AN ABSTRACT OF THE THESIS OF

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Abstract approved: ______________________
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The hypotheses of this study stated the following: Interaction with the computer game will significantly increase the class means in: (1) mathematical achievement, (2) attitudes toward mathematics, and (3) graphing ability in high school advanced algebra.

ALGEBRA ARCADE is a computerized simulation game played on a coordinate grid. One can play against one's self or another player. Greater knowledge of graphing functions results in a higher score. The game closely resembles commercially marketed videogames.

Eleven teachers, at seven high schools, each taught a control and an experimental class. Four hundred twenty-three students took both attitude tests and four hundred twenty-five students took both achievement tests.

Students were pretested and posttested with selected scales from the _Fennema-Sherman Mathematics Attitudes Scales_ and equivalent forms of the Intermediate Algebra portion of the _Descriptive Tests of Mathematics Skills_ (College Board) to measure mathematical achievement. Graphing ability was measured by the score on the Coordinate Plane and Graphing part of the Intermediate Algebra test. The experiment lasted four weeks and centered around the Quadratic Functions unit. The experimental group played ALGEBRA ARCADE in lieu of the in-class assignment during the 15-20 minutes at the end of class. The out-of-class assignment was the same.

Analysis revealed: (1) a significant difference, at the .08 level, in change of class means on mathematical achievement favoring use of the computer game, (2) very little difference (p=.38) in the change of class means on attitudes toward mathematics, and (3) a significant difference, at the .005 level, in change of class means on graphing ability favoring the use of the computer game.

Analysis of the other parts of the Intermediate Algebra test and the specific attitude scales revealed no significant differences; however, a negative trend was noted in the areas of Solving Equations and Inequalities and Effectance Motivation in Mathematics.

Selected Effects of a Computer Game on Achievement, Attitude, and Graphing Ability in Secondary School Algebra

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To Margie, Beth, and Tina

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I. INTRODUCTION

Humankind is on the verge of another major revolution which Alvin Toffler (1980) describes as the Third Wave. For centuries the First Wave, Agriculture, was a way of life. Then came the Second Wave, the Industrial Revolution. The Second Wave, which has lasted about a century is now beginning to ebb rapidly, being replaced by the Third Wave, the Information Age. In only forty short years informational technology has gone from a computer which occupied an entire room to microcomputers that can be held on your lap. The reduction in size and the corresponding reduction in cost has now made computers affordable to the majority of families in the United States.

The advent of the Information Age, with all its new technology, has affected everyone in our modern society. People of all ages are familiar with data bases on which information about them is stored from the moment they are born. Young people are brought up using such computer games as Speak 'n Spell, Dataman, Speak 'n Math, Lil' Professor, and Speak 'n Read. To get any employment one must register with the Social Security Administration. Adults find it hard to function in our society without at least one credit card. Home ownership, along with ownership of an automobile, is virtually impossible without financing. Most of these items require the individual being placed in somebody's data base.

Educationally speaking, we may be witnessing the greatest change in technology since Guttenburg's printing press. But what role has education played or will it play in the Information Age? Computers have been in education since the late 1950's. Until the advent of the microcomputer in the early 1980's, the educational use of the computer was confined to management of the schools (attendance, finances, maintenance) and some computer-assisted instruction using mainframe computers.

It was predictable that a logical area like mathematics would be among the first subjects to implement computer-assisted instruction. Such noted computer sytems as PLATO (Programmed Logic for Automated Teaching Operation) at the University of Illinois under the direction of Robert Davis, the CBE (Computer-Based Education) Center at Stanford

University under the direction of Patrick Suppes, and TICCIT (Time-shared Interactive, Computer-Controlled Information Television) reported positive effects on learning (Overton, 1981). But the systems were fairly expensive and really not accessible to all schools, since each needed to connect to a mainframe computer. The invention of the microchip (Boraiko, 1982) led to the mass marketing of small, inexpensive microcomputers that allowed education to truly enter the Information Society. The momentum was rapidly growing for support of computers in the nation's schools. The Priorities in School Mathematics (PRISM) Project (NCTM, 1981) reported that 75 per cent of the professional groups sampled and 80 per cent of the lay people sampled believed that the use of computers and other technology should be increased during the 1980's. Mathematics education (and education in general) was being being pushed into the Information Age. The next three NCTM Yearbooks (1981,1982,1983) each contained articles on incorporating computers into the mathematics classroom. Last year, the entire yearbook (NCTM, 1984) focused on computers in mathematics education.

Since mathematics was one of the pioneer subjects used for computer-assisted instruction, it was felt that mathematics education would lead the way in both implementing the direct teaching of computers and incorporating computer-assisted instruction into the curriculum. The mathematics teaching profession has supported this position. The National Council of Teachers of Mathematics issued <u>An Agenda for Action: Recommendations for School Mathematics in the 1980's</u> (1980). Among its recommendations was: "Mathematics must take full advantage of the power of calculators and computers at all grade levels" (p. 1). Other recommendations included: integrating computers into the mathematics curriculum and the development of diverse, stimulating, and imaginative educational materials. A natural way for people, especially young people, to be introduced to the computer is by playing games on it. In the early 1980's videogames hit the market and captivated the attention of everyone, especially the young. After seeing the stimulating and motivating effects of videogames, many producers of educational software began including games in their software packages. Today educational gaming is an accepted way of learning in the mathematics classroom. Videogames have found their way into many classrooms. Families and school systems are heavily investing in microcomputers and the software which the manufacturers say is educationally sound. Are the software producers correct? If these claims are accurate, what are the implications for mathematics education? In many ways the educational community failed to realize the full potential of television, will it do the same for computers?

The Problem

The purpose of this study was to investigate several hypotheses concerning the educational value of the videogame ALGEBRA ARCADE. ALGEBRA ARCADE (ISBN 0-534-01476-3) is marketed by Wadsworth, Inc. There are many programs on the market which demonstrate graphs when given an equation, but this program integrates that ability into a videogame format. It goes beyond drill and practice and involves a simulation of an adventure into the coordinate plane where the player(s) are attempting to make their graph catch the Algebroids placed in position by the computer while not hitting the Graph Gobbler which is controlled by the computer. This program is more than the traditional computer-assisted instruction (CAI) which merely gives a question, provides hints if the player does not know the answer, and then finally gives the correct answer while keeping track of the number of correct answers. It requires a higher level of cognitive skills than most videogames currently on the market. This type of computer augmented learning fits into the category of adjunct computer-assisted instruction as defined by Chambers and Sprecher (1980).

There also is some concern about the claims made by the distributor of ALGEBRA ARCADE. As an example of these claims, one is referred to a catalogue published by The Micro Center entitled Focus on Quality 1984. On page three the advertisement for ALGEBRA ARCADE reads, in part, that the game is "a sophisticated strategy game for one or two players that will have your students burning to plot equations." The advertisement goes on to say: "ALGEBRA ARCADE builds both a concrete and intuitive appreciation for the relationship between graphs and their equations." Thus, the manufacturer of this computer game is asserting that the game not only improves graphing skills, but also improves the student's attitudes toward mathematics.

The problem then, in essence, is to determine the educational value of the videogame ALGEBRA ARCADE. Will the game increase the student's mathematical ability? Does the game improve the student's graphing ability? Is the student's ability to work with functions increased? Does the utilization of this game in the classroom affect attitudes and interests toward mathematics? To maximize the game's potential the game was used during a unit on quadratic functions in high school advanced algebra classes. The functions the students were allowed to use varied as the study progressed.

Statement of the Hypotheses

The three hypotheses stated in the null form are:

H_1: There is no significant difference in the change of mean mathematical achievement of high school advanced algebra classes that include the interaction with the computer game and high school advanced algebra classes without interaction with the computer game.

H_2: There is no significant difference in the change of mean attitudes toward mathematics of high school advanced algebra classes that include interaction with the computer game and high school advanced algebra classes without interaction with the computer game.

H_3: There is no significant difference in the change of mean graphing ability of high school advanced algebra classes that include interaction with the computer game and high school advanced algebra classes without interaction with the computer game.

Need for the Study

Begle (1979) encouraged research along the lines of attitudes toward mathematics. In general, Begle concluded, findings in CAI have been positive with higher cognitive skills showing less significance and no deleterious affects on student attitudes. He concludes: "This seems to be another case in which further research would be reasonable" (p. 118). Speaking of computers, he states: "This is clearly an area about which we need more information, and a good deal more experimentation is called for" (p. 118).

In a report prepared for ERIC, Suydam (1981) reviews the past support for microcomputers and mathematics instruction. Among her conclusions she states that "encouragement and support should be given to research on computer uses" (p. 2).

Despite research on visualization and learning (Winn, 1982; Nugent, 1982), we are only at the infancy of research concerning this learning style. Dr. Mary Alice White, Professor of Psychology and Education at Teachers College/Columbia University and Director of the Laboratory for the Psychological Study of Telecommunication at Teachers College, makes some excellent points in an interview she gave to _Educational Technology_ (Sept., 1981). Dr. White's main point is that we have only begun to understand how people learn through visualization (in this case the television or video monitor), but we still are unsure how to determine what the person learned through visualization. She questions whether we even have the correct instruments to measure what is learned through visualization. Are paper and pencil tests an appropriate testing instrument?

To date there has been very little experimental research completed on the educational effects of videogames such as ALGEBRA ARCADE. The research that has been done on using computers in the mathematics classroom involves mostly drill and practice type games. Henry (1974) and Moore (1981) researched games in the classroom using the games of EQUATIONS and TAC-TICKLE at the middle school and computerized games of POE and EQUATIONS in an entry-level intermediate algebra course at the university, respectively. A search through _Dissertation Abstracts International,_ since 1975, using key words revealed sixty-four other abstracts of possible interest. Surveying the sixty-four abstracts, the list was narrowed to eleven which were of primary interest. While each of the eleven abstracts contained some useful information, none of them provided revealing insight regarding the proposed experiment. The two that seemed the closest were Signer (1982) and Gallitano (1983). Both used computers to teach the advanced algebra classes in their study, but Signer totally immersed the experimental class by teaching them programming and then having the students use the computer in their class work, while Gallitano compared the effectiveness of the students using a computer and calculators against using the calculator alone.

A search of the literature indicated that some of the major deficiencies appear to be:

1. lack of experimental research rather than the results of pilot studies done by the game designers;
2. lack of research at the high school level;
3. lack of research involving only students who appear to be succeeding in mathematics; and
4. lack of the consistent results in past research.

There is a general consensus on the need for more research.

Diem (1982) shares his concern over the present situation when he says:

> A critical juncture in the use of computer technology in the schools is rapidly approaching. For the first time, we have a segment of students weaned on computers. They play Pac-Man and Star Avengers as a previous generation played baseball. Their lives are touched daily with a technology absolutely unknown 30 years ago. The opportunity to use it in schools is at hand. Whether the schools will pick up the

> challenge and begin to restructure their ideas so that this technology becomes part of the learning environment is still unresolved, despite the unbridled optimism exhibited in some quarters (p. 21).

Stowitschek and Stowitschek (1984) share their concern over the lack of research in this area. They feel the results comparing the computer to other forms of instruction are "mixed." The superiority of the computer has not been established. Although there is agreement on the computer's potential, studies show little change in student achievement and little savings in time. They suggest that "the first step is to pinpoint the specific situations in which computer technology is beneficial" (p. 30). They go on to say:

> In summary, research on computers and instruction is promising but inconclusive. The research on teacher and classroom use of microcomputers is so meager that it provides little or no information on the major issue-how microcomputers can best be applied in the classroom (pp.31-32).

Finally, they point out:

> A wealth of issues regarding teacher use of microcomputers needs research. ... Previous attempts in education to embrace technology often resulted in disillusionment and ultimately, disuse. Now, however, the entire society appears to embrace computer technology. The sheer scale of the movement, combined with its potential for shaping the future of education, should prompt educators to demand the development of a sound research base (p. 36).

Studies are needed to provide valid and reliable data concerning the affective and cognitive effects of this type of computer game in the high school mathematics class. Within the past five years, CAI has grown at an exponential rate. Research has not been able to keep up with all the changes. This study is a response to that challenge.

