of calculus). She used a design in which one group spent two hours in place of going to class using the computer for instruction, while a second group received instruction in class over two hours. Marshman obtained her two groups from within a single class by matching groups based on their previous calculus grades. Thus only one instructor was involved. The study was replicated two additional times. Each time it was found that there were no significant differences between the CAI and non-CAI groups in the performance on a posttest.

College Algebra and Precalculus Studies

It is desirable to narrow the focus to the limited number of studies in college-level algebra or precalculus since this study deals with the use of CAI in a college algebra course. An early study of the use of CAI tutorials in college or high school algebra was done by Ziegler (1972) for her dissertation. This study did not use interactive terminals. Of course, microcomputers were not available at the time of her study. The computer was primarily used to customize homework sheets for students based on their performance on earlier homework sheets. A student's progress was otherwise controlled by the teacher. This was an application of computer-managed instruction, which is not the focus of this study.

In 1976 Bickerstaff's dissertation study investigated the effect of CAI drill and practice used for homework credit on both achievement and attitudes in a college-level intermediate algebra course. It was asumed that the 113 students in the study typified remedial algebra students in U.S. universities. Three modes were used in assigning homework. One group did all of its assignments by working specified exercises from the textbook. Another group completed corresponding exercises on the computer. The third group was assigned a prescribed combination of problems from the text and on the computer. Using an examination covering the content of the homework after the three-week period of the study, with covariates of ACT mathematics and English scores, scores on a pretest of arithmetic skills (which was not the subject of the homework used in the study), and total homework scores, Bickerstaff found no statistically significant difference in achievement between the three groups.

Diem completed a dissertation in 1982 on the effectiveness of CAI in a college algebra course at Florida Atlantic University. In concluding his review of the literature Diem made the appraisal that "it is apparent that development and evaluation of micro-computer software on a modular basis is a priority item in college level CAI" (p. 19).

He used four groups of students in his study from among those who were enrolled in the College Algebra course. The majority of students in his sample were in their junior or senior year because many of them were transfer students with a junior college background. One group (N=14) was given the traditional classroom instruction followed by textbook homework. A second group (N=14) studied with a computer tutorial program followed by textbook homework. A third group (N=14) received the ususal classroom instruction followed by the use of a computer drill and practice program. The fourth group (N=11) used both the computer tutorial and the computer drill-and-practice program. The math topic used in his study was linear inequalities.

While he did not find any significant differences between groups on a posttest, as was mentioned earlier in the discussion of the meta-analyses, he found a fairly large negative effect size. Specifically, he found that both of the groups using the computer tutorial did not do as well as the two groups that received the traditional classroom instruction. However, this outcome may have resulted from the confounding effect produced by the use of a substitute teacher during the period of the experiment in the two sections that used the computer tutorial. Diem (1982) took note of this possibility. He also recommended that the experiment be replicated using either a similar or an alternative population and that student background in mathematics be considered as a variable when comparing achievement levels.

In their 1984 study, Wenger and Brooks investigated some of the diagnostic uses of computers in precalculus. This was not a comparative study but rather an investigation into the possible diagnostic functions of computers. The topic of algebra is difficult for many students. In their efforts to make sense of the subject students formulate their own rules and procedures for doing problems. Often these student-generated rules or procedures are incorrect. For example, very early in a typical algebra course, at any level, the students are presented with what is known as the distributive properties: $a(b + c) = ab + ac$ and $(b + c)a = ba + ca$. These are valid ways to eliminate the parentheses in such expressions. However, many students attempt to apply a similar procedure to eliminate the parentheses in which exponentiation is involved. For example, $(b + c)^2 = b^2 + c^2$. Unfortunately, this is not a valid procedure since $(b + c)^2 = b^2 + 2bc + c^2$. Much more needs to be done to investigate the uses of computers to perform diagnostic functions. Intelligent tutors (see the history section in chapter I) do have some diagnostic capabilities.

In a study conducted by Graff (1987) on the use of computers as an aid to instruction for adults in introductory and intermediate algebra at Red Deer College, it was found that the groups that utilized computers made greater improvement between the pretest and posttest than students in the control classes. Graff reported that there was a total of approximately 160 students in the seven mathematics classes, with 20 to 35 in each class. In both the introductory and the intermediate algebra courses, he found that the computer groups had increases that were twice as large as the increases for the corresponding control groups. Graff's report was very brief and did not contain many of the statistics usually reported in such studies.

Summary

The instructional use of computers has approximately a 30-year history. The early uses of computers for instruction required huge main-frame computers and used methods of B.F. Skinner to deliver the instruction. Over the past three decades both the size of computers and their costs have shrunk dramatically, and the CBI programs are founded on a much broader base of learning theory, with efforts in the field of artificial intelligence (AI) moving us closer to the day when computers may be able to interact with students much as a human tutor would. The body of research in the use of CBI in a college algebra course, particularly those using microcomputers, is limited. The research results are mixed, with some studies reporting outcomes favoring CBI over traditional classroom teaching and other studies reporting outcomes favoring traditional classroom teaching over CBI. Thus, this study is directed towards adding to the knowledge of how microcomputers can be used to assist in instruction in such a course.

CHAPTER III

METHODOLOGY

Overview

Based on the literature review, the following hypotheses are the focus of this study.

Hypothesis 1. For each of two instructors, the students in their CAI class will do as well as or better than those in their control class on a posttest covering the topics in this study.

Hypothesis 2. As a group, the two CAI classes will do as well as or better than the two control classes as a group on a posttest covering the topics of this study.

Hypothesis 3. For each of two instructors, the students in their CAI class will do as well as or better than those in their control class on a delayed posttest, embedded in the final exam, covering the topics in this study.

Hypothesis 4. As a group, the two CAI classes will do as well as or better than the two control classes as a group on a delayed posttest, embedded in the final exam, covering the topics of this study.

Design of the Study

After a review of a number of tutorial software packages for College Algebra/ Precalculus, the software from Addison-Wesley was chosen because it covers the content thoroughly, and because the microcomputer lessons are based on sound pedagogy. The software is very user-friendly. That is, the programs are designed to make it very easy for the typical college student to use the software. Single keystroke commands are used to select options and to load a particular lesson. Finally, an attractive feature of this software was its very reasonable price. (The institutional price for the Intermediate Algebra disk, two backup disks, and documentation cost about $45.) Other software packages were rejected because they were designed for children, did not cover the appropriate topics, or did not present the math well.

The following procedures were used. A test of the software was conducted during the 1987 summer session to establish the validity and reliability of the software. A pilot study of both the software and the measurement instrument was conducted during the fall 1987 semester to establish the validity and reliability of the measurement instruments. The study itself was conducted during the Spring 1988 semester to compare the effectiveness of computer-assisted instruction (CAI) with the usual classroom instruction. All phases of this study were conducted at the University of North Carolina at Greensboro (UNCG) using one or more sections of the Introductory College Algebra course (Mathematics 119).

Test of Software

During the second summer session in 1987, the researcher attempted to conduct a test-run of the Addison-Wesley software in the College Algebra course being taught. The purpose was to determine the suitability of the computer modules on multiplying and dividing complex numbers, identifying the vertex and line of symmetry of a parabola, and solving systems of linear equations by the addition method for use in the study. Just one section of Math 119 was needed to assess the validity and reliability of the software. All of the students (N=40) were asked to study each tutorial after the topic had been briefly introduced in class. This was desirable under the circumstances since the software content validity and reliability were being tested.

However, an introduction to each CAI topic in class was not needed during the actual study. Some logistical difficulties surfaced as a result of the summer session schedule. The Apple computer lab, containing 12 Apple II computers, was not opened until the middle of the session. The lab is located in a different building from the one in which the course was taught. The delayed opening of the lab, combined with the rapid rate at which material is covered in a summer session course, caused the CAI topics to be bunched together. In the case of the tutorials on complex numbers, the introduction to complex numbers had to be delayed until the lab opened.

A CAI tutorial on systems of linear equations was included in this summer course. However, the unit on systems of linear equations is the very last topic in the syllabus. It would be difficult to make an accurate comparison on this topic because the instructor typically runs out of time toward the end of the course and does not cover it. Therefore, this unit was deleted from the study. The CAI unit on parabolas had several aspects not covered in the text; thus, either additional material would have to be inserted in the classroom lectures in the control classes or these aspects would have to be omitted from the pretest and posttest. Thus, the CAI topic of parabolas was deleted.

The three topics that were choosen for the actual study are as follows: 1) A lesson on complex numbers consisted of two modules. The first module dealt with the multiplication of complex numbers, and the second dealt with the division of complex numbers. The concepts of imaginary unit, complex conjugate, and the addition and subtraction of complex numbers were subsumed in both modules.

2) A second lesson was on completing the square. This lesson consisted of a single module which presented completing the square in the context of algebraic expressions. [Note: The use of completing the square to solve quadratic equations was not presented in this module. This deficit in the software was compensated for by written notes, examples, and exercises prepared by the researcher to equate the content on completing the square for both the experimental and control groups. (See Appendix A). It was felt that this was the ethical thing to do to prevent the students in the CAI sections from missing instruction in this application of completing the square. However, the pretest and posttest did not include solving quadratic equations by means of completing the square.]

3) The third topic was a lesson on solving linear equations. It consisted of two modules, the first of which dealt with solving elementary linear equations. The second module dealt with solving linear equations that contained either one set of parentheses or a set of parentheses on each side of the equation.

Results of the Study of the Software

To complete the software validation, each student responded to a questionnaire (see Appendix B for a copy of this instrument) either while studying the tutorial or as soon afterwards as possible. Nearly all students reported that the software was understandable and that the quizzes that accompanied each tutorial seemed fair in that they correlated well with the instruction provided by the computer tutorial. A report on the less favorable evaluations by topic follows.

For the unit on complex numbers three students indicated that it took a while to learn the response format required by the software. One student felt it took much more time than expected, and only one student indicated a strong negative response. The essence of this negative response was that the student felt the CAI lesson was a waste of time and that it would have taken less time to present the concepts in class.

For the unit on parabolas, one student indicated a problem in understanding the way questions were posed. One student felt that the sequencing of the presentation could have been improved. A third student indicated a strong negative response. Again the complaint was that the program was a waste of time and could be done better in class. It is likely that the strong negative responses for the first two topics were submitted by the same student. For the unit on solving systems of linear equations there were no adverse student comments.

Overall, only three students out of 40 had any negative comments to make on any one topic. For one topic there were no negative reactions. This was a very positive response pattern, especially considering the less than desirable conditions that prevailed. Since the CAI lessons used were well received by the students (based on the responses to the questionnaire), the software package appeared to have face validity and was judged suitable for use in the study.

Sample Selection For the Pilot Study

The purpose of this pilot study was to establish the validity and reliability of the measuring instruments, i.e., a pretest and a posttest. In addition, the validity and reliability of the software were further investigated due to the replacement of two of the original topics with two others, as indicated in the previous section.

This pilot study differed in design from the study itself. In this pilot study only one section of College Algebra taught by the researcher was used, with approximately half of the students receiving instruction on the revised three topics via CAI instead of classroom instruction, with the rest of the students remaining in class for instruction. (N=40, with 18 students receiving the CAI and 22 receiving classroom instruction). The pilot study took place during the Fall 1987 semester with a College Algebra class at the University of North Carolina at Greensboro (UNCG). A diagnostic test was given on the third day of the semester, after the enrollment stabilized. This test included questions on each of the three topics to be covered later on the computer, as well as a number of other basic topics (See Appendix C for a copy of the diagnostic test). The questions on this pretest that pertain to the CAI topics are marked with an asterisk.

On the fifth day of class students drew numbered chits from a bag. The chits were marked with a "1" or a "2", and the students were unaware of which number would denote the CAI group while the numbers were being drawn. Two students who fell into the CAI group could not participate due to schedule conflicts. One student didn't wish to be in the CAI group and was removed from that group and put in the control group.

A set of instructions on how to load the disk was given to each student in the CAI group. Included were detailed directions on how to select the options necessary to view the required tutorials. (See Appendix D for a copy of these directions.) Each student was asked to complete a questionnaire while they worked on a tutorial, or as soon afterward as possible. (See Appendix B for a copy of the questionnaire.)