Assumptions

The following are the assumptions used in this study:

1. The Intermediate Algebra portion of the *Descriptive Tests of Mathematical Skills* of the College Board is a valid and reliable measure of student achievement in high school advanced algebra. (See Appendices B and C.)
2. The *Fennema-Sherman Mathematics Attitude Scales* are valid and reliable measures of attitudes toward mathematics. (See Appendix D.)
3. Questions 3,14,16,18,21,23,25,27,28, and 30 on Form A and questions 1,14,15,18,20,23,24,25,26, and 27 on Form B of the Intermediate Algebra portion of the *Descriptive Tests of Mathematical Skills* for the College Board are indicators of a high school advanced algebra student's graphing ability. (See Appendices B and C.)

Definition of Terms

The following definitions were used in this study:

1. *Play* is a voluntary activity involving one or more persons.

2. A *game* is an activity in which the player(s) - one or two in this study - are striving to attain some predetermined goal while playing according to a set of predetermined rules.

3. An *educational game* refers to any game designed primarily to enhance learning rather than to entertain.

4. A *strategy game* is defined as an educational game requiring problem-solving in the form of a careful plan or method by the player to achieve a goal or prevent opponents from achieving their goal.

5. A *mathematical game* is an educational game in which mathematical ideas are incorporated into the rules in such a way that the more a player knows about mathematics, the more the player will score.

6. A *computer game* is a game played on the computer. The computer in this study will not be a player, but will randomly place the algebroids and graph gobbler on the playing field.

7. *ALGEBRA ARCADE* is a mathematical computer strategy game (ISBN 0-534-01476-3) marketed by Wadsworth, Inc.

8. A _video arcade game_ is a strategy game which is played on a machine that has a large visual display which shows the player the game board, animated action, and blinks or lights up when a player scores points.

9. _Achievement_ refers to the acquisition of mathematically related knowledge or skills as demonstrated by the scores on the Intermediate Algebra portion of the _Descriptive Tests of Mathematical Skills_ of the College Board.

10. A _videogame_ is "a rule-governed, goal-focused, microcomputer driven activity incorporating principles of gaming and CAI" (Driskell and Dwyer, 1984, p. 11).

11. _Graphing ability_ refers to the acquisition of the skills used to answer questions 3,14,16,18,21,23,25, 27,28, and 30 on Form A and questions 1,14,15,18,20, 23,24,25,26, and 27 on Form B of the Intermediate Algebra portion of the _Descriptive Tests of Mathematical Skills_ of the College Board.

12. An _attitude_ is defined as a learned "emotionally toned predisposition to react in a consistent way, favorable or unfavorable, toward a person, object, or idea" (Dutton and Blum, 1968, p. 259).

13. _Intuition_ is a mental visualization of concepts that seem self-evident. It is holistic or integrative as opposed to detailed or analytic.

14. _Adjunct computer-assisted instruction_ is a

computer program or series of programs which supplements a learning situation (Chambers and Sprecher, 1980).

15. _Primary Computer-assisted instruction_ is a computer program which provides instruction of a substitute or stand alone variety (Chambers and Sprecher, 1980).

16. _Effectance motivation_ is a word phrase coined by R. W. White (1959). White describes it in these terms:

> Our conception must therefore be that effectance motivation is aroused by stimulus conditions which offer difference-in-sameness. This leads to variability and novelty of response and interest is best sustained when the resulting action affects the stimulus so as to produce further difference-in-sameness. Interest wanes when action begins to have less effect; effectance motivation subsides when a situation has been explored to the point that it no longer presents new possibilities (p. 322) ... When this particular sort of activity (behavior which is focused and has the characteristics of exploration and experimentation) is aroused in the nervous system, effectance motivation is being aroused, for it is characteristic of this particular sort of activity that it is selective, directed, and persistent, and that instrumental acts will be learned _for the sole reward of engaging in it_ (emphasis added). ... Effectance motivation similarly aims for the feeling of efficacy, not the vitally important learnings that come as its consequence (p. 323).

Thus, effectance motivation is an intrinsic motivation that causes one to explore and master a particular area. Fennema and Sherman apply White's model to the learning of mathematics.

17. Attitudes toward mathematics refers to the cumulative scores on the following scales of the *Fennema-Sherman Mathematics Attitudes Scales:* Mathematics as a Male Domain, Confidence in Learning Mathematics, Attitude Toward Success in Mathematics, Effectance Motivation in Mathematics, and Usefulness of Mathematics.

Limitations

The limitations are as follows:

1. The study is limited to the students enrolled in the selected advanced algebra classes at the seven high schools selected for the study.
2. The study is limited by the extent to which subjects (students) seriously participate in playing the game.
3. The study is limited by the amount of time the students are given to work in class.

Delimitations

The delimitations are as follows:

1. This study will not attempt to deal with variables associated with a student's experiences with computers.
2. This study does not attempt to evaluate teachers.
3. This study does not attempt to evaluate schools.
4. This study does not attempt to evaluate school districts.
5. This study does not attempt to evaluate individual students.

Design of the Study

The study included eleven teachers at seven different high schools. The teachers all volunteered to be in the study. Each teacher taught at least two classes of Advanced Algebra or Algebra II. One class was designated as the control group and the other class served as the experimental group. In most cases, availability of the computer laboratory determined which of the classes served as the experimental group. If the teacher taught more than two Advanced Algebra or Algebra II classes (two of them taught three classes), it was randomly determined which of the two remaining classes would be the control group. Thus, the study involved eleven teachers and twenty-two classes. Eleven classes in the control group and eleven classes in the experimental group.

The experimental design chosen for this experiment was the Nonequivalent Control Group Design as defined in Campbell and Stanley (1963) and Issac and Michael (1981). The design is depicted below where O = observation and X = treatment.

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O    X    O
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O         O
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Figure 1. Experimental design

This design is actually regarded as a quasi-experimental design since the individual subjects were not randomly assigned from a common population to the experimental and control groups. Instead, the groups constitute a naturally assembled collective, in this case the class, as similar as availability permits but enough different to necessitate a pretest.

Data consisted of two pretests and two posttests given to each individual participating in the study. One pretest and one posttest consisted of the following specific attitudes from the *Fennema-Sherman Mathematics Attitudes Scales:* (1) Mathematics as a Male Domain, (2) Confidence in Learning Mathematics, (3) Attitude Towards Success in Mathematics, (4) Effectance Motivation in Mathematics, and (5) Usefulness of Mathematics. (See Appendix D.) The other pretest and posttest consisted of two different, but equivalent, forms of the Intermediate Algebra portion of the *Descriptive Test of Mathematics Skills* of the College Board. (See Appendices B and C.)

In order to describe and predict the class mean differences between pretest and posttest scores based on a number of possible variables (computer use, sex, grade level, teacher, computer-sex interaction, and computer-grade level interaction) a multiple regression analysis was completed on the data. Each model was tested for the strength of the relationship and a stepwise analysis was performed. As mentioned earlier, the classes were as similar as availability permitted.

Organization of the Remainder of the Study

The remainder of this study is separated into four parts. Chapter II reviews the literature regarding the role of intuition in learning mathematics, computers in mathematics education, computer-assisted instruction, educational gaming in mathematics, attitudes toward mathematics, and sex-related differences in mathematics. Chapter III presents an analysis of the game ALGEBRA ARCADE and the measuring instruments used along with the details of the procedure used in the study. Chapter IV provides an analysis of the data gathered and indicates the results of the tested hypotheses. Chapter V concludes the study with a summary, conclusions, and recommendations for further study.

II. REVIEW OF THE LITERATURE

A review of the literature, as it pertains to computer-assisted instruction and educational gaming in mathematics, by necessity, involves investigations into other areas of concern to mathematics educators. Based on the knowledge that positive interaction between the learner and the computer is necessary for learning to occur, this chapter is divided into the following subsections: (1) Introduction, (2) The Role of Intuition in Learning Mathematics, (3) Computers in Mathematics Education, (4) Computer-assisted Instruction in Mathematics, (5) Educational Computer Gaming in Mathematics, (6) Attitudes Toward Mathematics, and (7) Sex-related Differences in Mathematics.

Introduction

Throughout history, humankind has viewed play as part of the growing up process. Although the importance of play has varied from society to society, most societies recognized that it served a role in the learning process. For the most part, the role of play was only crucial for young children. It was certainly not appropriate for one involved in formal education

(Glickman, 1981). It was not until the progressive movement began to influence education, around the turn of the twentieth century, that play was suggested as an appropriate way to learn some subjects offered by the American educational system. Such reformers as Peirce, James, and John Dewey (1963) drew their ideas from the views set forth by Comenius, Rousseau, Pestalozzi, and Froebel. These ideas were picked up by such people as Montessori and Cuisenaire. Although the idea of game playing to learn a subject was advanced, the American educational system was reticent to use the approach.

Von Neumann and Morgenstern (1944) were among the first to publish work on game theory. The playing of games began to take on a new role, but their work seemed to be important only for the military and business rather than education. At this time two important events were taking place. First, researchers and mathematicians began to realize that many games could be analyzed mathematically. Secondly, the first computers were being produced. Eventually these computers would have the capabilities of simulating games. Through the early work in Artificial Intelligence (AI), computers were programmed to play such games as chess. People in the academic, military, and business fields were beginning to change their attitude toward game playing.

The Role of Intuition in Learning Mathematics

With the push for the modern mathematics curriculum in the mid 1960's and the theories advanced by such famous educational psychologists as Piaget, Bruner, and Dienes, the idea of using game playing to learn mathematics began to enter many American classrooms. Piaget's stages of learning (1962,1963) lent credence to the importance of play, especially in the early stages; Bruner (1966,1976) produced his theories on discovery learning; and Dienes (1960,1963,1964,1973a,1973b,1973c) developed his theoretical model of learning which involved playing with a concept before one was actually able to understand and apply the concept. Most of the games brought into the classroom at this time could be classified as mathematical or strategy type board games. Mathematical games required some knowledge of mathematics in order to win the game. Strategy games could be won by developing a winning strategy which did not have to involve any specific knowledge of mathematical content. The latter type game would involve Polya's idea of problem solving (1945) and discovery (1962). Dreyfus (1984) picks up this theme by comparing the ideas of Skemp, Dienes, Biggs, and

Collins and remarking how similar they all are. They all feel "the formation of mathematical concepts is conditional on the learner's active involvement with the subject matter during the process of learning" (p. 239). All three theories "indicate that the required mental activity on the learner's part can be stimulated by suitably structured (re)presentations of the concepts to be learned" (p. 239). What more perfect object to convey this to the student than through a computer, observes Dreyfus.

While play in itself is important, it also serves a critical role in the development of intuitive concepts. Poincaré (1956) and Hadamard (1949) both attempt to document the role that intuition has played in the area of mathematical creation. They make a strong case for the fact that mathematical ideas are not produced in a neat logical manner, in most cases the idea seems "to come from nowhere." Kline (1958) reinforces this idea when he asserts:

> Since even the great mathematicians think intuitively, we must all be sure that the intuitive meaning of each mathematical idea or procedure is made intuitively clear to the student (p. 426).

But what is intuition? What makes a concept intuitive? Bruner (1960) states that: "it is even unclear what constitutes intuitive understanding" (p. 55). He then goes on to say that intuition is used with two rather different meanings in mathematics. First, one "is said to think intuitively when having worked for a long time on a problem, he rather suddenly achieves the solution, one for which he has yet to provide a formal proof" (p. 55). Secondly, one "is said to be a good intuitive mathematician if, when others come to him with questions, he can make quickly very good guesses whether something is so, or which of several approaches to a problem will prove fruitful" (p. 56). He concludes that with respect to variables affecting intuitive thinking, we can only conjecture. In delivering the Terry Lectures of 1962 at Yale University, Polanyi (1967) explored and called for action in "the tacit dimension"- intuition. DeBono (1967,1970) explores many of the same ideas in his discussion on lateral thinking. Fishbein (1981) uses the term _intuitions_ as referring to mental representations of facts that appear self-evident. This definition is also used by Dreyfus and Eisenberg (1982). Fishbein, et. al. (1981) go even further by stating that: "accepting intuitively a certain solution or a certain interpretation means to accept it directly without (or prior to) resorting explicitly to a detailed justification" (p. 491). They follow this with: "An intuition is not reducible to a pure perception. An intuition is always an interpretation"

(p. 492). Wittman (1981) presents an excellent model (p. 394) in which he distinguishes between intuitive and reflective thinking. Davis and Hersh (1981) attempted to list the various meanings and uses of the word intuitive. They came up with the following list: (1) the opposite of rigorous, (2) visual, (3) plausible or convincing in the absence of proof, (4) incomplete, (5) relying on a physical model, and (6) holistic or integrative as opposed to detailed and analytic. All of these are actually notions of what intuition is. Samples (1976) and Samples, et. al. (1977) also worked with the notion of intuition and related it to split brain theory. Intuition becomes a right brain function and rationale a function of the left brain. What becomes apparent is that everyone has an idea or notion of what intuition means, but nobody has an exact definition. Davis and Hersh go so far as to state:

> Perhaps it would be foolish and self-defeating but a teacher _can_ teach mathematics and a researcher can write papers without paying attention to the problem of intuition. However, if one is not doing mathematics, but rather is trying to look at people who are doing mathematics and understand what they are doing, then the problem of intuition becomes central and unavoidable (p. 393).

They then use a lesson on the fourth dimension (a subject unfamiliar to most people, including many mathematicians) to illustrate their notion of intuition and intuitive concepts. Applying this model of intuitive development set forth by Davis and Hersh to a high school advanced algebra class, the unit on quadratic functions could serve the same role as the fourth dimension in examining intuition as presented in the learning theories advanced by Piaget, Bruner, and Dienes. The quadratic functions unit is new material for the high school advanced algebra student (just as the fourth dimension is to most mathematicians) and, hence, needs to be prefaced with some intuitive development of the ideas.

Computers in Mathematics Education

The literature is abundant in the last four years with prescriptions of how to implement a successful computer program into the schools and what educators should be doing with the computers. Lesgold and Reif (1982) describe where educators should be going with computers in the schools. The National Council of Teachers of Mathematics recently published The Impact of Computing Technology on School Mathematics: Report of an NCTM Conference (NCTM, 1984). Authors such as Taylor (1980) and Fey (1984) present their ideas on where schools should be implementing computers in the mathematics curriculum. The ERIC/SMEAC Mathematics Education Fact Sheet No. 4 (1981) along with articles by Camp and Marchionini (1981), Dekkers and Donatti (1981), Gawronski (1982), Bork, et. al. (1983), Braun (1983), Weller (1983), Wilkinson (1984), Salisbury (1984), and Ediger (1985) all offer insight into what educators should be doing with computers in mathematics education. The suggestions of these authors include: (1) using simulations to develop problem solving skills, (2) allowing the computer to do some of the more tedious calculations, (3) taking advantage of the full potential of hi-resolution graphics, (4) using the computer to build intuition for problem solving, (5) teaching programming, and (6) integrating the computer into the core of the mathematics curriculum.

These are but a few of the hundreds of articles published in the last five years. All one needs to do is look in the recent issues of such publications as the *Mathematics Teacher*, the *Arithmetic Teacher*, *The Computing Teacher*, *Journal for Computers in Mathematics and Science Teaching*, or *Educational Technology* to get ideas on implementing computers into the mathematics curriculum.

Computer-assisted Instruction in Mathematics

Until the 1980's computer-assisted instruction was done only on mainframe computers. The most noted projects were done at the University of Illinois on a system called PLATO (Program Logic for Automated Teaching Operation) which began in 1959 and the work done at Stanford University's Computer-Based Education (CBE) Center under the direction of Patrick Suppes in the early 1970's (Hirschbuhl, 1980). The main difference between the projects is that on the Stanford project the computer controls the pace of the instruction, while PLATO is interactive and allows the student to control the pace of the instruction. Then with the 1980's came the video arcade game craze and the microcomputer. The video arcade game held the attention of the older children just as "Sesame Street" and other popular educational television programs held the attention of younger children. The microcomputer industry began to produce programs which simulated what the video arcade games were doing. With the decline in prices, microcomputers began appearing in both the home and the classroom. Many educators began to see the advantages of using the graphics offered by the microcomputer. They wrote programs to demonstrate the concepts they were teaching. With modern animation, the idea of visual imagery in learning which was cited by Richard R. Skemp (1973,1979) and the iconic level of Bruner (1966) began to take on a new perspective. Many of the professional groups began getting involved by emphasizing the need for using computers to promote both computer literacy and as a tool in the mathematics learning environment. The Position Paper on Basic Skills published by the National Council of Supervisors of Mathematics (1977) was the first to include computer literacy in their list of basic skills. This report was followed quickly by the National Advisory Committee on Mathematics Education (NACOME) report (1977) which again mentioned the need for computer literacy. The following year, the National Council of Teachers of Mathematics (NCTM) endorsed a similiar position statement. This position was reinforced in the NCTM's An Agenda for Action: Recommendations for School Mathematics of the 1980's (1980).

With the advent of the microcomputer, the work with programmed learning which began with B. F. Skinner's machines (Skinner, 1968) has taken on new dimensions. Drill and practice activities with immediate feedback can be found for any of the microcomputers presently on the market. Strategy and simulation games, which purport to be educational, are mass marketed throughout the world. Continued work in the area of Artificial Intelligence (AI) is producing educational games which require more cognitive thinking on the part of the game player. Papert (1980) is attempting to give new insight and meaning to Piaget's views through his work with "children, computers, and powerful ideas" at the Artificial Intelligence Laboratory at the Massachusetts Institute of Technology. Kelman, et. al. (1983) document many of the ways that the computer is currently changing the teaching of mathematics. Roberts and Park (1983) provide insight into a new area called intelligent computer-assisted instruction (ICAI). They predict that ICAI will become commonly used in the next ten to fifteen years. Futurists (Evans, 1974; Toffler, 1980; Deken, 1981; Naisbitt, 1982) are predicting major changes in the area of education. Most feel children will not be attending a classroom, but will receive their education at home primarily by interacting with a computer. With the predicted decentralization, the "electronic cottage" has the potential to become reality. Shostak (1981) sees future education as decentralized. It will be carried out in the home on an individual basis through computers, with heavy reliance on data bases. Companies like Wicat Systems (Heuston, 1983) are already turning to the home market.

Chambers and Sprecher (1980) reviewed the literature and came up with the following conclusions: (1) the use of CAI either improved learning or showed no difference when compared to the traditional classroom approach; (2) the use of CAI reduced learning time when compared to the regular classroom; (3) the use of CAI improved student attitudes toward the use of computers in the learning situation; and (4) the development of CAI courseware following specified guidelines can result in portability combined with acceptance and use by other faculty. They found indications that low aptitude students profit more from CAI. There were also indications that retention rates for all students using CAI may be lower than for students using the traditional means of learning.

Saunders and Bell (1980) assessed the effect of weekly computer enhancement assignments on achievement and attitude in second year algebra. Their conclusion was that the computer lessons had little or no effect on the areas investigated.

Thomas (1979) reviewed the studies of achievement, attitude, retention, and time saving on CAI and concluded: (1) students exposed to CAI performed at a higher level than those not exposed, (2) the evidence of no difference between CAI taught and traditionally taught students predominated when CAI was used as a *replacement* for classroom instruction, (3) CAI exposed students had a more positive attitude towards their instructional situation and often toward the subject, (4) retention levels were comparable between the two groups, and (5) CAI reduced the time required for a student to complete a unit.

Shay (1980) concluded that simulations: (1) heightened interest, (2) created attitude changes although the degree and direction were unpredictable, and (3) led to acquisition of skills and personal growth if one allows for a debriefing period at the end of the simulation. It was also indicated the simulations should not be the preferred teaching technique.

Overton (1981) reviewed the literature and came to the following conclusions: (1) the results were very mixed on tutorial CAI so it was difficult to conclude that this type of CAI was an overwhelming success, but there appeared to be an apparent increase in student interest; (2) simulation made no significant difference on comprehensive achievement tests, but it had considerable potential in the area of motivation; and (3) effectiveness of computer programming activities for all students has not been clearly determined. She reports on a study by Bitter and Slauchert in which:

they found that those students who received

> computer-oriented instruction had significantly higher achievement levels than those not receiving the treatment. The experimental and control groups received the same mathematical content, but the normal homework assignments for the experimental group were replaced by computer homework exercises (p. 29).

Overton concluded that she could not make any global recommendations. Some of the research efforts had encouraging outcomes and in many cases the computer had a facilitating effect on mathematics achievement, attitudes toward mathematics, and student motivation and interest. The computer's ability to interact with the pupil, while pacing and evaluating both student and the lessons, was cited as a strong point for CAI. Finally, she indicates the computer is viewed as an effective problem solving tool and programming seemed to enhance those problem solving skills (although she wanted to see more research on whether it was reinforcing desirable mathematical methods that characterize mathematical problem solving).

Amarel (1983) indicates that the studies done on PLATO showed that the teacher was the major influence on achievement and attitude changes. Ploeger (1983), however, issues a warning that it is important to recognize that differences do exist between research on mainframe computers and research on microcomputers. The differences he cites are (1) the general impressions of the subjects toward the visible equipment and surroundings, (2) certain features of mainframe operating systems necessitate recognizable differences in performance of instructional computing programs, and (3) the timeliness of the programming and instructional tactics differs between mainframe and microcomputer instructional computing. He then goes on to discuss some of the many observational reports and case studies that abound in the literature on computer use in mathematics education.

Forman (1982) came up with many of the same conclusions as Chambers and Sprecher, but she also found that the effect on achievement occurred regardless of the type of CAI used (tutorial, drill and practice, demonstration, simulation, games), the type of computer system, the age range of the students, or the type of instruments used to make the measurements. Another major finding was that students have a positive attitude towards CAI, frequently accompanied by increased motivation, attention span, and attendance in courses. Forman also found that: tutorial and drill worked better for low-ability than middle-ability students; many reluctant learners become active and interested learners when involved in computer supported programs; the bulk of the studies showing CAI to be effective have concerned the use of adjunct CAI in which the classroom teacher was readily available; CAI is helpful to students reviewing materials with which they had prior familiarity; and retention rates may be lower than for traditional means.

Burns and Bozeman (1981) in their meta-analysis found results similar to those already reported along with no evidence that experimental design affected the outcomes. Another meta-analysis by Kulik, et.al. (1983) produced close to identical results.

In a synthesis of research on electronic learning, White (1983) made the following observations: (1) computers can improve learning; (2) more learning in the future will be electronically based; (3) electronic learning motivates children, the attraction of computer games will probably force us to use game formats more in educational materials; (4) electronic learning is attractive to students because of the allure of technology and its interactive nature; (5) learning programming may teach logical thinking (but will it transfer to other subjects?); and (6) computers increase (not decrease) socialization.

Kulik (1983) describes computer-based instruction (CBI) as a combination of CAI and computer-managed instruction (CMI). CMI is using the computer to store data on each student's progress by keeping a record of what the student has been taught and how well the student did on each lesson. In his synthesis of research on computer-based instruction Kulik found: (1) CBI can improve student learning; (2) students attitudes are slightly more favorable toward the subject, but not significantly; (3) attitudes toward computers rise significantly; and (4) CBI reportedly saves student learning time.

Heinrich (1984) says:

> Cause and effect relationships can be identified, studied, and managed. Research and development based on a theoretical construct that requires manipulation of all variables, including instructors, can lead us to an instructional science and technology capable of radically altering the institution of education (p. 69).

He makes the generalization that the development of instructional technology has disturbed the symbiotic relationship between the instructional materials and the teacher. He concludes by urging educators not to make the same mistake about computers that they are continuing to make about television. He feels they fail to realize that programmed instruction, not the machine itself, is their intellectual fountainhead. Wagschal (1984) makes a similar appeal.

Bear (1984) expresses a strong concern that educators are being pushed into computers by people outside of education with little research to support the implementation. He asserts that "the pressure on schools to implement microcomputer projects can largely be attributed to the highly successful mass marketing strategies employed by the manufacturers of hardware and software" (p. 11). Later, Bear says "although research has already documented the value of CAI for drill-and-practice, the verdict is not yet in on using computers to improve higher-level objectives" (p. 13).