A pre/posttest was prepared for the topics of multiplying and dividing complex numbers, solving both elementary linear equations and those with parentheses, and completing the square in an algebraic expression for use in this pilot study. Seven specific objectives were identified and the pre/posttest tested for each objective in three formats: multiple choice, true/false, and fill-in-the-blank questions. Thus there were 21 questions on the measurement instrument.

The 7 objectives were to 1) compute the product of two complex numbers, 2) compute the quotient of two complex numbers, 3) solve a simple linear equation of the form $ax=b$ or $ax+b=c$ or $ax+b=cx+d$, 4) solve linear equations containing parentheses, 5) identify the necessary third term in an expression like $x^2 + bx$ to make a perfect square, 6) identify the two terms needed to be inserted in the parentheses in a problem of the form $(x^2 + bx \qquad) + c$ for the first step in completing the square, and 7) express a trinomial square $x \ + bx + c$ in the form $(x \ + d)^2$.

A first draft of questions was reviewed by both instructors who were to participate in the study, as well as two additional instructors. These four instructors constituted a panel of experts. Some helpful suggestions were made to improve some of the questions. A second draft of the questions that incorporated the suggested changes was developed and reviewed by the same instructors. No further modifications were suggested by the instructors.

The reliability of a content-driven test is determined by the clarity of the questions. Thus, to establish the reliability of the measurement instrument four students were selected from a section of Math 119 being taught by the researcher during the Fall 1987 semester and were asked to take the test. They were instructed to evaluate each question carefully for clarity. Immediately after each student completed the test, they were asked for their comments and suggestions in an interview. A number of changes in wording were suggested. Any suggested change was written on the student's test paper next to the question to which the change pertained. A third draft of the test incorporated the changes suggested by the students. Thus, the reliability of the test was strengthened. (The final revised pretest may be found in Appendix E).

Description of the Setting for the Study

The study was done during the Spring 1987 semester at UNCG. The university enrolled nearly 8,000 undergraduates and 2,700 graduate students in the Fall of 1987. UNCG offers doctoral degrees in 13 areas, including Psychology, English, Education and Music. Greensboro is a metropolitian area consisting of approximately 170,000 people, and there are six other colleges and universities in the community. The UNCG Math Department consists of 22 full-time faculty members, plus 10 part-time faculty members. Math 119, the course that is the subject of this study, is required only by the Department of Clothing and Textiles. However, the following majors require calculus: business and marketing, teacher education, physics, business and economics, math, chemistry, finance, and management. Many students in the above majors take Math 119 to prepare themselves for calculus. The purpose of the study was to determine the effectiveness of CAI in College Algebra compared to classroom instruction.

Two instructors, each teaching two sections of College Algebra, were involved in the research. The researcher was acquainted with each instructor. They had taught the college algebra course used in the study at least several times in the past three years. The researcher presented an outline of the study to each instructor and invited each to participate. Both instructors accepted the invitation and expressed interest in taking part in the study. The instructors were designated as "1" or "2", intructor 1's sections as A & B, and instructor 2's sections as C & D. One of the sections for each instructor received instruction via CAI on the topics of the study-(1) multiplication and division of complex numbers, 2) completing the square, and 3) solving linear equations), and the other section served as a control group, receiving the usual classroom instruction throughout the semester.

Figure 1
<u>Visual representation of the components of the study</u>

	Instructor 1	Instructor 2
Sections	A (CAI)	C (CAI)
	B (control)	D (control)

Three of the sections met on a Monday-Wednesday-Friday (M-W-F) schedule for 50 minutes and the fourth section met on a Tuesday-Thursday (T-Th) schedule for 75 minutes. One instructor taught (M-W-F) sections at 9:00 a.m. and noon. Her noon section was one of the experimental groups and her 9:00 a.m. class was one of the control sections. The other instructor taught a (M-W-F) class at 8:00 a.m. and a (T-Th) class at 11:00 a.m. Her 8:00 a.m. section was the other experimental section and her 11:00 a.m. class was the other control class.

At the beginning of the semester all sections had at least 40 students, the maximum number allowed. By the end of the semester, due to attrition, the sections of Math 119 involved in this study contained between 22 and 30 students. Due to incomplete test scores for some students, it was necessary to omit them from the study. There were one case in the 8:00 a.m. CAI class, three cases in the 9:00 a.m. control section, two cases in the noon CAI class, and no cases in the 11:00 a.m. control class for which there were incomplete data. This resulted in two sections each having 21 students in them. By means of a random number table, subjects were deleted from the other two larger sections so as to have an equal number of subjects in each section. Six students were removed from the (T-Th) control section and 7 students were removed from the 9:00 a.m. control section. This was done to insure orthogonality. In the four sections of 21 students, the number of freshmen ranged from 14 to 18. The number of female students ranged from 9 to 15.

Table 2
Overall Population Profile for the Study

Section	Frosh	Soph	Jr	Senior	SA	Male	Female
8 am	18	2	0	0	1	6	15
9 am	17	3	0	1	0	7	14
11 am	14	6	0	1	0	11	10
noon	15	5	0	1	0	12	9

Note: The designation SA denotes a special admissions student.

Data Collection Procedures

The following data collection procedures were undertaken in this study. Since the first CAI topic, complex numbers, does not occur until the third week, it seemed reasonable to wait until the first day of the second week to give the pretest on the three CAI topics. By that time, the enrollments in the sections were stabilized.

The details of the CAI materials were explained to the two experimental sections following the pretest. At the appropriate time the students in the experimental sections were excused from class for two days and were expected to complete the assigned computer tutorials during this time.

The students in sections B & D, the control sections, studied the same topics in class at the corresponding times. A list of the names of the students in Sections A & C were kept in the CAI lab. Only these students were allowed to use the software for the course. This prevented the control group members from receiving double instruction on these three topics.

The researcher was present in the computer lab during the time periods when the students in the treatment group were scheduled to use the software. Assistance therefore, was available to the students, as needed.

Students in the experimental sections were excused from two consecutive one-hour classes (a Wednesday and a Friday) and signed up in advance for two hours of CAI to be done in place of classroom instruction. They were allowed to choose the two hours from designated blocks of time. A posttest was given immediately on these topics during the next class meeting. This posttest was a parallel version of the pretest. (See Appendix F for a copy of the posttest). A delayed posttest of the CAI topics was included in the final exam for the course. The version used as the pretest was also used for the delayed posttest. Approximately three months separated the pretest and delayed posttest.

In summary, the sources of data are the following:

a) scores on a pretest covering the three topics of this study (see Appendix E),

b) scores on a posttest (parallel version) covering the three topics of this study immediately after the treatment period (see Appendix F), and

c) scores on a delayed posttest (the pretest was used for this purpose) covering the three topics of this study.

Hypotheses and Statistical Approach of the Study

Hypothesis 1. For each of two instructors, the students in their C.A.I. class will do as well as or better than those in their control class on a posttest covering the topics in this study.

The analysis used to test this hypothesis utilized two one-way ANOVAS.

Hypothesis 2. As a group, the two C.A.I. classes will do as well as or better than the two control classes as a group on a posttest covering the topics of this study.

The analysis used to test this hypothesis utilized a single two-way ANOVA.

Hypothesis 3. For each of two instructors, the students in their C.A.I. class will do as well as or better than those in their control class on a delayed posttest, embedded in the final exam, covering the topics in this study.

The analysis used to test this hypothesis utilized two one-way ANOVAS.

Hypothesis 4. As a group, the two C.A.I. classes will do as well as or better than the two control classes as a group on a delayed posttest, embedded in the final exam, covering the topics of this study.

The analysis used to test this hypothesis utilized one two-way ANOVA.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

Description of Groups

In this chapter the results of the analysis of the pretest and posttest scores will be presented as they relate to the hypotheses. The following tables give the descriptive results for the groups on the pretest, posttest, and delayed posttest, respectively. The maximum score was 21.

Table 3
Descriptive Profile of the Research Population on the Pretest

Group	1 CAI 8 am	2 Control 9 am	3 CAI noon	4 Control 11 am
N	21	21	21	21
mean	10.9524	12.4762	11.6190	12.2857
sd	4.1167	2.5811	2.8014	3.3933

Table 4
Descriptive Profile of the Research Population on the Posttest

Group	1 CAI 8 am	2 Control 9 am	3 CAI noon	4 Control 11 am
N	21	21	21	21
mean	19.3810	17.8095	18.4762	20.0476
sd	2.8892	3.4874	2.3156	1.2440

Table 5
Descriptive Profile of the
Research Population on the Delayed Posttest

Group	1 CAI 8 am	2 Control 9 am	3 CAI noon	4 Control 11 am
N	21	21	21	21
mean	18.4762	17.4762	18.7143	19.2857
sd	2.9261	3.0269	2.2615	2.2615

The data in these three tables indicate a fairly consistent pattern. As would be expected, all groups showed improvement in mean scores from pretest to posttest, with a comparatively much smaller change downward in mean scores from posttest to delayed posttest. Only group 3, the noon CAI section, showed a small increase in mean scores from the posttest to the delayed posttest.

Two of the groups had approximately three times as many females as males in them (groups 1 and 2), while one group (group 4) had nearly equal numbers of males and females, and one group (group 3) had slightly more males than females.

Table 6
Gender Composition of the Groups

Group	1 CAI 8 am	2 Control 9 am	3 CAI noon	4 Control 11 am
Female	16	15	9	10
Male	5	6	12	11

Initial Group Equivalence

It is necessary to check for equivalence of the four groups (the two CAI sections and the two control sections) on prior knowledge of the topics of the study on the pretest. The equivalence of groups was tested by using effect coding, multiple regression, and Dunn's procedure. The 8:00 a.m. CAI class was designated as group 1, the 9:00 a.m. control class was designated as group 2, the noon CAI class was designated as group 3, and the 11:00 a.m. control class was designated as group 4, which served as the 'control' group for the effect coding. Groups 1 and 4 were taught by one instructor, and groups 2 and 3 were taught by the other instructor.

From the regression analysis it was found that the mean squares due to regression was 10.07937 and mean squares due to residuals was 10.74286. Thus, F = .93824 and signif F = .4262 (signif F refers to the probability of the obtained F value). Since the probability of obtaining an F value of .93824 is greater than .05, there are no significant differences among the means on the pretest for groups 1, 2, 3, and 4 at the alpha = .05 level. Thus, the four groups on the study were comparable on prior knowledge on the topics of the study. Table 7 presents a summary of the regression analysis.

Table 7
Regression Analysis

Multiple R	.18436		
R Square	.03399	R Square Change	.03399
Adjusted R Square	-.00224	F Change	.93824
Standard Error	3.27763	Signif F Change	.4263

Analysis of Variance

	DF	Sum of Sqs	Mean Sq
Regression	3	30.23810	10.07937
Residual	80	859.42857	10.74286

F = .93824 Signif F = .4262

Results for the posttest

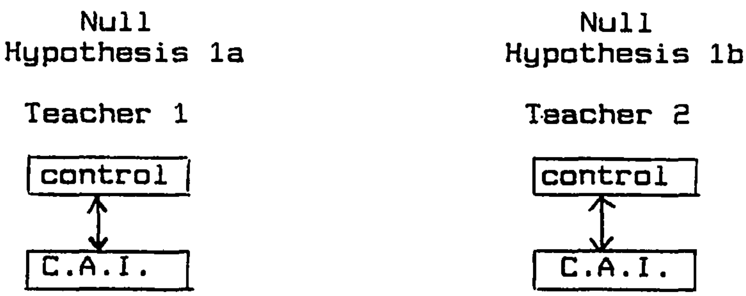
Hypothesis 1. For each of two instructors, the students in their CAI class will do as well as or better than those in their control class on a posttest covering the topics in this study. This research hypothesis can be divided into two null hypotheses.

Null Hypothesis 1a. For teacher 1 there will be no significant difference between her CAI class and her control class on the posttest.

Null Hypothesis 1b. For teacher 2 there will be no significant difference between her CAI class and her control class on the posttest.

Figure 2 illustrates the groups being compared in each null hypothesis.