Morris (1983) felt attitude and achievement were greatly increased in her sixth grade class when the use of computer games was implemented. But she still felt some questions needed to be addressed. Among them are:

> How can the translation of game skills and knowledge to related mathematics content be enhanced? For what grade level or achievement level are computer mathematics games effective? When (for what concepts and skills) are they appropriate? For what types of learners are they most effective (age, concept-development stage, etc.)? (p. 24)

In an interview given to Educational Technology (Feb., 1984), Dr. Michael W. Allen, Director of Educational Systems Research, Development, and Strategic Planning within the PLATO Training and Education Division at Control Data Corporation, provided some of the rationale for substituting work on the computer for in-class homework when he said "... the efficiency of computer-based instruction is going to be recognized as an important alternative to mandating two or three hours of homework" (p. 10).

In regard to attitudes, Clement states...

> ...that computer simulated games used as a teaching tool have brought about an attitude change among students. This is an area that has only started to be exploited. We need to understand what it is that will keep people entranced by computer games for hours at a time. Very often they are developing complex skills of planning and strategy that instructional designers would find difficult to emulate by traditional methods (p. 29).

As the review of the literature in this area indicates: much of the reporting in the area of computer-assisted instruction is observations, anecdotes, case studies, and pilot studies done by the software designers. There is a definite lack of consistent results in the research that has been conducted. Most of the success stories deal with drill and practice material, rather than material which would require a higher level of cognitive thinking. Bork (1984) and Komoski (1984) both call for further research into the quality of software and how it can best be utilized. Recently, the Research Advisory Committee of the National Council of Teachers of Mathematics issued its year end report (NCTM, 1985) which indicated several topics which they felt should receive special attention. The first topic listed was the role of technology in the teaching of mathematics about which the committee said:

> Research studies on the use of technology in the mathematics classroom are beginning to

appear, but to date the work does not seem to have a clear focus. Both empirical research and theoretical analyses must address the effects of technology on curricular organization, the pacing of instruction, and the development of core mathematical concepts. For instance, what are the relationships between skill and conceptual understandings that result from increased reliance on symbol manipulation systems? What gains or losses occur in students' attitudes and conceptions of mathematics with the substitution of such systems for paper-and-pencil work?" (p. 317)

Educational Computer Gaming in Mathematics

Although play is not something new, it has only been used in the public schools since the Progressive Movement usually associated with John Dewey. Since that period, the amount of school time spent on playful learning activities has varied greatly depending most heavily on the prevailing public opinion (Glickman, 1981). There is very little research in the literature on educational computer gaming because very little was done prior to the widespread use of the microcomputer. Prior to the 1980's, PLATO had a few games among its programs, but the majority of games played were board games not computer games. Studies such as those conducted by Bright, Harvey, and Wheeler (1977,1979,1980) indicate that gaming did affect the students' achievement. Furthermore, they found varying different variables such as game constraints (characteristics of the game) and verbalization (learner-learner interactions) did have a significant effect on achievement.

With the advent of the microcomputer, mathematics educators began to examine its potential for the mathematics classroom. They were particularly intrigued by the hi-resolution graphics which was lacking on most mainframe systems. In an effort to take advantage of the new technology to improve mathematics instruction, the National Science Foundation (NSF) and the National Institute for Education (NIE) jointly supported research to develop materials that could be used on microcomputers to enhance the learning of mathematics. Many of the projects developed prototypes of software which could be used in the teaching of mathematics through two types of computer-assisted instruction: demonstration and tutorial. Many of the programs took advantage of the hi-resolution graphics capabilities and tried to take advantage of interaction between the computer and the learner. It was during this period of development that the term "electronic chalkboard" came into use.

One of the NSF-NIE projects was awarded to the University of Illinois. With less work being done on the PLATO project, they were turning their efforts to the microcomputers. The project incorporated the computer graphics in the demonstration and tutorial mode, but they went even further to develop an educational computer game called GREEN GLOBS (Dugdale, 1981, 1982). The goal of the Illinois project was to develop "an activity that uses the computer's unique capabilities to provide students a meaningful and highly motivating experience with the graphing of equations" (p. 3). The game GREEN GLOBS served as a prototype of what Dugdale calls "the 'intrinsic models' approach" (1983, p. 1). It proved to be a useful prototype. Within months there was a common feeling among other designers of software for the mathematics classroom that they needed to include an activity involving educational gaming in their software package. One such set of programs, which is now marketed by Wadsworth, Inc., is called THE ELECTRONIC BLACKBOARD and contains a gaming feature called Carroll Critters. ALGEBRA ARCADE is an extension of the work done on Carroll Critters.

Meanwhile, outside of education, the videogame craze was hitting the market. First the arcade became popular and then the computer games found their way into the family home. During the past five years much has been written both positively and negatively about computer games in general and videogames in particular (Bowman and Rotter, 1982; Grady, 1983; TECHnically Speaking, 1983; Driskell and Dwyer, 1984; Bowman, 1982; Needham, 1982-3). Both supporters and detractors admit that most children are fascinated and enjoy playing videogames. Many writers are also concerned, both pro and con, about some of the same problems when they discuss the nongame uses of computers in education (Morris, 1983; Ohanian, 1983; O'Brien, 1983; Stevens, 1982; Gleason, 1981; Hoffman, 1982; Clement, 1981; Steffin, 1981; Barstow, 1983; Stolker, 1983; Mirabelli, 1983; Ferguson, 1983; Parsons, 1983; Getman, 1983). These articles reflect the authors' concerns about the value provided by the computers and videogames from many different viewpoints (physical, psychological, sociological, and educational).

Bowman (1982), in an excellent article, examines the intrinsic rewards found in playing PAC-MAN (a portable arcade game marketed by Coleco Industries, Inc. of West Hartford, CT.) and discusses what implications he feels these games have for education. Bowman carefully examines the intrinsic rewards players receive from playing PAC-MAN and then provides an analogy between the learning occurring in the video arcade and the learning situation in the classroom. He questions whether some of that intrinsic motivation can be transplanted from the video arcade into the classroom to cultivate more learning.

Driskell and Dwyer (1984) report on work the United States Navy is doing to obtain more qualified technicians. Many of the recent recruits are not verbal learners, rather they are visual learners, thus the Navy has developed videogames which it feels have the potential to teach the recruits the educational background the Navy needs.

Dunne (1985) investigated the use and effectiveness of gaming techniques in educational computer software. Educational Products Information Exchange Institute carried out the evaluation of one hundred seventy commercially available educational computer programs. With regard to the use of arcade techniques, Dunne makes the following observation:

> The use of arcade style graphics and gaming techniques are also beginning to play a significant role in educational software. Although only 30% of all the gaming programs in the sample used arcade techniques, they grew from 18% of the gaming programs with 1981 copyright dates to 41% of the gaming programs with 1983 copyright dates (p. 8).

He concludes by saying:

> It seems clear that educational computer games can be powerful instructional tools, but specific gaming techniques need to be carefully matched to a program's educational intent. Future research into creating effective educational computer games should

> address the context (e.g., the subject area, instructional approach, users, etc.) in which specific gaming techniques work best (p. 10).

In summary, the use of computer games, especially videogames, is in its infancy. Philosophical arguments aside, we are beginning to see articles describing the implementation of these games into the classroom, but the results of research on the effectiveness of this type of game are meager. It is a fertile area where more research is needed.

Attitudes Toward Mathematics

Prior to the early 1970's, the literature includes very little discussion with regard to student attitudes toward mathematics. The attention this area has received since then probably reflects the shift in the mathematics curriculum from being content-centered to being learner-centered. This shift was predominantly brought about by the theories of such prominant cognitive theorists as Piaget and Bruner.

The question that arises most often in this area is: Are attitudes important in learning mathematics? The primary argument that they are not important rests on the fact that research shows a low correlation between attitude and achievement. The argument that attitudes are important centers on the risk of drawing conclusions from measuring instruments with questionable validity (Klum, 1980).

Aiken (1970) reviewed the literature prior to the 1970's. The most widely used attitude test was _Dutton's Scale for Measuring Attitudes Toward Mathematics_ (Dutton and Blum, 1968). While this test is short and only has the student check a limited number of responses, it fails to take into account the fact that attitudes toward mathematics is a multidimensional phenomena. The _Mathematics Attitude Scale_ (Aiken, 1974) is an improvement in the sense that Aiken uses two scales (enjoyment and value) and recognizes that there is more than one dimension to attitudes toward mathematics. Watson (1983) has investigated the reliability and discriminant validity of the _Aiken Attitude to Mathematics Scale._ He concluded that the scales measure different aspects of attitudes toward mathematics. The scales were validated individually and combined. Watson found a slightly lower degree of correlation than Aiken, but it was still high.

Reyes (1980) indicates this multidimensional aspect of attitudes toward mathematics has been carried even further with the work of Fennema and Sherman (1976). The _Fennema-Sherman Mathematics Attitudes Scales_ reflect the authors' feelings that there are four specific attitudes that are important in their relationship to students' achievement. Those attitudes are: confidence in mathematics, mathematics anxiety, attribution of causes of success/failure in mathematics, and the perceived usefulness of mathematics. The test is divided into nine parts containing a total of 109 questions. In addition to the four parts given above, the scales include mother, father, teacher, effectance motivation, and male domain. Broadbooks, et. al. (1981) did a construct validation study of the test and concluded that the "eight factors were interpreted to indicate that the scales measure eight different constructs within the domain of mathematical attitudes" (p. 556). They further concluded that "these results also provide evidence of the appropriateness of constructing multidimensional scales to measure attitudes toward mathematics" (p. 556). Other studies (Powers, et.al., 1984) obtained mixed results on validity and reliability when they were investigating the scale on perceived causality. The Fennema-Sherman Mathematics Attitude Scales were selected to be used in this study because the instruments better account for the multidimensional aspects of attitudes toward mathematics and they also incorporate a more contemporary view regarding the affective domain in mathematics.

An examination of National Assessment of Educational Progress (NAEP) results in mathematics indicates that attitudes toward mathematics decline as the student gets older (Carpenter, et.al., 1980). Bell (1983) makes the following observations after reviewing the literature: there is very little evidence to support the belief that higher attitudes lead to higher achievement, he calls for more research in the variances between the sexes on this issue, and concludes "if one intention of modern courses is to enhance enjoyment this intention is apparently not being achieved" (p. 254).

Smith (1973) observed that CAI experience brings more students' mathematical self-concept into line with their mathematical achievement. He concluded CAI did not decrease student attitude. Working with the computer tended to allay the students' fear of failure. Dalton and Hannafin (1984) report on a case study designed to determine if student self-esteem and achievement were affected through the use of reinforcement in CAI. They found no significant differences.

A study by Minato and Yanase (1984) showed attitude to be a more important factor in difference in achievement among lower ability students than among higher ability students. This may be an important factor since many studies show CAI to be most effective on lower ability students.

As can be seen from the above, the study of attitudes is not a clear-cut subject. In many studies, attitudes toward mathematics was thrown in as an afterthought. There seems to be some general agreement that attitudes toward mathematics are multidimensional, but there is no consensus on measuring instruments. One would think that attitudes would play a major role in learning mathematics, but the research may not support that conclusion.

Sex-related Differences in Mathematics

The early 1970's saw a growth in the interest in attitudes toward mathematics and by the last half of the decade researchers were beginning to analyze the results that they were obtaining. They observed not only a sex-related difference in achievement scores, but also sex-related differences in attitudes toward mathematics.

None of the articles denied that test results show a difference in mathematical achievement between males and females. In trying to explain this difference the whole nurture vs. nature argument came into full view. The articles ranged from pure nature (Hoben, 1984) to pure nurture (Fennema, 1981). Much of the discussion revolved around differences in spatial perception (Fennema and Tarte, 1985).

Sherman (1979) concluded that cognitive predictors were better than affective predictors of achievement scores in mathematics. Sherman (1980) also observed that there were no differences between boys and girls in eighth grade in the areas of spacial visualization, number of college preparation mathematics courses or mathematics taken in eighth grade, problem solving, or mathematics achievement. But in eleventh grade, boys out performed girls in all these areas. Fifteen of sixteen correlations between attitudes and performance were significant for the girls, but only three of sixteen for the boys. Females' scores declined in four areas of attitude and rose in two, while males' scores declined in one and rose in two areas. She concluded that attitude has a stronger effect on achievement than spatial visualization and perception of mathematics as a male domain is an important causal variable.

Leder (1980) observed that there seems to be a relation between fear of success and sex differences in performance and participation in mathematics courses. Environmental pressures play a critical role. Fear of success in mathematics was found to play a significant role in the success of girls in mathematics. Those girls who succeeded in mathematics were those who believed their success would be approved by others.

Armstrong (1981) looked at the results of two national surveys- NAEP and Women In Mathematics (WIM). She found: females achieved higher in mathematics in eighth grade, but males achieved higher in twelfth grade and females participate less in the higher level courses. She concluded: "Apparently, achievement differences are not solely a function of differences in participation" (p. 371).

Fennema (1981) found in her studies that males attribute failure to external causes, while females attribute failure to internal causes. In the area of success, males attributed it to internal causes, while females attribute it to external or unstable sources. She depicts this situation as what Dweck calls "learned helplessness."

In reviewing the literature, Badger (1981) observed that as students got older, not only did the sexes differ more on male domain, but they also differed significantly on confidence and usefulness. By then the boys were performing significantly better on mathematics achievement tests. These findings in the United States were very similar to those found in

England. She further comments that it is not possible to single out one factor as the prime cause of such differences, instead it seems to be a constellation of factors which influence performance in varying degrees. Spatial visualization correlated highly with performance, but no causal relationship could be implied. Girls are apparently more vulnerable to affective influences. Research indicates that girls' poorer performance could be linked to broader social issues. Finally, lack of self-confidence and withdrawal from mathematics activities by girls is cited as a consistent finding in the literature.

The ERIC/SMEAC Mathematics Education Fact Sheet No. 1 (Kirschner, 1981) examines the following items regarding female participation in high school mathematics: peer influence, differential treatment by teachers, stereotyping mathematics as a male domain, female attitudes toward mathematics, anxiety and confidence, and parental influences. They conclude that the number of females participating in high school mathematics can be increased and call for the use of intervention strategies such as the "Multiplying Options and Subtracting Bias" established by Fennema, et. al. (1979).

Koehlker and Fennema (1982) cite several examples of both sides of the nurture vs. nature issue. They then present data to show that currently: (1) males achieve higher on both SAT-M and NAEP tests, (2) female enrollment in mathematics courses drops more than male enrollment right after the high school entry level courses in mathematics, and (3) female students are still making the traditional career choices. They see the variable related to mathematics education inequalities in three categories: attitudes, influence of significant others, and influences of schools. Under attitudes they see confidence in one's ability to learn and perform well in mathematics, perceived usefulness of mathematics, and perception of mathematics as a male domain as the main factors. The other influencing factors consist of teachers, counselors, peers, and parents. To remedy this situation, the authors suggest that teachers need to be more aware of their impact on students and at the same time the schools should be disseminating information regarding the usefulness of mathematics to students, teachers, counselors, and parents. They should keep emphasizing that when a student stops taking mathematics the student begins closing career options and the school should consider implementing intervention plans.

Just when it seemed the nurture side of the argument was winning the battle, an article out of John

Hopkins University (Phi Delta Kappa, 1981) fuels the flame again. Benbow and Stanley (1982) conducted a five-year longitudinal study of students who were identified in seventh or eighth grade as mathematically precocious by the John Hopkins University talent search to determine what sex differences emerged. They then suggest the following possible interpretation of the data: male superiority in mathematics reasoning ability might be due to the fact that mathematically gifted males are developing intellectually at a faster rate than are mathematically gifted females. They attribute higher class grades to the better classroom behavior of the female students and the higher dropout rate of females in mathematics to a stronger liking of verbal areas.

Ethington and Wolfle (1984) concluded in their study that neither mother's education nor attitudes toward mathematics exhibited significantly different effects on mathematical achievement. Mathematics exposure was the main contributor to mathematics achievement followed by spatial visualization, grades, and sex in that order. They also felt that the interactions between sex and other variables may complicate the picture greatly. The variances cannot be explained by a single variable. They go on to indicate that the present research suggests once again that most of the difference in mathematics achievement between men and women can be explained by differences in background, ability, attitude, grades, and formal exposure in the classroom (with the latter having the most influence in explaining variation).

As one can see, the nurture vs. nature argument goes on, there are no clear-cut winners. If working on such attitudes as confidence in learning mathematics, usefulness of mathematics, and mathematics as a male domain can close the sex-related gap on mathematics achievement then it certainly is worth trying.

Summary

In the final analysis this survey of the literature covered many topics. Despite the cry for a "return to basics," we are still using the student-centered curriculum theorized by Piaget and Bruner. In the last five years the microcomputers have found their way into almost every school in our nation. The literature is full of articles on how to implement them into the mathematics curriculum.
Computer-assisted instruction has become the main use of computers in the mathematics classroom. While many studies have been done on CAI in the mathematics classroom, research results are not very conclusive. A

relatively new area of CAI is educational computer gaming, including videogames, on which very little true research has been done. Most of the published material is anecdotes, case studies, or merely observations. The discussion on attitudes indicates that we are still "finding our way" in this unexplored area, but we need to try and ascertain whether the computer and the new computer games foster a more positive, more negative, or neutral change in the students' attitudes toward mathematics. Finally, the discussion regarding sex-related differences that exist in mathematics education makes one wonder if the introduction of the computer into the mathematics classroom could make any difference.

All these areas indicate that we have a long way to go before mathematics teaching becomes a science. More research is a must if we wish to find the most effective ways of teaching and learning mathematics.

III. THE STUDY

This chapter contains various aspects of the study and is divided into the following main sections: (1) Game Selection, (2) The Hypotheses, (3) The Measuring Instruments, (4) The Experiment, (5) Statistical Analysis of the Data, and (6) Summary.

Game Selection

The purpose of this study was to investigate several hypotheses concerning the educational value of the videogame ALGEBRA ARCADE (ISBN 0-534-01476-3). ALGEBRA ARCADE is marketed by Wadsworth, Inc. There are many programs on the market which demonstrate graphs when given an equation, but this program integrates that ability into a videogame. It goes beyond drill and practice and involves a simulation of an adventure into the coordinate plane where the player(s) are attempting to make their graph catch the Algebroids placed in position by the computer while not hitting the Graph Gobbler which is controlled by the computer. This program is more than the traditional computer-assisted instruction (CAI) which merely gives a question, provides hints if the player does not know the answer, and then finally gives the correct answer while keeping track of the number of correct answers made by the player. It requires a higher level of cognitive skills than most videogames currently on the market. This type of computer augmented learning fits into the category of adjunct computer-assisted instruction as defined by Chambers and Sprecher (1980).

This particular game contains other useful utility features. It can be played by one or two players, it contains options which include: allowing the player(s) to specify types of functions used, saving games, turning the sound on or off, changing the size of the coordinate grid, using an optional timer, and the opportunity to try out different strategies before making an actual play in the game. There is a user's guide which illustrates the features and functions of the game in detail and gives hints for playing. The diskette will run on an Apple II Plus or Apple IIe microcomputer. Different versions are available for the IBM PC, ATARI 800, or Commodore 64. The schools involved in this experiment were equipped with Apple II Plus or Apple IIe microcomputers.

The option that was most useful during the experiment was specifying a type of function. This allowed the game to be used with only linear functions or quadratic functions in a chosen form. Thus, the class could concentrate on whichever type of function was being presented in class that day.

The option most underused during the experiment was the practice field. This feature allows the player to see what a graph looks like before the player uses it in a game. Thus, a player could get an intuitive idea of what the graph looks like and test it with no jeopardy to the player's score.

Creative Computing gave the game its 1984 Outstanding Software Award (See Appendix E) and syndicated columnists Shelly Heller and Judith Axler Turner gave the program a positive review in their nationally syndicated column (See Appendix F).

The Hypotheses

The purpose of the study was to investigate the educational value of the game ALGEBRA ARCADE. The following hypotheses were formulated:

H_1: There is a significant difference in the change of mean mathematical achievement of the high school advanced algebra classes that include the interaction with the computer game and the high school advanced algebra classes without interaction with the computer game.

H_2: There is a significant difference in the change of mean attitudes toward mathematics of the high school advanced algebra classes that include interaction with the computer game and the high school advanced algebra classes without interaction with the computer game.

H_3: There is a significant difference in the change of mean graphing ability of the high school advanced algebra classes that include interaction with the computer game and the high school advanced algebra classes without interaction with the computer game.

Measuring Instruments

The Intermediate Algebra portion of the *Descriptive Tests of Mathematics Skills* (DTMS) of the College Board (College Entrance Examination Board, 1980) was used to measure mathematical achievement and graphing ability. There are two equivalent forms, one was used as a pretest and the other as a posttest. This test is appropiate for the student level and it contains a cluster of problems on graphing and the coordinate plane. The Fennema-Sherman Mathematics Attitudes Scales was selected as the attitude test. It accounts for the multidimensional aspects of attitudes toward mathematics and incorporates a contemporary view of the affective domain in mathematics education.

The Intermediate Algebra Test

Mathematical achievement was measured by the Intermediate Algebra portion of the Desciptive Tests of Mathematics Skills of the College Board. (College Entrance Examination Board, 1980) The test was designed for the College Board by Educational Testing Services (ETS) who provide validity and reliability data in the publication Guide to the Use of the Descriptive Tests of Mathematics Skills (College Board, 1979). The test consists of thirty multiple choice questions covering three subskills: (1) algebraic operations, (2) solution of equations and inequalities, and (3) the coordinate plane and graphs. There are ten questions for each subskill. It is a timed thirty minute test.

With regard to cluster scores, the College Board cautions against looking at any individual scores due to the small number of questions. However, because errors due to chance tend to balance out when a group is averaged, an average cluster score for a group of students is more reliable than an individual score. Thus, one can be much more confident in using average group cluster scores. The College Board (College Entrance Examination Board, 1980) claims:

> Comparison of average cluster scores obtained by a group of students at the beginning and at the end of a unit may disclose skill areas that need more attention. ... When the content of a given test relates closely to the objectives of a particular course, the test may also be used to access the effectiveness of different instructional strategies (pp. 8-9).

Fennema-Sherman Mathematics Attitudes Scales

The *Fennema-Sherman Mathematics Attitudes Scales* (Fennema and Sherman, 1976) are divided into nine individual attitude scales which are hypothesized to relate to the learning of mathematics. Any combination of the scales can be used to test attitudes. Broadbooks, et. al (1981) did a construct validation study of the test and concluded that the "eight factors were interpreted to indicate that the scales measure eight different constructs within the domain of mathematical attitudes" (p. 556). They further concluded that "these results also provide evidence of the appropriateness of constructing multidimensional scales to measure attitudes toward mathematics" (p. 556). Other studies (Powers, et.al., 1984) obtained mixed results on validity and reliability when they were investigating the scale on perceived causality.

Given below are the nine scales and what each purports to measure as reported by Fennema and Sherman (1976):

(1) The Attitude Toward Success in Mathematics Scale was designed to measure the degree to which the student anticipates positive or negative consequences as a result of success in mathematics.

(2) The Mathematics as a Male Domain Scale intends to measure the degree to which students see mathematics as a male, neutral, or female domain in the following ways: (a) the relative ability of the sexes to perform in mathematics, (b) the masculinity/femininity of those who perform well in mathematics, and (c) the appropriateness of study in mathematics for the two sexes.

(3)-(4) The Father/Mother Scale is used to measure the student's perception of their father's/mother's interest, encouragement, and confidence in the student's ability. It also includes the student's perception of the father's/mother's interest, confidence in doing, and knowing the usefulness of mathematics.

(5) The Teacher Scale is intended to measure the student's perception of the teacher's attitude toward the student as a learner of mathematics. It also measures the student's perception of the teacher's interest, encouragement, and confidence in the student's ability to learn and do mathematical tasks.

(6) The Confidence in Learning Mathematics Scale is intended to measure one's confidence in one's ability to learn and do mathematical tasks.