Figure 2
A Diagram of the Groups Being Compared
In the Test of Null hypotheses 1a and 1b



A one-way analysis of variance was done after selecting the data for the instructor who taught groups 1 and 4, 8:00 am Monday-Wednesday-Friday, and 11:00 am Tuesday-Thursday, respectively. A variable GROUP was defined to equal 1 for each of the control sections, and equal 2 for each of the CAI sections. The ANOVA was done for posttest scores by GROUP. Thus there were 2 sections and 42 cases; 21 in a control group and 21 in the corresponding CAI group. For alpha = .05 the critical F value is F(1 ,42) = 4.07. The F value computed for the test for a significant difference between this instructor's control and CAI sections was .943, having a probability of .337 (as is shown in Table 8) and thus at the alpha = .05 level, Null Hypothesis 1a may be retained.

Table 8
ANOVA of Posttest Scores by Groups For Instructor One

Source of variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main effects	4.667	1	4.667	.943	.337
GROUP	4.667	1	4.667	.943	.337
Explained	4.667	1	4.667	.943	.337
Residual	197.905	40	4.948		
Total	202.571	41	4.941		

A one way ANOVA was also done for instructor 2 after selecting groups 2 and 3, the 9:00 am and noon Monday-Wednesday-Friday sections, respectively. No significant difference was found since F = .533 (p = .470) is less than the critical F-value of 4.07. Table 9 shows that Null Hypothesis 1b may also be retained at the alpha = .05 level.

Table 9
ANOVA of Posttest Scores by Groups For Instructor Two

Source of variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main effects	4.667	1	4.667	.533	.470
GROUP	4.667	1	4.667	.533	.470
Explained	4.667	1	4.667	.533	.470
Residual	350.476	40	8.762		
Total	355.143	41	8.662		

In order to determine the appropriate statistical analysis to test Null Hypothesis 2, it is necessary to test for significant differences between means on the posttest for the two CAI groups, and for the two control groups.

Analysis of the CAI Groups on the Posttest

An anlysis of variance was made on the posttest by teacher for the two CAI groups. Table 10 presents the results of that analysis. From Table 10 it can be seen that there was no significant difference between the two CAI groups. The observed F value was 1.254 having a probability of .269 which is greater than an alpha of .05. This is to be expected since the students in both of the CAI groups received their instruction from the same source, the computer, with assistance from the researcher. The influence of the two classroom teachers was limited to preparing their students for doing CAI and interactions in the classroom subsequent to the computer-assisted instruction.

Table 10
ANOVA on Posttest by Instructor For the CAI Groups

Source of variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main effects	8.595	1	8.595	1.254	.269
TCH*	8.595	1	8.595	1.254	.269
Explained	8.595	1	8.595	1.254	.269
Residual	274.190	40	6.855		
Total	282.786	41	6.897		

* TCH is the Teacher variable

Analysis of the Control Groups on the Posttest

An analysis of variance was done on the posttest scores by teacher for the two control groups. Table 11 presents the results of that analysis. There is clearly a significant difference between the means of the two control groups ($p < 0.008$). This could be due to a teacher effect or some other variable not controlled for in the study. An F value of 7.673 was observed, having a probability of .008, which indicates a significant difference at the alpha = .05 level.

Table 11
ANOVA on Posttest by Instructor For the Control Groups

Source of variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main effects	52.595	1	52.595	7.673	.008
TCH**	52.595	1	52.595	7.673*	.008
Explained	52.595	1	52.595	7.673	.008
Residual	274.190	40	6.855		
Total	326.786	41	7.970		

* Significant at the .05 level
** TCH is the Teacher variable

Due to the significant difference found between the control groups it is necessary to use an analysis of covariance in testing Hypothesis 2.

Testing Hypothesis 2

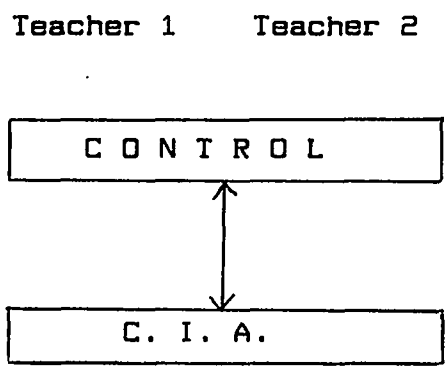
The essence of this study is the comparison of two modes of instruction, computer-assisted instruction and the usual classroom instruction. Hypothesis 2 (together with Hypothesis 4) is at the heart of making that comparison.

Hypothesis 2. As a group, the two experimental, C.A.I., classes will do as well as or better than the two control classes as a group on a posttest covering the topics of this study. The corresponding null hypothesis is the following:

Null Hypothesis 2. There is no significant difference between the two CAI classes as a group and the two control classes as a group on a posttest covering the topics of this study.

Figure 3 illustrates the groups being compared in testing Null Hypothesis 2.

Figure 3
A Diagram of the Groups Being Compared
In the Test of Null Hypothesis 2



To test this null hypothesis an analysis of covariance was conducted on the posttest scores by group, with teacher as the covariate. The results of this analysis is provided in table 12. Since an observed F value for groups of .000 has a probability of 1.00, Null Hypothesis 2 may be retained.

Table 12
Analysis of Covariance of Posttest Scores by Group with Teacher as the Covariate

Source of variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main effects	51.857	2	25.929	3.766	.027
GROUP	.000	1	.000	.000	1.00
TCH * (Covar)	51.857	1	51.857	7.532	.007
Explained	51.857	2	25.929	3.766	.027
Residual	557.714	81	6.855		
Total	609.571	83	7.344		

* TCH is the teacher variable

The total population mean on the posttest, for all four groups, was 18.93, with a maximum score of 21. Coincidentally, it happened that the mean on the posttest for the two control classes combined and for the two CAI classes combined were also each equal to 18.93. This is why there are the zero values in the Main Effects row for GROUP in Table 12 above. One normally expects to see some differences when comparing groups, so this result was unexpected.

Results for the Delayed Posttest

Hypothesis 3. For each of two instructors, the students in their CAI class will do as well as or better than those in their control class on a delayed posttest, embedded in the final exam, covering the topics in this study.

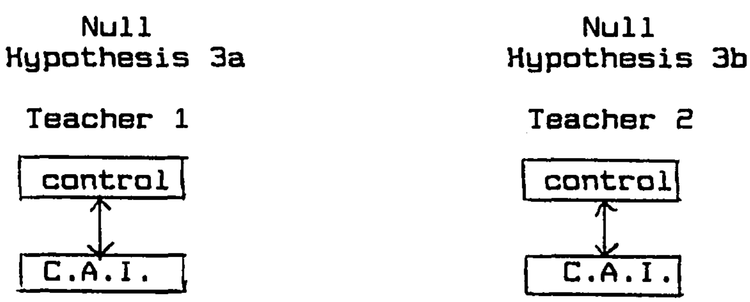
This research hypothesis can be divided into two null hypotheses:

Null Hypothesis 3a. For teacher 1 there will be no significant difference between her CAI class and her control class on the delayed posttest.

Null Hypothesis 3b. For teacher 2 there will be no significant difference between her CAI class and her control class on the delayed posttest.

Figure 4 illustrates which groups are being compared in the test of Null Hypotheses 3a and 3b.

Figure 4
A Diagram of the Groups Being Compared
In the Test of Null hypotheses 3a and 3b



One instructor taught groups 1 and 4, 8:00 a.m. Monday-Wednesday-Friday (M-W-F) and 11:00 a.m. Tuesday-Thursday (T-Th), respectively. Using the same procedure employed to test Null Hypothesis 1a, a one-way analysis of variance was completed after selecting the data for the instructor of these sections to test Null Hypothesis 3a. A variable GROUP was defined to equal 1 for each of the control sections, and equal 2 for each of the CAI sections. The ANOVA was done for delayed posttest scores by GROUP. Thus there were 2 sections and 42 cases: 21 in a control group and 21 in the corresponding CAI group. For alpha = .05 the critical F-value is F(1, 42)= 4.07. The F value computed for the test for a significant difference between this instructor's control and CAI sections was 1.006, having a probability of .322. Thus, Null Hypothesis 3a may be retained.

Table 13
<u>ANOVA of Delayed Posttest Scores by Groups For Instructor One</u>

Source of variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main effects	6.881	1	6.881	1.006	.322
GROUP	6.881	1	6.881	1.006	.322
Explained	6.881	1	6.881	1.006	.322
Residual	273.524	40	6.838		
Total	280.405	41	6.839		

A one-way ANOVA was also done for the other instructor after selecting groups 2 and 3, the 9:00 a.m. and noon M-W-F sections, respectively, to test Null Hypothesis 3b. No significant difference was found since F = 2.255 (p = .141) is less than the critical F value of 4.07. Thus Null Hypothesis 3b may be retained.

Table 14
ANOVA of Delayed Posttest Scores
by Groups For Instructor Two

Source of variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main effects	16.095	1	16.095	2.255	.141
GROUP	16.095	1	16.095	2.255	.141
Explained	16.095	1	16.095	2.255	.141
Residual	285.524	40	7.138		
Total	301.619	41	7.357		

To determine the appropriate statistical procedure to test Null Hypothesis 4 it is necessary to test for a significant difference between means on the delayed posttest for the two CAI groups, and for the two control groups.

Analysis of the CAI Groups On the Delayed Posttest

An analysis of variance was made on the delayed posttest by teacher for the two CAI groups. Table 15 presents the results of that analysis. Since the observed F value of .087 has a probability of .769, from Table 15 it can be seen that there was no significant difference between the two CAI groups.

Table 15
<u>ANOVA on Delayed Posttest by Teacher For the CAI Groups</u>

Source of variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main effects	.595	1	.595	.087	.769
TCH*	.595	1	.595	.087	.769
Explained	.595	1	.595	.087	.769
Residual	273.524	40	6.838		
Total	274.119	41	6.686		

* TCH is the Teacher variable

Analysis of the Control Groups On the Delayed Posttest

An analysis of variance was done on the delayed posttest scores by teacher for the two control groups. Table 16 presents the results of that analysis. There is clearly a significant difference between the means for the control groups since the observed F value of 4.817 has a probability of 0.034 which is less than an alpha of .05. The possible reasons for the significant differences found between the control groups on the posttest and on the delayed posttest will be explored in Chapter 5.

Table 16
ANOVA on Delayed Posttest by Teacher For the Control Groups

Source of variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main effects	34.381	1	34.381	4.817	.034
TCH**	34.381	1	34.381	4.817*	.034
Explained	34.381	1	34.381	4.817	.034
Residual	285.524	40	7.138		
Total	319.905	41	7.803		

* Significant at the .05 level
** TCH is the Teacher variable

Due to the significant difference found between the control groups it is necessary to use an analysis of covariance in testing Hypothesis 4.

Testing Hypothesis 4

Hypothesis 4. As a group, the two experimental, CAI, classes will do as well as or better than the two control classes as a group on a delayed posttest, embedded in the final exam, covering the topics of this study. The corresponding null hypothesis is the following:

Null Hypothesis 4. There is no significant difference between the two CAI classes as a group and the two control classes as a group on a delayed posttest, embedded in the final exam, covering the topics of this study.

Figure 5 illustrates the groups being compared in testing Null Hypothesis 4.

Figure 5
<u>A Diagram of the Groups Being Compared In the Test of Null Hypothesis 4</u>

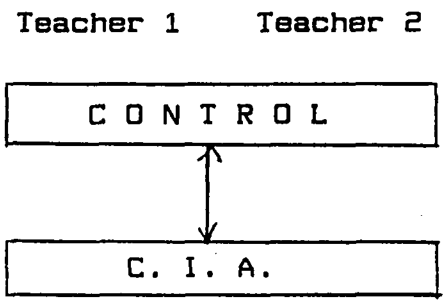


Table 17
<u>Analysis of Covariance of Delayed Posttest Scores by Group with Teacher as the Covariate</u>

Source of variation	Sum of Squares	DF	Mean Square	F	Sig of F
Main effects	13.929	2	6.964	.971	.383
GROUP	.964	1	.964	.134	.715
TCH * (Covar)	12.964	1	12.964	1.807	.183
Explained	13.929	2	6.964	.971	.383
Residual	581.060	81	7.174		
Total	594.988	83	7.169		

* TCH is the teacher variable

To test this null hypothesis an analysis of covariance was made on the delayed posttest scores by group, with teacher as the covariate. The results of this analysis is provided in Table 17. Since the observed F value for groups was .134, having a probability of .715, it can be seen that Null Hypothesis 4 may be retained.