(7) The Mathematics Anxiety Scale is intended to measure feelings of anxiety, dread, nervousness, and associated bodily symptons related to doing mathematics.

(8) The Effectance Motivation Scale is intended to measure effectance motivation (see definition on p. 15) as applied to mathematics.

(9) The Mathematics Usefulness Scale is designed to measure a student's beliefs about the usefulness of mathematics to the student currently and in the future.

To establish content validity Fennema and Sherman worked together (one checking the other) to get a set of questions they thought would work. They field tested the questions and pared the number down even further. They used the following criteria (in order of importance) for selecting the questions to be on the final test: (a) items which correlated highest with the total score for each sex, (b) items with higher standard deviations for each sex, (c) items which yielded results consistent with the theoretical construct of a scale, and (d) items which differentiated mathematics and non-mathematics students.

In the final version, each scale has twelve questions, six positively stated and six negatively stated. Each question has five possible answers: strongly agree, agree, undecided, disagree, and strongly disagree. Each response is given a score 1-5. On the positively stated questions strongly agree receives a five, while on the negatively stated questions strongly disagree receives a five. The weight of five, except in the Male Domain Scale, is given to the response that is hypothesized to have a positive effect on the learning of mathematics. The Male Domain Scale is weighted so that the less a person stereotypes mathematics, the higher the score. A person's total score on each scale is cumulative, the higher the total, the more positive the attitude toward mathematics. To get a profile of overall attitude, the scores on the various scales are added together.

As the search of the literature indicates, several of these attitudes seem to have more profound effects than others. Several scales are not relevant to this study. The scales selected were: (1) Confidence in Learning Mathematics, (2) Mathematics as a Male Domain, (3) Attitude Toward Success in Mathematics, (4) Effectance Motivation, and (5) Usefulness of Mathematics. Anxiety was not used because it is the negative manifestation of confidence. (Fennema and Sherman, 1976, p. 8) Once the scales were picked, the questions were randomly distributed into one instrument. (See Appendix D.)

The Experiment

Teacher Selection

The study involved eleven teachers at seven high schools in Eastern Wisconsin and Northeastern Illinois. The participating teachers were chosen on a volunteer basis. A list of potential schools to participate in the experiment was developed by giving a presentation on the proposed study at the September 1984 meeting of the Milwaukee Educational Computing Association (MECA). Additional school names were obtained through personal contact with mathematics department heads in the Milwaukee Metropolitan area, members of the Wisconsin Mathematics Council (WMC), and members of the Milwaukee

Area Mathematics Council (MAMC). Fifty-three schools were initially contacted regarding participation in the study. The list of potential schools was further reduced by taking into consideration the availability of computers at the school and the course description. The study excluded courses designed for the exceptional student. The administrations of the schools were contacted formally to inquire if their school would be willing to participate in the study and, if so, what steps were necessary to formalize the agreement.

The Population

The study included eleven teachers at seven different high schools teaching five hundred twenty-one (521) students. The teachers all volunteered to be in the study. Each teacher taught at least two classes of Advanced Algebra or Algebra II. One class was designated as the control group and the other class served as the experimental group. Availability of the computer laboratory usually determined which of the classes served as the experimental group. If the teacher taught more than two classes of Advanced Algebra or Algebra II (two of them taught three classes), it was randomly determined which of the two remaining classes would be the control group. Thus, the study involved eleven teachers and twenty-two classes. Eleven classes in the control group and eleven classes in the experimental group.

The class sizes ranged from twelve to thirty-three students with an average of twenty-four students. Five hundred twenty-one (521) students participated in the study. After eliminating those students who were absent for the pretest or posttest, four hundred twenty-three (423) students took both attitude tests and four hundred twenty-five (425) students took both algebra tests. (See Appendix A.)

Experimental Design

The experimental design chosen for this experiment was the Nonequivalent Control Group Design as defined in Campbell and Stanley (1963) and Issac and Michael (1981). The design is depicted below where O = observation and X = treatment.

```
O    X    O
------------
O         O
```

Figure 2. Experimental design

This design is actually regarded as a

quasi-experimental design since the individual subjects were not randomly assigned from a common population to the experimental and control groups. Instead, the groups constitute a naturally assembled collective, in this case the class, as similar as availability permits but enough different to necessitate a pretest.

Procedures

Each teacher was instructed to teach the control class as they normally would teach the class. Their experimental class was to be taught as similarly as possible to the control, with the following exception: the teacher made a daily determination of how many problems the control class was expected to complete on their homework during class time. The experimental class spent that time playing ALGEBRA ARCADE in lieu of doing the in-class problems. Both classes did the same out-of-class homework problems. In all cases the game was incorporated into the Quadratic Functions unit. This unit involves considerable graphing and is new material for most students at this level.

The experiment lasted four (4) weeks. The investigator met with each teacher in the study individually prior to their starting the experiment. Each teacher was given suggested uses of the game (to assure some uniformity) during their individual meetings with the investigator. They also received a memo, but actual control was left to the teacher's determination (See Appendix G). One week prior to starting the Quadratic Functions unit, both groups were pretested. The experimental group then began using ALGEBRA ARCADE. Prior to actually starting the Quadratic Functions unit, the students were allowed to use only linear functions. This was familiar material, thus they worked on mastering the game and the computer. During the first two weeks of the Quadratic Functions unit, the students were allowed to use only quadratic functions. It is possible to select one of three forms (standard, vertex, and factored) which the student must use. The last week of the Quadratic Functions unit, the students were allowed to use any function they wished to try. At the end of four weeks both groups were posttested. Since interaction, both with the computer and fellow students, is an integral part of this method of teaching, the teacher was asked to have each student play against several different students rather than the same student all the time.

To summarize, the experimental treatment consisted of the experimental group playing ALGEBRA ARCADE in lieu of the in-class assignment during the fifteen to twenty minutes at the end of class. The out-of-class assignments remained the same. The treatment began immediately after the pretest, one week prior to starting the Quadratic Functions unit, and continued through the posttest, the end of the Quadratic Functions unit. The Quadratic Functions unit was three weeks long, thus allowing four weeks between the pretest and posttest with the experimental group receiving the treatment throughout the entire time.

Data Collection

The data consisted of two pretest scores and two posttest scores from each individual participating in the study. One pretest and one posttest consisted of the Mathematics as a Male Domain, Confidence in Learning Mathematics, Attitude Towards Success in Mathematics, Effectance Motivation in Mathematics, and Usefulness of Mathematics Scales from the *Fennema-Sherman Mathematics Attitudes Scales.* (See Appendix D.) The other pretest and posttest consisted of two different, but equivalent, forms of the Intermediate Algebra portion of the *Descriptive Test of Mathematics Skills* of the College Board. (See Appendices B and C.)

Statistical Analysis of the Data

The difference between class means on the posttest and the pretest were analyzed using the multiple regression model provided by Neter and Wasserman (1974). (See Snedecor and Cochran (1980) and Popham (1967)) The independent variables consisted of use of the game, sex, grade level, game-sex interaction, game-grade level interaction, and teacher. The dependent variable was the difference between group means on the posttest and the pretest. Thus, the model is a first order model with fourteen independent variables represented in the following way:

$$
\begin{aligned}
Y_i = {} & \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_3 X_{i3} + \beta_4 X_{i4} + \\
& \beta_5 X_{i5} + \beta_6 X_{i6} + \beta_7 X_{i7} + \beta_8 X_{i8} + \\
& \beta_9 X_{i9} + \beta_{10} X_{i10} + \beta_{11} X_{i11} + \beta_{12} X_{i12} + \\
& \beta_{13} X_{i13} + \beta_{14} X_{i14} + \beta_{15} X_{i1} X_{i2} + \beta_{16} X_{i1} X_{i3} + \\
& \beta_{17} X_{i1} X_{i4} + \epsilon_i
\end{aligned}
$$

where

$$
X_{i1} = \begin{cases} 1 & \text{if class i worked on computer} \\ 0 & \text{if class i did not work on computer} \end{cases}
$$

$X_{i2} =$ ratio of females in class i

X_{i3} = ratio of sophomores in class i

X_{i4} = ratio of seniors in class i

$$X_{i5} = \begin{cases} 1 & \text{if teacher 1} \\ 0 & \text{otherwise} \end{cases}$$

$$X_{i6} = \begin{cases} 1 & \text{if teacher 2} \\ 0 & \text{otherwise} \end{cases}$$

$$X_{i7} = \begin{cases} 1 & \text{if teacher 3} \\ 0 & \text{otherwise} \end{cases}$$

$$X_{i8} = \begin{cases} 1 & \text{if teacher 4} \\ 0 & \text{otherwise} \end{cases}$$

$$X_{i9} = \begin{cases} 1 & \text{if teacher 5} \\ 0 & \text{otherwise} \end{cases}$$

$$X_{i10} = \begin{cases} 1 & \text{if teacher 6} \\ 0 & \text{otherwise} \end{cases}$$

$$X_{i11} = \begin{cases} 1 & \text{if teacher 7} \\ 0 & \text{otherwise} \end{cases}$$

$$X_{i12} = \begin{cases} 1 & \text{if teacher 8} \\ 0 & \text{otherwise} \end{cases}$$

$$X_{i13} = \begin{cases} 1 & \text{if teacher 9} \\ 0 & \text{otherwise} \end{cases}$$

$$X_{i14} = \begin{cases} 1 & \text{if teacher 11} \\ 0 & \text{otherwise} \end{cases}$$

$X_{i1} X_{i2}$ = game-sex interaction

$$\left.\begin{array}{l} X_{i1} X_{i3} \\ \\ X_{i1} X_{i4} \end{array}\right\} \text{game-grade level interaction}$$

$Y_i =$ difference between class mean on the posttest and class mean on the pretest for class i

$\beta_1, \beta_2, \ldots, \beta_{17} =$ partial regression coefficients

$\epsilon_i =$ error for class i

$i = 1, \ldots, 22$

With this model, the estimated values for the partial regression coefficients were calculated using the Number Cruncher program. The overall F-test was used to establish how strong the relationship was between the dependent variable and the set of independent variables. A series of F-ratios were then calculated to determine whether the model could be reduced. Thus, in a stepwise manner, the best model was obtained. Finding the best model, the regression analysis reduced to a paired T-test. The regression analysis was done in the Oregon State University Mathematics Department on an IBM PC using the Number Cruncher Statistical System marketed by Number Cruncher Statistical Systems, Inc. and Dr. Jerry L. Hintze of Kaysville, Utah.

Summary

This chapter contained a discussion of various aspects of the study and was divided into the following main sections: (1) Game Selection, (2) The Hypotheses,

(3) The Measuring Instruments, (4) The Experiment, and (5) Statistical Analysis of the Data. The section on the experiment went into detail on: (1) Selection of Teachers, (2) The Population, (3) Experimental Design, (4) Procedure, and (5) Data Collection.

IV. RESULTS OF THE STUDY

Chapter IV is divided into the following five major sections: (1) Method of Statistical Analysis, (2) Hypotheses Test Results, (3) Disposition of the Hypotheses, (4) Findings Not Directly Related to the Hypotheses, and (5) Summary.

Method of Statistical Analysis

The data was collected during the 1984-5 academic year and initially scored on a Scan-Tron reader at Waukesha North High School in Waukesha, Wisconsin. The compiled results for each class were then analyzed on an IBM PC in the Mathematics Department at Oregon State University using the Number Cruncher Statistical System. A mean score was computed for each class. In the area of attitudes toward mathematics, there were class means for each of the twenty-two classes on both the pretest and posttest for Overall Attitudes Toward Mathematics and the scales of: (1) Mathematics as a Male Domain, (2) Confidence in Learning Mathematics, (3) Attitude Toward Success in Mathematics, (4) Effectance Motivation, and (5) Usefulness of Mathematics. (See Appendix H.) For achievement in mathematics and graphing ability, there were twenty-two class means on both the pretest and posttest for mathematical achievement and the clusters of: (1) algebraic operations; (2) solving equations and inequalities; and (3) the coordinate plane and graphing. (See Appendix I.)