Concluding Comment

All of the hypotheses were confirmed. The CAI tutorial was found to be as effective as the ususal classroom instruction. Implications for practice as well as recommendations for further research as present in Chapter IV.

CHAPTER V

SUMMARY OF THE STUDY

Statement of the Problem and the Purpose of the Study

This study investigated the use of a tutorial package in Mathematics 119, College Algebra, taught at the University of North Carolina at Greensboro in the Spring 1988 semester. This course served as a precalculus course for students planning to take calculus eventually. A tutorial software package by Addison-Wesley was used to provide the computer-assisted instruction (CAI). The syllabus for this course was lengthy and the length posed a dilemma. On the one hand, since this course was a prerequisite for a subsequent course, there was a need to cover the topics in the syllabus. On the other hand, it was extremely difficult for instructors to cover all of the topics in the syllabus while still attending to the learning needs of the students. This dilemma led to the consideration of a computer tutorial package as a possible solution. The purpose of this study was to examine the effectiveness of a computer tutorial compared to the usual classroom instruction on three topics from the syllabus.

The research hypotheses of this study were:

Hypothesis 1. For each of two instructors, the students in their CAI class will do as well as or better than those in their control class on a posttest covering the topics in this study.

Hypothesis 2. As a group, the two CAI classes will do as well as or better than the two control classes as a group on the posttest covering the topics in this study.

Hypothesis 3. For each of two instructors, the students in their CAI class will do as well as or better than those in their control class on a delayed posttest, embedded in the final exam, covering the topics in this study.

Hypothesis 4. As a group, the two CAI classes will do as well as or better than the two control classes as a group on a delayed posttest, embedded in the final exam, covering the topics of this study.

These research hypotheses were restated as null hypotheses, which served as the bases for the statistical analysis described in the next section. They are repeated here for convenience.

Null Hypothesis 1a. For teacher 1 there will be no significant difference between her CAI class and her control class on a posttest.

Null Hypothesis 1b. For teacher 2 there will be no significant difference between her CAI class and her control class on a posttest.

Null Hypothesis 2. There is no significant difference between the two CAI classes as a group and the two control classes as a group on a posttest covering the topics of this study.

Null Hypothesis 3a. For teacher 1 there will be no significant difference between her CAI class and her control class on a delayed posttest, embedded in the final exam, covering the topics of this study.

Null Hypothesis 3b. For teacher 2 there will be no significant difference between her CAI class and her control class on a delayed posttest, embedded in the final exam, covering the topics of this study.

Null Hypothesis 4. There is no significant difference between the two CAI classes as a group and the two control classes as a group on a delayed posttest, embedded in the final exam, covering the topics of this study.

Procedures and Data Analysis

Two experienced instructors known to the researcher participated in the study. For each instructor, one of her classes served as a control section, and her other section served as an experimental (CAI) section. Students in the control sections received all of their instruction in the classroom. Students in the CAI sections were excused from two consecutive classes and required to study, via CAI, three introductory-level topics preselected from the syllabus by the researcher. The students took a pretest given before receiving any instruction on the three designated topics. A posttest, given after treatment, and a delayed posttest embedded in the final exam were used to compare achievement on the three designated topics.

In each analysis an alpha of .05 was used to test for significance. A pretest was given to all four sections before any instruction was given on the three topics of the study. A regression analysis was performed on the data from the pretest to establish the initial equivalency of prior knowledge of the three math topics for the four sections of College Algebra that participated in this study. The results of that analysis established that there were no significant differences in the mean scores on a pretest covering the three topics of the study. Thus, the four sections were comparable in prior knowledge of the topics of the study. It was necessary to establish the comparablitiy of the four groups on prior knowledge in order determine the appropriate statistical methods were appropriate to use for the analyses that follow.

The primary research focus was to compare the effectiveness of two methods of instruction. One method of instruction was to use computer-assisted instruction via a tutorial software package to provide instruction in three targeted topics. The other method of instruction was the usual classroom instruction on those three topics. The investigation was directed towards addressing the hypotheses listed above.

The Analysis for Null Hypotheses 1a and 1b

Null Hypothesis 1a. For teacher 1 there will be no significant difference between her CAI class and her control class on a posttest.

Null Hypothesis 1b. For teacher 2 there will be no significant difference between her CAI class and her control class on a posttest.

A posttest was given on the first class day after treatment. Null hypotheses 1a and 1b were each tested by using a one-way ANOVA of the mean scores on a posttest covering the three topics of the study for each instructor's control section and her corresponding CAI section. For each instructor it was found that there was no significant difference between her control section and her CAI section. Thus, Null Hypotheses 1a and 1b were confirmed.

The Analysis for Null Hypothesis 2

Null Hypothesis 2. There is no significant difference between the two CAI classes as a group and the two control classes as a group on a posttest covering the topics of this study.

Before testing null hypothesis 2 it was necessary to determine whether there was a significant difference between the two CAI sections, or a significant difference between the control sections, on the posttest. If no significant differences were found then analysis of variance maight be used to test null hypothesis 2. If, however, there was a significant difference, then analysis of covariance had to be used.

A one-way ANOVA was conducted to test for a significant difference between the mean scores on the posttest for the two CAI sections. That analysis found that there was no significant difference. Since the students in each CAI section received their instruction from the same source--i.e., the computer, it was expected that no significant differences between the two CAI sections would be found.

A one-way ANOVA was conducted to test for a significant difference between the mean scores on the posttest for the two control sections. That analysis found that there was a significant difference. Possible explanations of this significant difference are explored in the following section.

As a result of the significant difference between control sections, it was necessary to test Null Hypothesis 2 by means of an analysis of covariance on the mean of the posttest scores by group, with teacher as a covariate. The analysis of covariance verified that there were no significant differences on the posttest between the two control sections combined and the two CAI sections combined, after controlling for the teacher variable. Thus, Null Hypothesis 2 was confirmed. This confirmation indicates that instruction of the three math topics of the study by means of CAI was as effective as the usual classroom instruction. An unusual outcome was that the two control sections combined had exactly the same mean on the posttest as the two CAI sections combined. Thus there was no difference at all between the mean score for the combined control sections and the mean score for the combined CAI sections on the posttest.

The Analysis of Null Hypotheses 3a and 3b

Null Hypothesis 3a. For teacher 1 there will be no significant difference between her CAI class and her control class on a delayed posttest, embedded in the final exam, covering the topics of this study.

Null Hypothesis 3b. For teacher 2 there will be no significant difference between her CAI class and her control class on a delayed posttest, embedded in the final exam, covering the topics of this study.

A delayed posttest was given at the end of the semester, about two and a half months after the posttest. This delayed posttest was embedded in the final exam for the course. Null hypotheses 3a and 3b were each tested using a one-way ANOVA of the mean scores on a delayed posttest covering the three topics of the study for each instructor's control section and her corresponding CAI section. For each instructor it was found that there was no significant difference between her control section and her CAI section. Thus, Null Hypotheses 3a and 3b were confirmed.

The Analysis of Null Hypothesis 4

Null Hypothesis 4. There is no significant difference between the two CAI classes as a group and the two control classes as a group on a delayed posttest, embedded in the final exam, covering the topics of this study.

Before testing null hypothesis 4 it was necessary to determine whether there is a significant difference between the two CAI sections, or a significant difference between the control sections, on the delayed posttest. If no significant differences were found then analysis of variance might be used to test null hypothesis 4. If, however, there was a significant difference, then analysis of covariance had to be used.

A one-way ANOVA was conducted to test for a significant difference between the mean scores on the delayed posttest for the two CAI sections. That analysis found that there was no significant difference. As observed earlier, since the students in each CAI section received their instruction from the same source--i.e., the computer, it was expected that no significant differences between the two C.A.I. sections would be found.

A one-way ANOVA was conducted to test for a significant difference between the mean scores on the delayed posttest for the two control sections. That analysis found that there was a significant difference. Possible explanations of this significant difference are explored in the following section.

As a result of the significant difference between control sections, it was necessary to test Null Hypothesis 4 by means of an analysis of covariance on the mean of the delayed posttest scores by group, with teacher as a covariate. The analysis of covariance verified that there was no significant difference on the posttest between the two control sections combined and the two control sections combined, after controlling for the teacher variable. Thus, Null Hypothesis 4 was confirmed. This confirmation indicates that instruction of the three math topics of the study by means of CAI is as effective as the usual classroom instruction in terms of long-term retention.

Conclusions

The main conclusions of this study were 1) that the two CAI sections as a group performed as well as or better than the two control sections as a group on the posttest, after controlling for instructors; and 2) that the two CAI sections as a group performed as well as or better than the two control sections as a group on the delayed posttest, after controlling for instructors. These findings are consistent with the research in computer-assisted instruction. The theoretical implication is that CAI may be used in place of classroom instruction in a college algebra course.

It can also be concluded that for each instructor, her CAI section performed as well as or better than her control section on, 1) a posttest and 2) a delayed posttest embedded in the final exam, covering the three topics of this study.

The literature search revealed several meta-analyses of the use of computers to deliver instruction. In the various meta-analyses of computer-based instruction (CBI) at a variety of educational levels, it was found that the evidence favors CBI over classroom instruction. That is to say, a clear majority of the studies favored CBI. If no general effect of CBI existed one would expect about half of the studies to favor CBI and half to favor conventional instruction. Since that was not the case, Kulik et al. (1987) rejected the null hypothesis of no effect of CBI on student achievement.

The literature search also revealed that much of the research has been done in areas other than college algebra, using types of CBI other that tutorials on a microcomputer. As cited in Chapter II, Diem (1982) indicated in his dissertation that the development and evaluation of microcomputer software on a modular basis are priority items in college-level CAI. This study is a part of that effort.

As indicated in the search of the literature, the use of computer-assisted instruction has been tested in a wide variety of settings, modes, subject areas, and grade levels.

In a majority of the studies in which computer-assisted instruction was compared with traditional classroom instruction, it was found that computer-assisted instruction was at least as effective as classroom instruction. The research in the use of computer tutorials in a college algebra course is sparse. This study confirmed the findings of those studies and extended our understanding of how computer-assisted instruction may be used in place of classroom instruction.

For each instructor no significant difference was found between her control section and her CAI section on both the posttest and delayed posttest. This indicates that computer-assisted instruction is a viable alternative to classroom instruction on certain topics. The CAI treatment was found to be effective independent of instructors. Thus, most instructors would be able to successfully use this CAI tutorial package.

It was found that there was a significant difference between the two control sections for both the posttest and the delayed posttest. This may be due to teacher effect. In conversations with the researcher the instructors indicated differing conduct with the students in the control sections. One instructor conducted herself with the expectation that her students would properly follow instructions without subsequent reinforcement. The other instructor provided reminders and checked with her students to determine that they were properly following instructions. It was the control section of the latter instructor that had a significantly higher mean score on both the posttest and the delayed posttest than the corresponding mean score for the control section of the former instructor. Thus, it may be the degree of guidance exercised by the instructor that accounts for the significant difference found between the control groups.

There may be other factors not controlled for that account for the significant difference found between the control groups. Perhaps the two groups of students in the control sections differed in some way that would make one group perform better than the other group. The students in one control group, for example, may have been more responsive to the teaching style of their instructor than was the case for the other control group. There may have been differences in student background variables such as SAT scores, number of years of math in high school, age, or the student's major that may account for the significant difference found between the control sections.

Implications for Practice

The practical implications of the study are as follows: 1) certain introductory topics in a college algebra course may be presented by means of computer-assisted instruction outside the class rather than in class, with comparable effectiveness; 2) it may be possible to make more time available in the classroom by having students study some of the introductory topics by means of computer-assisted instruction; and 3) college students tend to react favorably to the use of computers for instruction (as indicated by responses to the CAI questionnaire). The additional time so provided would allow the instructors to attend more fully to student needs and to present more thoroughly in class the other topics in the syllabus.

Mathematics departments in colleges and universities might find CAI via microcomputers to be a means of providing some instruction outside the classroom. The evidence provided by this study indicates that this would be the case. Since most colleges and universities already have microcomputer labs, the additional investment needed to implement a program of CAI tutorials would be minimal.

Recommendations for Further Research

1) A similar study should be done using a broader range of topics presented on the computer. Perhaps one or more introductory topics, one or more topics from the intermediate material, and one or more topics of comparatively greater

difficulty could be used to detect whether the level of difficulty of the topic is correlated with outcomes.

2) A study should be done to determine which background variables--for example, previous experience with computers in general and with CAI in particular, attitudes towards computers, strength of math background, and gender--are most predictive of success with computer-assisted instruction.

3) A study needs to be conducted in which students from a number of sections of a course simultaneously study CAI in a lab while continuing to receive instruction in their classes. This type of study will be a challenge to design. It is a challenge that must be met. Only in this way can it be determined whether it is possible to reduce the time pressures experienced by instructors of a college algebra course.

4) Perhaps the importance that is attached to a final exam in a course masked the true delayed treatment effects. Thus, the study should be replicated with the delayed posttest given perhaps two or three weeks after treatment rather than being incorporated in the final exam.

5) A study of a longer term use of computers in a college algebra course needs to be done to determine whether

there is a strong novelty effect in the use of computer-assisted instruction. That is, the use of CAI should be used more extensively over a longer period of time to determine if the effectiveness of CAI diminishes over time. For example, over a period of several weeks, rather than just two days, students would be required to study at least six topics by means of CIA while continuing to study concurrently other topics in class.

Summary and Closing Statement

The effectiveness of computer-assisted instruction on three topics from college algebra was compared with the effectiveness of the usual classroom instruction. This study established the comparable effectiveness of computer-assisted instruction within the design of the study. The study was a first step in the investigation of the use of computer-assisted instruction in a college algebra course. Many more studies along the lines recommended in the previous section need to be carried out before a better understanding is gained of whether computer-assisted instruction may effectively be used concurrently with classroom instruction on distinct topics. If instructors are to be able to address more fully the learning needs of their students while still covering the syllabus, then more research is needed on how CAI may be able to provide additional classroom time.

BIBLIOGRAPHY

Adams, D. M. (1985). Computers and Teacher Training: A Practical Guide. New York: Haworth Press.

Adams, T. M., Waldrop, P. B., Justen III, J. E., & McCrosky, C. H. (1987). Aptitude-Treatment Interaction in CAI. Educational Technology, 27, 21-23.

Alberte-Hallam, T., Hallam, S. F., & Hallam, J. (1985). Micro Computer Use: Word Processors, Spreadsheets, and Data Bases. Academic Press.

Baird W. E. (1986). The Influence of Computers and Informatics on Mathematics and its Teaching. J. of Computers in Mathematics & Science, 6(2), 49-51, Winter 1986-87.

Bangert-Drowns, R. L., Kulik, J. A., & Kulik, C-L. C. (1985). Effectiveness of Computer-Based Education in Secondary School. Ann Arbor: University of Michigan, Center for Research on Learning and Teaching.

Bangert-Drowns, R. L. (1985). Meta-Analysis of Findings on Computer-Based Education with Precollege Students. Chicago, IL: Annual Meeting of the American Educational Research Association. (ERIC Document Reproduction Service No. ED 263 905)

Battersby, M. E. (1987). A CAI Program to Facilitate the Development of Critical Thinking Skills. In International Conference on CAL in Post-Secondary Education, (Proceedings), (pp. 249-251). Calgary:The University of Calgary.

Bell, Frederick Harold (1970). A Study of the Effects of a Computer-Oriented Approach to Calculus. Dissertation Abstracts International, 31A, 1096-A.

Bickerstaff, Douglas D. (1976). The Effect of Computer Assisted Instruction Drill and Practice Used to Obtain Homework Credit on Achievement and Attitudes of College Level Intermediate Algebra Students (Doctoral dissertation, Kansas State University, 1976). Dissertation Abstracts International, 37, 5659A.

Bloom, L. M., Comber, G. A., & Cross, J. M. (1987). Microcomputer Graphics and Calculus Teaching. Australian Mathematics Teacher, 43(1), 5-8.

Bostron, K., Cole, A. J., Hartly, J. R., Lovelly, K., & Tait, K. (1982). An Evaluative Study of the Effects and Effectiveness of Microcomputer-Based Teaching in Schools. Leeds, England: The University of Leeds. (ERIC Document Reproduction Service No ED 224 461).

Boysen, V. A. (1980). Interaction of Field Dependence-Independence with Type of Feedback Used in Computer-Assisted Equation Solving (Doctoral dissertation, Iowa State University, Ames, Iowa, 1980). Dissertation Abstracts International, 41, 972A.

Brody, P. J. (1986). Computers in the Classroom. Educational Technology, 226(1), 32-33.

Brown, S. W., & Cutlip, M. B. (1987). Computer-Based Education in College: A Study of Cognitive and Affective Outcomes. In International Conference on CAL in Post-Secondary Education, (Proceedings), (pp. 71-76). Calgary: The University of Calgary.

Burns, P. K., & Bozeman, W. C. (1981). Computer-Assisted Instruction and Mathematics Achievement: Is There a Relationship? Educational Technology, October, 1981, 32-39.

Byers, Cary R. (1973). An Experimental Comparison of Three Modes of Computer-Supported Instruction. (Doctoral dissertation, University of Minnesota, 1973). Dissertation Abstracts International, 34, 6938A.

Chambers, J. A. (1987). The Near Future of Computer Based Education. In International Conference on CAL in Post-Secondary Education, (Proceedings), (pp. 51-58). Calgary: The University of Calgary.

Clark, R. E. (1985). Evidence of Confounding in Computer-Based Instruction Studies: Analyzing the Meta-Analysis. ECTJ, 33(4), 249-262.

Coburn, P., Kelman, P., Roberts, N., Snyder, T. F., Watt, D. H., & Weiner, C. (1985). Practical Guide to Computers in Education. Reading, MA: Addison-Wesley.

Cooke, D. W. (1986). A Computer Assisted Instruction Unit on Exponential and Logarithmic Functions (Doctoral dissertation, University of South Carolina, 1986). Dissertation Abstracts International, 47, 2933A.

Coombs, D. H. (1977). Games? They're a Serious Approach to Learning. In Ruth Weinstock (Ed.), Communications Technologies in Higher Education: 22 Profiles (pp. 63-67). Washington, D.C.: Communications Press, Inc.

Coombs, D. H. (1977). More on Simulation Gaming. In Ruth Weinstock (Ed.), Communications Technologies in Higher Education: 22 Profiles (pp. 85-89). Washington, D.C.: Communications Press, Inc.

Cromie, W. J., (1987). Expert Systems and Medical Education. Educational Researcher, 17(3), 10-12.

Culp, G. H., & Castleberry, Sam J. (1971). Computer-Assisted Instruction in Undergraduate Organic Chemistry: An Evaluation of Selected Programs. Science Education, 55(3), 423-430.

Cyert, R. M. (1986). The Impact of Microcomputers on Education. Perspectives in Computing, 6(2), 4-8.

Davies, L. J. (19). Teaching University Students How to Learn. Improving College and University Teaching, 31(4), 160-165.

DeBoer, D. D. (1974). A Comparative Study of the Effects of a Computer-Oriented Approach to Introductory Calculus (Doctoral dissertation, George Peabody College for Teachers, 1973). Dissertation Abstracts International, 34, 3912B.

DiSessa, A. A. (1987). Artificial Worlds and Real Experience. In R. W. Lawler & M. Yazdani (Eds.), Artificial Intelligence and Education (p. 55).

Diem, D. C. (1982). The Effectiveness of Computer-Assisted Instruction in College Algebra (Doctoral dissertation, Florida State University, 1982). Dissertation Abstracts International, 43, 1456A.

Duin, A. H., Computer-Assisted Instructional Displays: Effects on Students' Computing Behaviors, Prewriting, and Attitudes. J. of Computer-Based Instruction, 15(2), 48-56, Spring 1988.

Duncan, K. A., & Harris, D. I. (Eds.). (1985). Computers in Education. North-Holland.

Edwards, J., Norton, S., Taylor, S., Weiss, M., & Dusseldorp, R. (1975). How Effective is CAI? A Review of the Research. Educational Leadership, 33, 147-153.

Feurzeig, W. (1987). Algebra Slaves and Agents in a LOGO-Based Mathematics Curriculum. In R. W. Lawler & M. Yazdani (Eds.), Artificial Intelligence and Education (pp. 27-54).

Fine, B. (1962). Teaching Machines. New York: Sterling Publishing.

Fiszer J. , Bernard-Daugeras, N., Favard-Sereno, C., & Lauthier, M. (1985). A First Step in Computer-Based Learning of Molecular Embryology at the University and First Achievements. In K. A. Duncan & D. I. Harris (Eds.), Computers In Education (pp. 199-206). North-Holland.

Forsyth, R., Conrad, B., & Holzmann, W. (1987). Computer Tools in an Elementary Linear Algebra Course: A Case Study. In International Conference on CAL in Post-Secondary Education, (Proceedings), (pp. 265-267). Calgary: The University of Calgary.

Freese, R., Lounesto, P., & Stegenga, D. A. (1986). The Use of muMATH in the Calculus Classroom. J. of Computers in Mathematics & Science Teaching, 6(1), 52-55.

Fuller, N., Prusinkiewicz, P., & Rambally, G. (1985). L.E.G.O.-An Interactive Computer Graphics System for Teaching Geometry. In K. A. Duncan & D. I. Harris (Eds.), Computers In Education (pp. 359-364). North-Holland.

Futrell, M. K., & Geisert, P. (1984). The Well-Trained Computer. Englewood Cliffs, N.J.: Educational Technology Publishing.

Gallego, J. A., Ruiz, J. J., Fernandez, F. J. P., & Fernandez, A. S. (1985). Computer-Assisted Instruction in Linear Programming. European J. of Engineering Education, 10(3 & 4), 329-338.

Geoffrion, L. D., & Geoffrion, D. P. (1983). Computers and Reading Instruction. Reading, MA: Addison Wesley.

Glass, G. V. (1976). Primary, Secondary, and Meta-Analysis of Research. Educational Researcher, 5, 3-8.

Gonzalez, J. (1985). Teaching Problem Solving in Complex Situations Using Simulation Models. In K. A. Duncan & D. I. Harris (Eds.), Computers In Education (pp. 233-237). North-Holland.

Graff, L. G. (1987). Computer Managed Learning Evaluated in a Test Project with Adult Mathematics Learners. In Proceedings, International Conference on CAL in Post-Secondary Education (pp. 275-277). Calgary:University of Calgory.

Gray, S. H. (1988). Sequence Control Menus and CAI: A Follow-up Study. J. of Computer-Based Instruction, 15(2), 57-60.

Hall, K. A. (1982). Computer-Based Education. Syracuse, NY: ERIC Clearinghouse on Information Resources.

Hannafin, M. J., & Hughes, C.W. (1986). A Framework for Incorporating Orienting Activities in Computer-Based Interactive Video. International Science, 15, 239-255.

Hatfield, L. L. (1970). Computer Assisted Mathematics: An Investigation of the Effectiveness of the Computer as a Tool to Learn Mathematics. Unpublished doctoral dissertation from University of Minnesota. First Study; conducted in 1969. University Microfilms No. 71-18, 720.

Haven, R. N. (1985). Instructional Software, 1984 Trends and State of the Art. Chicago, Ill: American Educational Association Annual Meeting. (ERIC Document Reproduction Service No. ED 263 891.

Heid, M. K., Sheets, C., Matras, M. A., & Menasian, J. (1987). Classroom and Computer Lab Interaction in a Computer-Intensive Algebra Curriculum. Unpublished communication with the authors.

Hein, L. I., (1987). Simulation as a CAL Strategy for Adult Learners. In International Conference on CAL in Post-Seconday Education, (Proceedings), (pp. 279-281). Calgary:The University of Calgary.

Hickernell, F., & Proskurowski, W. (1985). The Use of Microcomputers in the Teaching of Calculus. Collegiate Microcomputer, 3(2), 111-125.