A preliminary analysis of the data directly related to the hypotheses indicated the following: (1) in mathematical achievement nine of the eleven experimental classes did relatively better than the control class of the same teacher, (2) in attitudes toward mathematics four of the experimental classes did relatively better than the control classes, and (3) in graphing ability nine of the the experimental classes did relatively better than the control classes. In absolute terms: (1) in mathematical achievement five experimental and five control classes showed a gain, (2) in attitudes toward mathematics four experimental classes showed a gain and two control classes showed a gain, and (3) in graphing ability nine experimental classes showed a gain and five control classes showed a gain. While no definite pattern existed, it did seem to relate closely to the teacher. In mathematical achievement, nine teachers had both classes lose or both classes gain. In attitudes toward mathematics, seven teachers had both classes gain or both classes lose. In graphing ability, seven teachers had both classes gain or both classes lose. Overall out of the twenty-two classes in the experiment: (1) ten showed gains in mathematical achievement, (2) six showed a gain in the attitudes toward mathematics, and (3) fourteen showed a gain in graphing ability.

Using the information provided by students at the top of their answer sheets, the following information was calculated for each of the twenty-two classes: (1) ratio of females in the class, (2) ratio of sopohomores in the class, and (3) ratio of seniors in the class. (See Appendix A.) There were four places where the student needed to provide this information and it was carefully cross checked.

The Number Cruncher Statistical System was then used to analyze the data using the difference between class means on the posttest and pretest in mathematical achievement, attitudes toward mathematics and graphing ability as the dependent variables. The independent variables were classified as: (1) use of the computer game, (2) ratio of females in the class, (3) grade level of students in the class, (4) the teacher, (5) computer-sex interaction, and (6) computer-grade level interaction. The multiple regression analysis provided the following data:

(1) parameter estimates,

(2) standard error of parameter estimates,

(3) t-value or F-value and p-value to test whether that factor should be omitted from the model, and

(4) analysis of variance report which included the F-ratio and p-value.

Hypotheses Test Results

Hypothesis one states that there is no significant difference in the change of mean mathematical achievement between the classes using ALGEBRA ARCADE and the classes not using ALGEBRA ARCADE. Using multiple regression analysis on the full model gave the information contained in Tables 2 and 3 (see next page).

As one can see in Table 3, the p-value is 0.025, thus the Overall F-test is significant. A series of F-ratios were calculated to determine if any of the variables (sex, grade level, computer-sex interaction, and computer-grade level interaction) could be dropped from the model. The results are shown in Table 1.

Table 1.

Factors Dropped

Mathematical Achievement

Step	Factor Dropped	Partial F-test
1	computer-grade level interaction	0.050
2	grade level	1.288
3	computer-sex interaction	10.562 *
4	sex	3.297

* $p < .05$

Table 2.

Partial Multiple Regression Report

Mathematical Achievement Full Model

Factors		Parameter Estimate	Standard Error	t-value (b=0)	Prob. b=0
constant	b_0	-1.16			
computer	b_1	-2.47	1.21	-2.04	0.111
sex-rel	b_2	1.73	2.43	0.71	0.516
grade level	b_3	2.70	3.75	0.72	0.511
	b_4	.47	2.42	0.19	0.856
teacher related	b_5	-1.22	2.29	-0.53	0.621
	b_6	-1.88	.96	-1.96	0.121
	b_7	-1.20	.67	-1.81	0.145
	b_8	- .22	.64	-0.34	0.752
	b_9	.15	.62	0.25	0.817
	b_{10}	- .75	.65	-1.16	0.312
	b_{11}	3.78	2.24	1.69	0.167
	b_{12}	.43	.82	0.52	0.628
	b_{13}	3.23	.84	3.86	0.018
	b_{14}	- .80	1.06	-0.76	0.489
interaction	b_{15}	4.76	2.75	1.73	0.158
	b_{16}	.59	4.17	0.14	0.894
	b_{17}	- .19	4.80	-0.04	0.970

Table 3.

Analysis of Variance

Mathematical Achievement Full Model

Source	df	Sums of Squares	Mean Square	F Ratio	Prob>F
Constant	1	.04	.04		
Model	17	33.46	1.97	9.10	0.025
Error	4	.87	.22		
Total	21	34.32	1.63		

Only the variable computer-sex interaction had a significant F-ratio. A closer inspection was done graphically (see next page). Figure 3 shows the Mathematical Achievement Differences with the teacher effect removed leaving the variables: (1) use of the computer game, (2) sex (ratio of females in the class), and (3) computer-sex interaction in the model. Figure 4 depicts the Mathematical Achievement Differences with the teacher effect removed leaving the variables use of the computer game and sex (ratio of females in the class) in the model. From the graphs, it appeared that one teacher (number seven) was creating the large F-ratio. Further analysis on Number Cruncher confirmed that dropping teacher seven gave a new F-ratio of 2.27 which was not significant. Thus, the factors listed in Table 3 were dropped from the model. The smaller number of variables (teacher and use of the computer game) reduced the multiple regression analysis to a paired T-test.

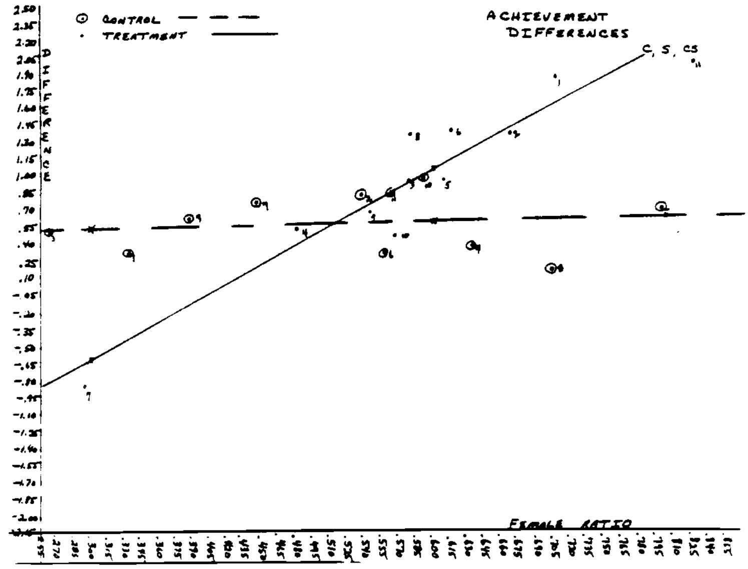


Figure 3. Mathematical Achievement With Computer-sex Interaction

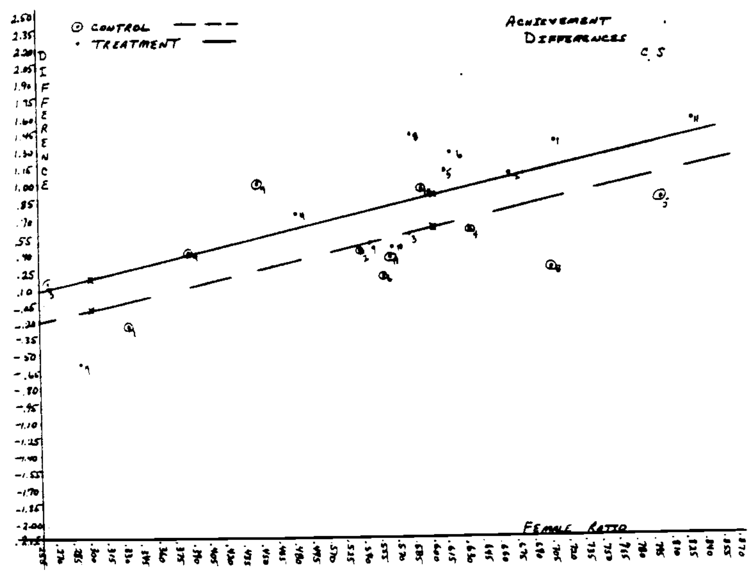


Figure 4. Mathematical Achievement Without Computer-sex Interaction

Each teacher taught a control and an experimental class, so they provided an excellent basis for the blocking. Thus, the teacher was held constant with the use of the computer game (which is exactly what the hypothesis deals with) varying. The paired T-test provided a t statistic of 1.52 and a p-value of 0.08. Thus, there is a significant difference, at the .08 level, in the change of mean mathematical achievement of the high school advanced algebra classes that used the computer game and the high school advanced algebra classes that did not use the computer.

The second hypothesis stated that there is no significant difference in the change of mean attitudes toward mathematics between classes using ALGEBRA ARCADE and the classes not using ALGEBRA ARCADE. The multiple regression analysis on the full model produced the information given in Tables 5 and 6 (see next page).

The F-ratio and a p-value of 0.105 indicated that the Overall F-test was not as significant for this hypothesis. A series of F-ratios were calculated to determine if any of the variables (sex, grade level, computer-sex interaction, and computer-grade level interaction) could be dropped from the model. The results are shown in Table 4.

Table 4.

Factors Dropped

Attitudes Toward Mathematics

Step	Factor Dropped	Partial F-test
1	computer-grade level interaction	4.107
2	grade level	0.510
3	computer-sex interaction	0.243
4	sex	1.492

None of the factors had a significant F-ratio. Thus, the factors listed in Table 4 were dropped from the model, leaving only the factors of teacher and use of the computer game.

Table 5.

Partial Multiple Regression Report

Attitudes Toward Mathematics Full Model

Factors		Parameter Estimate	Standard Error	t-value (b=0)	Prob. b=0
constant	b_0	13.28			
computer	b_1	-20.51	7.54	-2.72	0.053
sex-rel	b_2	-10.18	13.76	-0.74	0.501
grade level	b_3	-15.02	22.26	-0.67	0.537
	b_4	-6.64	6.10	-0.41	0.701
teacher related	b_5	-11.86	15.56	-0.76	0.488
	b_6	-4.83	6.19	-0.78	0.479
	b_7	-8.91	4.24	-2.10	0.104
	b_8	-2.63	3.88	-0.68	0.535
	b_9	-7.16	3.49	-2.05	0.110
	b_{10}	-5.38	3.80	-1.41	0.230
	b_{11}	1.73	15.98	0.11	0.919
	b_{12}	-6.56	5.51	-1.19	0.300
	b_{13}	6.41	5.08	1.26	0.275
	b_{14}	-10.73	7.43	-1.44	0.222
inter-action	b_{15}	35.55	19.19	1.85	0.138
	b_{16}	-19.28	30.56	-0.63	0.562
	b_{17}	17.88	33.40	0.54	0.621

Table 6.

Analysis of Variance

Attitudes Toward Mathematics Full Model

Source	df	Sums of Squares	Mean Square	F Ratio	Prob>F
Constant	1	113.57	113.57		
Model	17	497.97	29.29	3.75	0.105
Error	4	31.24	7.81		
Total	21	529.21	25.20		

The multiple regression analysis then reduced to a paired T-test. Since each teacher taught a control and experimental class, the blocking was on the basis of teachers and using the computer game was allowed to vary. The analysis produced a t statistic of .305 and a p-value of 0.383. Thus, there is no significant difference in the change of mean attitudes toward mathematics of the high school advanced algebra classes that included the computer game and the high school advanced algebra classes without the computer game.

The final hypothesis was that there was no significant difference in the change of the mean graphing ability between classes using ALGEBRA ARCADE and the classes not using ALGEBRA ARCADE. Using the difference between the class means on the posttest and pretest for graphing as the dependent variable, a regression analysis was performed on the full model. The analysis produced a F-ratio of 8.16 and a p-value of 0.030. The partial multiple regression report and analysis of variance report are given in Tables 8 and 9, respectively (see next page).

A series of F-ratios were calculated to determine if any of the variables (sex, computer-sex interaction, grade level, and computer-grade level interaction) could be dropped from the model. The results are shown in Table 7.

Table 7.

Factors Dropped

Graphing Ability

Step	Factor Dropped	Partial F-test
1	computer-grade level interaction	1.565
2	grade level	0.187
3	computer-sex interaction	3.073
4	sex	4.436

Table 8.