Hickey, Albert E. (1974). Research Guidelines for CAI. Newburyport, Mass.: Albert E. Hickey Associates.

Hocking, J. (1985). The Computer in Higher Education: Not Just Another Mechanical Device. Educational Technology, 25(8), August 1985, 19-23.

Hollen Jr., T. T., Bunderson, C. V., & Dunham, J. L. (1971). Computer-Based Simulation of Laboratory Problems in Qualitative Chemical Analysis. Science Education, 55(2), 131-136.

Holoien, O. (1971). Calculus and Computing: A Comparative Study of the Effectiveness of Computer Programming as an Aid in Learning Selected Concepts in First-Year Calculus (Doctoral dissertation, University of Minnesota, 1970). Dissertation Abstracts International, 31, 4490A.

Hsiao, F. S. T. (1984). A New CAI Approach to Teaching Calculus. J. of Computers in Mathematics and Science Teaching, v4(2), 29-36.

Hundhausen, J. R., (1980). Advanced Ordinary Differential Equations in an Engineering Environment: A Computer-Assisted Approach. American Mathematical Monthly, 87(8), 662-669.

Jamison, D., Suppes, P., & Wells, S. (1974). The Effectiveness of Alternate Instructional Media: A Survey. Review of Educational Research, 44, 1-67.

Janke, R. W., & Pilkey, P. J. (1985). Microcomputer Diagnostic Testing in Elementary Mathematics Classrooms. In K. A. Duncan & D. I. Harris (Eds.), Computers In Education (pp. 347-350). North-Holland.

Jeger, A., & Slotnick, R. S. (1985). Towards a Multi-Paradigmatic Approach to Evaluation of CAI: Experiences from the N.Y.I.T. Computer-Based Education Project. (ERIC Document Reproduction Service No. ED 260 703)

Jones, K. L., & Lamb, C. E. (1985). Programming in Mathematics Education: An Essential Component in the Development of Reasoning Skills. In K. A. Duncan & D. I. Harris (Eds.), Computers In Education (pp. 341-345). North-Holland.

Kearsley, G. (Ed.). (1987). Artificial Intelligence and Instruction. Reading, MA: Addison-Wesley.

Kiesler, S., & Sproull, L. (Eds.). (1987). Computing and Change on Campus. Cambridge: Cambridge University Press.

Koohang, A. A. (1984). Traditional Method Versus Computer-Aided Instruction Method in Teaching BASIC Programming to Vocational High School Students. (ERIC Document Reproduction Service No. ED 273 247)

Kulik, C-L. C., & Kulik, J. A. (1985). Effectiveness of Computer-Based Education in Colleges. (ERIC Document Reproduction Service No. ED 263 890)

Kulik, C-L., C., & Kulik, J. A. (1986). Effectiveness of Computer-Based Education in Colleges. AEDS Journal, 19(2-3), 81-108, Winter/Spring 1986.

Kulik, C-L. C., Kulik, J. A., & Schwalb, B. J. (1986). The Effectiveness of Computer-Based Adult Education: A Meta-Analysis. J. Educational Computing Research, 2(2), 235-252.

Kulik, J. A., & Kulik, C-L. C. (1988). Timing of Feedback and Learning. Review of Educational Research, 58(1), 79-97.

Kulik, J. A. (1983). Synthesis of Research on Computer-Based Instruction. Educational Leadership, 41, 19-21.

Kulik, J. A., Kulik, C-L. C., & Bangert-Drowns, R. L. (1985). The Importance of Outcome Studies: A Reply to Clark. J. Educational Computing Research, 1(4), 381-387.

Kulik, J. A., & Kulik, C-L. C. (1987). Review of Recent Research Literature on Computer-Based Instruction. Contemporary Educational Psychology, 12, 222-230.

Kulik, J. A., Kulik,C-L. C., & Cohen, P. A. (1980). Effectiveness of Computer-based College Teaching: A Meta-Analysis of Findings. Review of Educational Research. 50(4), 525-544.

Lang, C. R. (1976). Computer Graphic Simulations in High School Physics. Unpublished doctoral dissertation from Kansas State University. University Microfilms No. 68-17, 690.

Lawler, R. W., & Yazdani, M. (Eds.). (1987). Artificial Intelligence and Education Volume One. Norwood, N.J.: Ablex Publishing.

LeBlanc, P., & Dumas, J. (1987). A Randomized Cross-Over Study on the Effectiveness and Acceptability of Drill and Practice Type of CAL. In International Conference on CAL in Post-Secondary Education, (Proceedings), (pp. 299-301). Calgary: The University of Calgary.

Liu, H.-C. (1975). Computer-Assisted Instruction in Teaching College Physics (Doctoral dissertation, Western Michigan University, 1975). Dissertation Abstracts International, 36A, 1411A.

Lundgren, C. A. (1986). A Comparison of the Effects of Programmed Instruction and Computer-Assisted Instruction on Achievement in English Grammar. The Delta Phi Epsilon Journal, 28(4), 1-9.

Making Sense of the Future. A Position Paper on the Role of Technology in Science, Mathematics, and Computing Education. (1988). Cambridge, MA: Educational Technology Center Harvard Graduate School of Education.

Manion, M. H. (1985). CAI Modes of Delivery and Interaction: New Perspectives for Expanding Applications. Educational Technology, 25, January 1985, 25-28.

Marsham, B. (1985). An Experiment in Interactive Computerized Teaching of a Topic From Advanced Calculus. In K. A. Duncan & D. I. Harris (Eds.), Computers In Education (pp. 351-358). North-Holland.

McCall, M. B., & Holton, J. L. (1982). Integration of CAI into a Freshmen Liberal Arts Math Course in the Community College. J. of Computers in Mathematics & Science, 2(2), 35-37, Winter 1982.

Merrill, P. F., & Tolman, M. N. (1986). Computers in Education. New York: Academic Press.

Meyer, J. H., & Beaton, G. R. (1974). An Evaluation of Computer-Assisted Teaching in Physiology. J. of Medical Education, 49(3), 295-297.

Nelson, R. B., & Erwin, T. Dary. (1986). Examining the Organizational Characteristics of CAI Projects in Institutions of Higher Education. J. Educational Technology Systems, 14(4), 297-305.

Oberem, G. E. (1987). ALBERT: A Physics Problem-Solving Monitor and Coach. In International Conference on CAL in Post-Secondary Education, (Proceedings), (pp. 179-184). Calgary: The University of Calgary.

Ohlsson, S. (1987). Some Principles of Intelligent Tutoring. In R. W. Lawler & M. Yazdani (Eds.), Artificial Intelligence and Education (pp. 203-237).

Olds Jr., H. F. (1986). The Computer an an Educational Tool. Haworth Press.

Ortiz, E. (1988). A Comparative Study of a Computer Programming and a Textbook Approach in Teaching the Concept of Variable. A paper presented at the AERA Annual Meeting in New Orleans, April, 1988.

O'Shea, T. (1982). A Self-Improving Quadratic Tutor. In Sleeman D. & Brown, J. S. (Eds.), Intelligent Tutoring Systems (pp. 309-336). Academic Press.

Piddock, P. (1985). TRIG- An Intelligent Drill-And-Practice System for Introductory Trigonometry. In K. A. Duncan & D. I. Harris (Eds.), Computers In Education (pp. 365-369). North-Holland.

Powell, J. V. (1987). Affective Response of College Students to an Exemplary Application of CBI. J. of Computer-Based Instruction, 14(4), 142-145.

Prindle, L., & McLaughlin, T. F. (1987). A Computer Spelling Testing Program with Clerical English Students: An Empirical Evaluation. J. of Computer-Based Instruction, 14(3), 146-149, Autumn 1987.

Proceedings. (1982). The Computer: Extension of the Human Mind. Eugene, OR.: Educational Management, University of Oregon.

Quesada, J. F. C. (1986). The Mathematics Laboratory in Engineering Studies. European J. of Engineering, 11(2), 187-190.

Riel, M. M., Levin, J. A., & Miller-Souviney, B. (1987). Learning with Interactive Media: Dynamic Support for Students and Teachers. In R. W. Lawler & M. Yazdani (Eds.), Artificial Intelligence and Education (pp. 117-134).

Ries, C. P., & Granell, J. (1985). CAI in College-Level Nutrition Education: A Feasibility Study. J. of Nutrition Education, 17(4), 130-134.

Roblyer, M.D. (1985). The Greening of Educational Computing: A Proposal for a More Research-Based Approach to Computers in Instruction. Educational Technology, 25, January 1985, 40-44.

Romero, S. R. (1980). The Effectiveness of Computer Assisted Instruction in Mathematics at the Middle School (Doctoral dissertation, University of the Pacific, 1979). Dissertation Abstracts International, 41, 577A.

Rubincam, I. (1987). Frequently Cited Authors in the Literature on Computer Applications in Education. J. of Computer-Based Instruction, 14(4), 150-156, Autumn 1987.

Rushinek, A. (1985). Correlations Between Instruction, Course, and CAI Tutorials. In K. A. Duncan & D. I. Harris (Eds.), Computers In Education (pp. 51-55). North-Holland.

Scandura, J. M., & Scandura, A. B. (1987). The Intelligent Ruletutor: A Structured Approach to Intelligent Tutoring, Phase II. J. Structured Learning, 9, 195-259.

Scanlon, E., & O'Shea, T. (Eds.). (1987). Educational Computing. Chichester:John Wiley & Sons.

Sheriff, T. M. (1988). An Exploratory Study of the Problem Solving Strategies Used by Selected Young Adolescents While Playing a Microcomputer Test Adventure. Unpublished doctoral dissertation, University of North Carolina Greensboro.

Shirey, J. R. (1976). The Effects of Computer-Augmented Instruction on Students' Achievement and Attitudes (Dictoral dissertation, University of Oregon, 1976). Dissertation Abstracts International, 37, 3386A.

Skinner, B.F. (1986). Programmed Instruction Revisited. Phi Delta Kappan, 68(2), 103-110.

Sleeman D. (1987). PIXIE: A Shell for Developing Intelligent Tutoring Systems. In R. W. Lawler & M. Yazdani (Eds.), Artificial Intelligence and Education (pp. 239-263).

Sleeman D., & Brown, J. S. (1982). Intelligent Tutoring Systems. Academic Press.

Sleeman D. & Brown, J. S. (1982). Introduction. In Sleeman D. & Brown, J. S. (Eds.), Intelligent Tutoring Systems (pp. 1-11). Academic Press.

Smith, D. A. (Ed.). (1980). Computers In Teaching. 1979 State of the Art Report of Instructional Computing. CONDUIT Publishing.

Smith, E. S. (1980). The Effect of Computer-Assisted Instruction on Academic Achievement, School Daily Attendance, and School Library Usage at Margaret Murray Washington Career Center (Doctoral dissertation, George Washington University, 1980). Dissertation Abstracts International, 41, 2431A.

Smith, P., & Dunn, S. (1985). Tomorrow's University: Serving the Information Society-Getting Ready for the Year 2000. Educational Technology, July 1985, 5-11.

Smith, R. B. (1976). The Effects of Computer-Assisted Feedback on Students' Performance in a Televised College Course. Dissertation Abstracts International, 36, 5163A.

Spille, H. A., Galloway, S. W., & Stewart, D. W. (1985). How to Evaluate Courseware Designed for use in Education or Training Programs for Adult Learners, Educational Technology, March 1985, 40-42.

Spock, P. A. (1987). Feedback and Confidence of Response for a Rule-Learning Task Using Computer-Assisted Instruction. Paper presented at the Annual Meeting of the American Educational Research Association, Washington, D.C., April, 1987.

Steele, T. D., Hedges, D. A., Dickinson, J. (1987). Instructional Designs for the Basic Health Sciences: A Computer Assisted Tutorial System. In International Conference on CAL in Post-Seconday Educations, (Proceedings), (pp. 361-363). Calgary: The University of Calgary.

Sterrett, A., & Karian, Z. A. (1978). A Laboratory For an Elementary Statistics Course. American Mathematical Monthly, 85(2), 113-116.

Sullivan, D., Lewis, T., & Cook, C. (1986). Using Computers Today. New York: Houghton Mifflin.

Summers, E. G. (1985). Microcomputers as a New Technological Innovation in Education: Growth of the Related Journal Literature. Educational Technology, 25, August 1985, 5-14.

Suppes, P., & Fortune, R. F. (1985). Computer-Assisted Instruction: Possibilities and Problems. NASSP Bulletin, 69, 30-34.

Suppes, P., & Morningstar, M. (1972). Computer-Assisted Instruction at Stanford, 1966-1968. New York:Academic Press.

Tsai, S-Y. W., & Pohl, N. F. (1977). Student Achievement in Computer Programming: Lecture vs. Computer-Aided Instruction. J. of Experimental Education, 46, 66-70.

Vaughn Jr., A. C. (1977). A Study of the Contrast Between Computer-Assisted Instruction and the Traditional Teacher/Learner Method of Instruction in Basic Musicianship (Doctoral dissertation, Oregon State University, 1978). Dissertation Abstracts International, 38, 3357A.

Vinsonhaler, J. F., & Bass, R. K. (1972). A Summary of Ten Major Studies on CAI Drill and Practice. Educational Technology, July, 1972, 29-32.

Wedman, J. F. (1987). Citation Patterns in the Computer-Based Instruction Literature. J. of Computer-Based Instruction, 14(3), 91-95, Summer 1987.

Weinstock, R. (Ed.). (1977). Communications Technologies in Higher Education, 22 Profiles. Washington, D.C.:Communications Press.

Weizenbaum, J. (1987). Educational Technology: The Voice of a Skeptic. EDUTECH Report, 3(2-3), 1-5.

Wenger, R. H. (1986). Congitive Science and Algebra Learning. Unpublished document.

Wenger, R. H., & Brooks, M. W. (1984). Diagnostic Uses of Computers in Precalculus Mathematics. NCTM Yearbook, 1984, 217-231.

Winkler, J. D. (1984). How Effective Teachers Use Microcomputers For Instruction. Santa Monica, Calif: Rand Corp. (ERIC Document Reproduction Service No. ED 264 839)

Wittrock, M. C. (1986). Handbook of Research on Teaching (3rd ed.). New York: Macmillion.

Yazdani, M. (1987). Intelligent Tutoring Systems: An Overview. In R. W. Lawler & M. Yazdani (Eds.), Artificial Intelligence and Education (pp. 183-201). Norwood, N. J.: Ablex Publishing.

Ziegler, C. A. (1974). Individualized, Monitored, Syntax-Directed Computer-Aided Instruction in College and High School Algebra (Doctoral dissertation, University of California, Berkeley, 1972). Dissertation Abstracts International, 34B, 5420B.

APPENDIX A

CLASSROOM SUPPLEMENT FOR COMPLETING THE SQUARE

A Supplement For CAI Unit on Completing the Square

*** THE FOLLOWING PROBLEMS SHOULD BE DONE IMMEDIATELY AFTER FINISHING THE CAI TOPIC ON COMPLETING THE SQUARE. ***

NOTE: The following problems show how the method of completing the square that you studied on the computer can be used to solve quadratic equations of the form $ax^2 + bx + c = 0$. If a = 1, then first divide both sides of the equation by 'a' so as to make the first term equal to x . If a = 1 to start with, then the method of completing the square can be used immediately. The examples below illustrate how to solve quadratic equations of both types.

EXAMPLE: Solve $x^2 - 8x + 7 = 0$ by completing the square.
Since the leading coefficient is already 1, we don't have to divide by 'a'.

$x^2 - 8x = -7$ (Transpose the +7)

$x^2 - 8x + 16 - 16 = -7$ (Add & subtract $(b/2)^2$).

$(x - 4)^2 = -7 + 16$ (Transpose the −16 and factor left hand side).

$(x - 4)^2 = 9$ (Combine −7 + 16)

$x - 4 = \pm\sqrt{9} = \pm 3$ (Square root of both sides)

Thus, $x = 4 \pm 3$, i.e., $x = 7$ or 1.

EXAMPLE: Solve $x^2 + 13x + 38 = 0$ by completing the square. Since the leading coefficient a = 1, we again do not have to divide by 'a' first.

$x^2 + 13x = -38$ (transpose the 38)

$x^2 + 13x + 169/4 - 169/4 = -38$ (add & subtract $(b/2)^2$)

$(x + 13/2)^2 = -38 + 169/4$ (transpose −169/4 and factor left hand side)

$(x + 13/2)^2 = \underline{17/4}$ (Combine −38 and 169/4)

$x + 13/2 = \pm\sqrt{17/4}$ (Take square root of both sides)

$x = -13/2 \pm \sqrt{17/4}$ (Transpose 13/2)

$x = -13/2 \pm \sqrt{17/4} = -13/2 \pm \sqrt{17}/2$.

$x = (-13 \pm \sqrt{17})/2$

EXAMPLE: Solve $2x^2 + 12x - 20 = 0$ by completing the square.

SOLUTION: First divide by the leading coefficient of 2. This yields:

$x^2 + 6x - 10 = 0.$

$x^2 + 6x = 10$ (Transpose the -10).

$x^2 + 6x + 9 - 9 = 10$ (Add & subtract $(b/2)^2$).

$(x + 3)^2 = 19$ (Transpose the -9 & factor left hand side).

$x + 3 = \pm\sqrt{19}$ (Take square root of both sides).

Thus, $x = -3 \pm \sqrt{19}$ (Transpose the $+3$).

EXAMPLE: Solve $5x^2 - 10x - 40 = 0$ by completing the square. Since $a=5$, we must first divide both sides by 5 to obtain:

$x^2 - 2x - 8 = 0.$

$x^2 - 2x = 8$ (Transpose the -8 term)

$x^2 - 2x + 1 - 1 = 8$ (Add & subtract $(b/2)^2$)

$(x - 1)^2 = 8 + 1$ (Transpose -1 and factor left hand side)

$(x - 1)^2 = 9$

$x - 1 = \pm\sqrt{9} = \pm 3$. Therefore,

$x = 1 \pm 3$ & thus, $x = 4$ or -2.

THE FOLLOWING EXERCISES ARE TO BE DONE BY THE METHOD DEMONSTRATED IN THE FOUR EXAMPLES ABOVE.

1) $3x^2 + 12x + 15 = 0$ 2) $2x^2 - 4x - 5 = 0$

3) $x^2 + x - 6 = 0$ 4) $3x^2 - 4x + 1 = 0$

5) $x^2 - 2x - 2 = 0$ 6) $x^2 + 3x + 3 = 0$

APPENDIX B

CAI QUESTIONNAIRE

Fill out this questionnaire ANONYMOUSLY either while you are doing the lesson or before you leave the lab. PLACE THE COMPLETED QUESTIONNAIRE IN THE BOX PROVIDED IN THE LAB. Your cooperation in completing this form is vital for the evaluation of the software. Thank you.

1) The topic studied ------------------

2) did you have any problem reaching the tutorial or the quiz? If yes, please explain.

3) List below anything about the tutorial or quiz that was unclear or confusing. For example, was a question worded ambiguously? Was your choice of options unclear at any point? Continue your response on the back if more space is needed.

4) The following questions are to access your perceptions of your experiences while using the computer to study this topic.

a) The tutorial was i) helpful, ii) unhelpful, iii) so so, iv) other
IF YOU CHOOSE OTHER, PLEASE EXPLAIN.

b) The experience was i) pleasant, ii) unpleasant iii) other
IF YOU CHOOSE OTHER, PLEASE EXPLAIN.

c) The quiz measured your knowledge & understanding of the topic i) fairly ii) unfairly iii) other
IF YOU CHOOSE OTHER, PLEASE EXPLAIN.

Appendix C

DIAGNOSTIC TEST

DIAGNOSTIC TEST

Circle the letter of your choice

1. 2 3 + 4 5 =

   a) 50 b) 26 c) 90 d) 70

2. $(-3)^4$ =

   a) -81 b) 12 c) -12 d) 81

3. $(6x^2 - x - 3) - (4x^2 - 3x + 5) =$

   a) $2x^2 + 2x - 8$ b) $2x^2 + 2x + 2$
   c) $2x^2 - 2x + 8$ d) none of these

4. $(3x - 4y)(2x + 3y) =$

   a) $6x^2 + xy - 12y^2$ b) $6x^2 - xy - 12$

   c) $6x^2 + 12xy - 12y^2$ d) $6x^2 - xy - y^2$

5. The completely factored form of $4x^2 - 25$ is

   a) $(2x-5)^2$ b) $(2x-5)(2x+5)$
   c) $(2x+5)^2$ d) none of these

6. The completely factored form of $4x^2 - 28x - 72$ is

   a) $4(x+2)(x-9)$ b) $2(2x^2 - 14) - 72$
   c) $2(2x+2)(x+9)$ d) none of these

7. If $3x+14=7x-9$, then $x=?$

   a) 1/2 b) 5/4 c) 23/4 d) 23/10

8 "Two less than three times a number is 19." When translated into a mathematical expression, this statement becomes...

   a) $2-3x=19$ b) $2x-3=19$ c) $3x-2=19$
   d) $3x+2=19$

9 The area of a circle with a circumference of 10 cm is

Note: $C = 2\pi r$ and $A = \pi r^2$

a) 25 b) $25/\pi$ c) 100
d) 100π

FOR THE REST OF THE TEST SHOW YOUR WORK FOR EACH QUESTION.

*10) Multiply these complex numbers.

$(5 - 4i)(7 + 2i) =$

*11) Divide the following complex numbers.

$(-2 + 5i)/(7 + 4i)$

*12) Solve the following system of linear equations by using the <u>addition method</u>.

$3x - 5y = 21$

$2x + 4y = -8$

*13) Given the equation $y = -2(x - 3)^2 + 5$.

a) What are the coordinates of the vertex?

b) What is the equation of the line of symmetry?

c) Is there a maximum value of y?
If so, what is it?

d) Is there a minimum value of y?
If so, what is it?

*14) For the parabola $y = 3(x + 2)^2 - 4$, replacing the number "-4" with "+5" will have what effect on the parabola is to

a) move it down   b) move it right   c) move it left

d) move it up   e) narrow it   f) widen it

APPENDIX D

DIRECTIONS FOR USING THE SOFTWARE TUTORIAL PACKAGE

Spring, 1988

Notes for Computer-Assisted Instruction

General Information

You are part of a group that will study three topics on the Apple computers in the lab in room 301 of Curry Hall. See the map below for the location of Curry Hall. The software is very user friendly and there will be a consultant present to assist you.

****
***

PLEASE FILL OUT A COPY OF THE SURVEY SHEET AS YOU DO EACH LESSON ON THE COMPUTER. COPIES ARE AVAILABLE IN THE LAB.

****
***

To boot-up a disk, (ie., to load the program), put the disk into drive #1 with the label side up and towards you. Push down the tab on the front of the disk drive. Turn on the TV monitor by using the button on the top right of the monitor. Turn the computer on by using the on/off toggle switch at the left side of the back of the computer. The disk will automatically be loaded and you are ready to go! MAKE SURE THAT THE CAPS LOCK KEY IN LOWER LEFT HAND CORNER IS

DOWN! IN ALL OF THE CAI LESSONS THE COMPUTER WILL LOAD THE DISK.

If you wish to change an answer BEFORE you have hit the return key, you can use the cursor-left key (located in the lower right hand part of the keyboard) to delete one letter at a time. The minus key is located to the right of the zero key in the top row. The shift key is NOT needed to type a minus sign.

TOPIC 1: Complex numbers.

(This relates to Section 1.4 in your text)

Boot-up the Intermediate Algebra disk, in the manner explained above. The Main Menu will be displayed as follows:

Main Menu

1. Coordinate Geometry Menu
2. Polynomials and Factoring Menu
3. Radicals and Complex Numbers Menu
4. Quit program

Select option 3 (Radicals & Complex Numbers) from the main menu. The screen will clear and the following submenu will appear:

Radicals and Complex Numbers Menu

1. Radical Expressions
2. Multiplying Complex Numbers
3. Dividing Complex Numbers

Now, select option 2 (Multiplying Complex Numbers) from the submenu. The screen will again clear and the following menu will appear:

Multiplying Complex numbers

1. Tutorial
2. Quiz
3. Return to main menu

*** Finally, to study the multiplication of complex numbers, select the tutorial (option 1) and study the multiplication of complex numbers until you feel confident you understand it well. When you select the tutorial option, the computer will ask you if you are sure. Just press the'y' key to indicate yes. The lesson is now loading. (When the red light on the disk drive goes out, it is done loading.) When the lesson has been loaded, a message will be displayed on the screen saying "Get ready to study multiplying complex numbers". Hold the shift key down and hit the '?' key, located in the lower right hand part of the keyboard, to begin the lesson with a worked-out example.

NOTE: A LIST OF OPTIONS APPEARS AT THE BOTTOM OF THE SCREEN. DURING A TUTORIAL OR QUIZ YOU MAY REQUEST TO SEE A WORKED OUT EXAMPLE SIMPLY BY PRESSING THE '?' KEY. YOU SHOULD ALWAYS TYPE a shifted '?' AT THE START OF A NEW LESSON TO SEE HOW THE PROBLEMS WILL BE DISPLAYED BY THE COMPUTER. IF YOU TYPE 'SHIFT ?' IN THE MIDDLE OF WORKING OUT AN EXERCIES, THE COMPUTER WILL GIVE YOU A HINT OR HELPFUL COMMENT ON WHAT TO DO NEXT. THE COMPUTER WILL COUNT ASKING FOR THIS HELP AS AN MISTAKE IN ITS RECORD OF YOUR PERFORMANCE. THEREFORE, DON'T ASK FOR HELP IN THE MIDDLE OF A QUIZ QUESTION.

NOTE: The method used to multiply complex numbers is the F-O-I-L method. Thus, the problems in this tutorial are presented in the following format.

(-5 + 6I)(2 - 5I)

= □ I I I

Enter the part of the answer where the blinking cursor is and hit the return key. The cursor will move to the next part on the answer in the order one gets from using the F-O-I-L method for multiplying. Keep this in mind as you enter the various parts of the answer. For this particular we would enter -10 + 25I +12I -30I^{2}. You are then prompted to simplify this answer by combining the two middle terms and replacing the I^2 with -1. Thus, you would enter 37 as the coefficient of I and replace -30I with 30.

*** After you have finished studying the tutorial, hit the escape key, which is located in the upper left hand corner of the keyboard. The results of your work will be displayed. Hit 'n' in response to the question of printing the results. The computer is not connected to the printer, so the results can't be printed.

Then take the quiz by selecting the quiz option from the Multiplying Complex Numbers Menu. You'll see a message "Get ready to take a quiz on multiplying complex numbers". Hit a key to get started with the quiz. You also need to hit a key after the completion of each quiz question in order to go on to the next problem. You will be given a ten-question quiz, with problems presented in the same format as in the tutorial. Remember that typing '?' will display a worked out example for you if you have not begun working a problem, and it will display a hint if you are working on a problem. <u>Have the lab consultant or myself record your score before you go on</u>.

<u>IMPORTANT</u> When you have completed the quiz on multiplying complex numbers, choose option 3 (return to main menu) and then choose option 3 (Radicals & Complex Numbers Menu) again and select option 3 (Dividing Complex numbers). In this section, fractions like 20/5 should be entered as an integer; in this case the number 4 would be entered for the value of 20/5. Study the tutorial long enough to master this concept and take the quiz when you are ready. REMEMBER that after a "Get ready ..." message, you have to hit a key to get started. Have the lab consultant or myself record your quiz grade before you go on. RETURN TO MAIN MENU. READ THE FOLLOWING BEFORE CHOOSING THE LESON ON COMPLETING THE SQUARE.

TOPIC 2: Completing the square.

(This also relates to Section 1.5 in your text.)

NOTE: In a problem like "What is the third term needed in $x^2 + 10x$ to make a perfect square?", the computer would expect you to type 25. Another type of problem in this section has the following format:

$(x^2 - 6x \qquad) + 3.$

You are expected to enter the two terms, that go inside the parentheses, one at a time. For this problem you would type 9 and hit the return key, then type -9 and hit return again. At this point the screen would contain $(x^2 - 6x + 9 - 9) + 3$.

You would be prompted for further responses, such as the result of combining the -9 and the +3 and rewriting x^2 -6x +9 as a perfect square.

NOTE: When a problem involves fractions, type them in the form 25/4, 9/16, etc. Don't enter decimal numbers or mixed numbers.

*** Select option 2 (Polynominals & Factoring menu) from the main menu and select option 1 (Completing the Square) from the submenu. As before, study the tutorial (doing at least 10 problems) and then take the quiz when you feel ready. Have the lab consultant or myself record your score. THEN TURN OFF THE COMPUTER. This will make booting up the Introductory Algebra disk easier.

TOPIC 3: Linear Equations.

(This relates to Section 1.5 in your text.)

NOTE: It is necessary to enter one part of the answer at a time, hitting the return key after typing each part. Also, adding a negative number is the same as subtracting. For example, the computer may ask you what number has to be added to 3x + 25 = 8 to get all of the constants on the right. You would answer with -25, because adding -25 is the same as subtracting 25.

You will be prompted by the computer for what to type at any stage of a problem. When you complete a problem, the computer automatically goes on to another problem. You will have to type the letter 'x' as well as the coefficient when entering your answers in this lesson.

*** Boot-up the Introductory Algebra disk (As explained on page one). The main menu will appear on the screen:

Main Menu

1. Solve equations menu
2. Factoring menu
3. Simplifying expressions menu
4. Solving linear systems menu.
5. Quit program

Select option 1 (Solve equations menu) from the main menu. The screen will clear and the following submenu will appear:

Solving equations menu

1. Solving linear equations
2. Using parentheses

Select option 1 (Solving linear equations) from the submenu. As above, study the tutorial (you should solve at

<u>least 9 problems in this tutorial since there are a couple of different kinds of problems presented</u>) and take the quiz when you feel ready. Have the lab consultant or myself record your score before you go on.

<u>IMPORTANT</u> Go back to the Solving Equations Menu, option 1, and then choose option 2 (Using parentheses). This is also required. As before, do at least 5 problems in the tutorial and take the quiz when you feel ready. Have the lab consultant or myself record your score before you go on.
TURN COMPUTER OFF.

APPENDIX E

PRETEST

NAME

Version A

* CIRCLE THE LETTER OF THE CORRECT ANSWER FOR PROBLEMS 1 THROUGH 7.

1) The terms needed to complete the square for

$(x^2 + 10x \qquad) + 3$ are:

a) +5, -5   b) +100, -100   c) +25, -25

d) none of the above.

2) The product $(-2 + 7i)(5 + 3i)$ is:

a) $11 + 29i$ b) $-31 + 29i$

c) $11 - 29i$ d) $-31 - 29i$

3) $x^2 - 5x + (25/4) =$

a) $(x - 5/2)^2$ b) $(x + 25/4)^2$ c) $(x + 5/2)^2$

d) $(x - 25/4)^2$

4) The quotient (9-7i)/(1-3i) is equal to:

a)-6/5 + 2i b) -15/4 - (15/2)i

c) 3 - 2i d) 3 + 2i

5) According to the method of completing the square, the third term

necessary to make x^2 - 7x into a perfect trinomial square is:

a) + 49 b) +49/4 c) -7/2 d) -49

6) The solution to the linear equation 3x + 7 = -11 is:

a) -18 b) -4/3 c) -6 d) 6

7) Find the solution to 3(2x + 3) + 5 = 3 - 5x

a) -5/11 b) -5 c) -11 d) -1

WRITE EITHER TRUE OR FALSE IN THE BLANK FOR PROBLEMS 8 THROUGH 14.

------ 8) (True/False)

$$\frac{3 + i}{7 - 2i} = \frac{(3 + i)(2 + 7i)}{45}$$

------ 9) (True/False)

$(4 - 3i)(2 + i) = 5 - 2i$

------ 10) (True/False)

According to the method of completing the square, given the expression $x^2 + x$, the third term needed to make a perfect square is 1/2.

------ 11) (True/False)

The solution to $5(2x - 3) + 7 = 3x + 6$ is 2.

------ 12) (True/False)

In order to complete the square for

$(x^2 - 6x \quad) - 7$ we need to add and subtract 3.

------ 13) (True/False)

The solution to the linear equation $5x + 2 = 9$ is $x = 7/5$.

------ 14) (True/False)

$x^2 - 9x + (81/4) = (x + 9/2)^2$.

For the next group of problems fill in the blank with an appropriate answer.

15) The product of 2 + i times 3i, written in the form a + bi, is ____________________.

16) The quotient $\dfrac{7 - 3i}{1 + 4i}$ is equal to ______________.

Express answer in the form a + bi.

17) The solution to 5x + 17 = 3x - 3 is ____________________.

18) The solution to 4(3 - 2x) + 26 = 3x + 5 is ________________.

19) The third term needed to make $x^2 - 3x$ a perfect

square is ______.

20) Fill in the blanks with the two appropriate terms needed to complete the square. Include the sign of each term.

$(x^2 - 16x$ _____ _____$) + 4$

21) Fill in the blank with the appropriate term to make the equation true.

$x^2 - 11x + (121/4) = (x$ _____ $)^2$.

APPENDIX F

POSTTEST

SS # ______________________________

NAME ______________________________

Version B

* CIRCLE THE LETTER OF THE CORRECT ANSWER FOR PROBLEMS 1 THROUGH 7.

1) Find the solution to $5(4x - 3) + 11 = -22 + 2x$.

a) $-5/3$ b) 2 c) -1 d) 3

2) The product $(-4 + 3i)(2 + 5i)$ is:

a) $-23 - 14i$ b) $7 - 14i$

c) $23 + 14i$ d) $-7 - 14i$

3) The terms needed to complete the square for $(x^2 - 12x \quad) + 5$ are:

a) $+6, -6$ b) $+36, -36$ c) $+144, -144$

d) None of the above.

4) $x^2 - 3x + (9/4) =$

a) $(x + 3/2)^2$ b) $(x - 9/4)^2$ c) $(x + 9/4)^2$
d) $(x - 3/2)^2$

5) The solution to the linear equation $5x - 8 = 12$ is:

a) 4/5 b) -5/4 c) -3 d) 4

6) According to the method of completing the square, the third term

necessary to make $x^2 - x$ into a perfect trinomial square is:

a) 1/4 b) 1/2 c) 1 d) -1

7) The quotient (5-3i)/(2-5i) is equal to:

a) -5/29 + (19/29)i b) -5/21 - (31/21)i

c) 25/29 + (19/29)i d) 25/29 + (31/29)i

WRITE EITHER TRUE OR FALSE IN THE BLANK FOR PROBLEMS 8 THROUGH 14.

----- 8) (True/False)

$x^2 - 10x + 25 = (x - 5)^2$

----- 9) (True/False)

The solution to the linear equation 3x + 7 = 9 is x = 2/3.

----- 10) (True/False)

$(3 - 5i)(5 + 2i) = 5 - 19i$

----- 11) (True/False)

According to the method of completing the square, given the expression $x^2 + 5x$, the third term needed to make a perfect square is 5/2.

----- 12) (True/False)

$$\frac{2 + 4i}{5 - 3i} = \frac{(2 + 4i)(5 - 3i)}{16}$$

----- 13) (True/False)

The solution to $3(4x - 1) + 4 = 10x + 5$ is 1.

----- 14) (True/False)

In order to complete the square for

$(x^2 - 4x \quad) - 3$ we need to add and subtract 4.

*** FOR THE NEXT GROUP OF PROBLEMS FILL IN ***

*** THE BLANK WITH AN APPROPRIATE ANSWER. ***

15) Fill in the blanks with the two appropriate terms needed to complete the square. Include the sign of each term.

$(x^2 - 8x$ _____ _____$) + 6$

16) The third term needed to make $x^2 - 9x$ a perfect square is __________.

17) The solution to $5(1 - 3x) + 15 = 2x + 54$ is ____________.

18) The solution to $4x + 11 = x - 7$ is

19) Fill in the blank with the appropriate term to make the equation true.

$x^2 + 20x + 100 = (x \_\_\_\_)^2$

20) The product of $3 + 2i$ times $5i$, written in the form $a + bi$, is ________________.

21) The quotient $(5-2i)/(4+3i)$ is equal to ________________.

Express answer in the form $a + bi$.