Partial Multiple Regression Report

Graphing Ability Full Model

Factors		Parameter Estimate	Standard Error	t-value (b=0)	Prob. b=0
constant	b_0	.56			
computer	b_1	1.22	.68	1.81	0.145
sex-rel	b_2	.65	1.36	0.48	0.655
grade level	b_3	-2.15	2.10	-1.02	0.364
	b_4	1.08	1.35	0.80	0.471
teacher related	b_5	-2.24	1.28	-1.75	0.155
	b_6	-1.90	0.54	-3.54	0.024
	b_7	-0.79	0.37	-2.11	0.102
	b_8	-0.20	0.36	-0.55	0.614
	b_9	-0.39	0.35	-1.14	0.317
	b_{10}	-0.17	0.36	-0.47	0.661
	b_{11}	2.37	1.25	1.90	0.131
	b_{12}	.10	.46	0.23	0.832
	b_{13}	.25	.47	0.55	0.613
	b_{14}	.98	.59	1.66	0.172
inter-action	b_{15}	- 3.17	1.54	-2.06	0.108
	b_{16}	2.55	2.33	1.10	0.335
	b_{17}	4.51	2.68	1.68	0.168

Table 9.

Analysis of Variance

Graphing Ability Full Model

Source	df	Sums of Squares	Mean Square	F Ratio	Prob>F
Constant	1	.52	.52		
Model	17	9.38	.55	8.16	0.030
Error	4	.27	.07		
Total	21	9.65	.46		

None of the factors had a significant F-ratio. Thus, the factors listed in Table 9 were dropped from the model, leaving only the factors of teacher and use of the computer game.

The multiple regression analysis reduced to a paired T-test. Since every teacher taught an experimental and a control class, the teachers were blocked and using the computer game was allowed to vary. The analysis produced a t statistic of 3.22 which has a p-value of 0.005. Thus, there was a significant difference, at the .005 level, in the change of the mean graphing ability of the high school advanced algebra classes that included the computer game and the high school advanced algebra classes without the computer game.

Disposition of the Hypotheses

Based on the results obtained in the last section, the following statements can now be made:

Using the Intermediate Algebra test as an indication of mathematical achievement, the classes in this study who used ALGEBRA ARCADE showed a positive difference which was significant, at the .08 level, in the mean change in mathematical achievement over the classes in this study who did not use ALGEBRA ARCADE.

Using the *Fennema-Sherman Mathematics Attitudes Scales* as an indication of attitudes toward mathematics, the classes in this study who used ALGEBRA ARCADE did not show a difference in mean change in positive attitudes toward mathematics over the classes in this study who did not use ALGEBRA ARCADE.

Using the Coordinate Plane and Graphing Cluster of the Intermediate Algebra test as an indication of graphing ability, the classes in this study who used ALGEBRA ARCADE showed a significant difference, at the .005 level, in the mean change in graphing ability over the classes in this study who did not use ALGEBRA ARCADE.

Thus, assuming the tests are indicators of what they are intended to measure, there is at least one commercially available computer game, ALGEBRA ARCADE, for which the classes in this study who used it

(a) did significantly better, at the .08 level, in the mean change in mathematical achievement,

(b) showed no difference in the mean change in attitudes toward mathematics, and

(c) showed a significant difference, at the .005 level, in the mean change in graphing ability

than the classes in the study who did not use the computer game.

Findings Not Directly Related to the Hypotheses

A multiple regression analysis was performed on the results obtained on the other two clusters of the Intermediate Algebra Test (Algebraic Operations and Solving Equations and Inequalities) to see what effects using the educational computer game had on the skills tested in those portions of the test. The terms in the multiple regression model corresponding to computer-grade level interaction, grade level, computer-sex interaction, and sex were dropped from the model in a stepwise manner. The calculated F-ratios are shown in Table 10.

Table 10.

F-ratios for Individual Clusters

Step	Factor Dropped	Part A* Partial F-test	Part B* Partial F-test
1	computer-grade level interact.	0.113	0.121
2	grade level	0.519	0.371
3	computer-sex interaction	6.822**	6.260**
4	sex	0.011	0.949

* Part A is Algebraic Operations
Part B is Solving Equations and Inequalities
** $p < .05$

In both clusters, the factor of computer-sex interaction was significant; however, this is not surprising since these two clusters account for two-thirds of the achievement score. An analysis similar to the one done on mathematical achievement was performed. Dropping teacher number seven from the model reduced the F-ratios for Algebraic Operations and Solving Equations and Inequalities to 2.317 and 0.460, respectively. Thus, the factors listed in Table 10 were dropped from the model.

The remaining variables (teacher and use of the computer game) were analyzed using a paired T-test. The Algebraic Operations data produced a t statistic of 1.31 and a p-value of 0.110. The same analysis performed using the Solving Equations and Inequalities data produced a t statistic -1.40 and a p-value of 0.904. These results indicate that using the educational computer game had a non-significant negative effect on the Solving Equations and Inequalities scores. However, the latter conclusion must be tempered by the fact that very little solving of equations and inequalities was included in the unit and the students using the computer game were doing more visualizing and less paper and pencil work.

To examine what was happening in the subsections of the attitude scales, a multiple regression analysis was run on each of the more specific scales. The F-ratios calculated are given in Table 11.

Table 11.

Factors Dropped

Attitude Scales

Step	Factor Dropped	Partial F-test Pt 1	Pt 2	Pt 3	Pt 4	Pt 5*
1	computer-grade level interact.	0.943	6.552	3.070	0.393	2.686
2	grade level	0.013	1.741	0.432	0.733	0.527
3	computer-sex interaction	3.294	1.105	0.083	2.906	0.505
4	sex	0.231	1.090	0.259	0.761	2.018

* Pt 1 is Mathematics as a Male Domain

Pt 2 is Confidence in Learning Mathematics

Pt 3 is Attitude Toward Success in Mathematics

Pt 4 is Effectance Motivation in Mathematics

Pt 5 is Usefulness of Mathematics

None of the F-ratios in Table 11 are significant. Thus, the variables in Table 11 were dropped form the model, leaving teacher and use of the computer. A paired T-test was performed with blocking being done by teacher. The results are summarized in Table 12.

Table 12.

Results of paired T-tests

on each attitude scale

Attitude Scale	t-statistic	p-value
Male Domain	0.96	0.177
Confidence	0.02	0.493
Success	0.43	0.336
Effectance	-1.47	0.914
Usefulness	0.45	0.331

As can be seen in Table 12, using the educational computer game had a non-significant negative effect on effectance motivation. The other four attitude scales showed no significant difference.

Finally, an analysis using paired T-tests was performed using only pretests on the items which were hypothesized (attitudes toward mathematics, mathematical achievement, graphing ability). The results are shown in Table 13.

Table 13.

Results of paired T-test on Pretest

for each hypothesized area

Pretest	t statistic	p-value
attitudes	0.77	0.229
achievement	0.62	0.274
graphing	-0.64	0.734

The figures in Table 13 show that there was no significant difference between the control and experimental groups in the areas of attitudes toward mathematics, mathematical achievement, and graphing ability at the start of the study. For a comparison, the p-values obtained at the start of the experiment, the p-values obtained at the end of the experiment, and the p-values obtained on the differences are shown in Table 14.

Table 14.

Comparison of P-values

for Each Hypothesis

Hypothesis	Pretest	Posttest	Differences
Attitudes	0.229	0.143	0.383
Achievement	0.274	0.023	0.080
Graphing	0.734	0.016	0.005

Summary

In this chapter, the method of statistical analysis was described, the hypotheses were tested for results, a disposition was given for each hypothesis, and findings not directly related to the hypotheses were discussed.

With regard to the hypotheses:

(1) the classes using ALGEBRA ARCADE did significantly better, at the .08 level, than the classes not using ALGEBRA ARCADE in change of mathematical achievement,

(2) there was no significant difference between the classes using ALGEBRA ARCADE and those not using

ALGEBRA ARCADE in change of attitudes toward mathematics,

(3) the class using ALGEBRA ARCADE did significantly better, at the .005 level, than the the classes not using ALGEBRA ARCADE in graphing ability.

Examining the other attitude scales and the other two parts (algebraic operations and solving equations and inequalities) of the Intermediate Algebra test, no significant differences were found, but a negative trend was noted on solving equations and inequalities and the scale of effectance motivation in mathematics.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter is divided into three sections which include: (1) a review of the entire study, (2) the conclusions with their relationship to other research, theories, and practice in the field of mathematics education, and (3) recommendations for further study.

Summary

The Problem

Computers have been used in education since the 1950's, but it took the invention of the microchip and the advent of the microcomputer in the early 1980's to make the computer available to the majority of the students in the United States schools. The microcomputer was smaller in size, more portable, and less expensive than the mainframe computers. The microcomputer also had more immediate feedback and hi-resolution graphics. Videogames were developed which took advantage of the hi-resolution graphics capability of the microcomputer.

Videogames were originally developed for entertainment either at an arcade or in the home.

Seeing the motivation and excitement created by the videogames, software designers and manufacturers began producing educational computer games and claiming that they increased learning in a specified subject area. Although many mathematics educators such as Dugdale and Dunne maintain that educational gaming shows positive effects on the learning of mathematics, a search of the literature revealed little research on the educational value of computer gaming in mathematics. Questions still remain concerning the reliability of these claims and the educational soundness of these games.

The purpose of this study was to investigate the claims of the manufacturers and several mathematics educators that educational computer gaming can provide positive results in the teaching and learning of mathematics. One such game is ALGEBRA ARCADE marketed by Wadsworth, Inc. The manufacturer of this educational computer game claims that the game not only improves graphing skills, but also improves the student's attitudes toward mathematics. The game has many useful options such as: (1) one or two players: (2) allowing the player(s) to specify the types of functions to be used, (3) saving games, (4) varying the coordinate grid, (5) an optional timer, and (6) the opportunity to try out different strategies on a practice field before making an actual play in the game. Unlike other CAI programs which are based on tutorial or drill and practice concepts, ALGEBRA ARCADE does closely resemble a true videogame.

Thus, the essence of this study was to determine the educational value of the videogame ALGEBRA ARCADE. Will the game increase the student's mathematical ability? Does the game improve the student's graphing ability? Is the student's ability to work with functions increased? Does the utilization of this game in the classroom affect attitudes and interests toward mathematics?

The hypotheses for this study, in condensed form, are that playing the educational computer game ALGEBRA ARCADE will significantly increase the mathematical achievement, positive attitudes toward mathematics, and graphing ability of students enrolled in second year high school algebra over those students who do not use ALGEBRA ARCADE.

Design of the Study

The subjects were not randomly assigned from a common population to the experimental and control group, instead the classes constituted naturally assembled collectives as similar as availability permitted. Thus, the experiment required the

Nonequivalent Control Group Design involving twenty-two classes of second year high school algebra students in seven high schools. Eleven teachers volunteered to participate in the study. Each teacher taught at least two classes of second year high school algebra. Each teacher taught a control class and an experimental class in the study. In most cases, availability of the computer laboratory determined which class was the experimental group. A total of four hundred twenty-five (425) students took both algebra tests and four hundred twenty-three (423) students took both attitude tests.

Procedure

Each teacher received a copy of the proposal and overview of the experiment. The investigator met individually with the teachers to explain the game ALGEBRA ARCADE and what was expected of the teachers and students involved in the study. Each teacher received a follow up memo, after the individual meeting, regarding administration of the pretests and what was expected during the study. Finally, each received a memo regarding the administration of the posttest. Following an individual demonstration of ALGEBRA ARCADE, each teacher received a copy of the game with a user's guide so they could better familiarize themselves with the game.

Each teacher taught their control class as it normally would have been taught. Their experimental group was taught exactly the same way except the teacher made a daily determination of how many problems the teacher expected the control class to do before the end of the period. The experimental class spent that time playing ALGEBRA ARCADE in lieu of doing those problems. The teachers used whatever method they chose to present the topic for the day to both classes; however, fifteen to twenty minutes had to be left to work on the in-class portion of the assignment while the experimental group spent the in-class time playing ALGEBRA ARCADE. Both groups had the same out-of-class assignment.

The experiment centered around a unit on quadratic functions. This material was new to the students in this course and involved being able to graph quadratic functions and visualize their graphs. The experimental treatment consisted of the experimental group playing ALGEBRA ARCADE in lieu of the in-class assignment during the fifteen to twenty minutes at the end of class. The treatment began immediately after the pretest (one week prior to the start of the Quadratic Functions unit) and continued until the posttest (the completion of the Quadratic Functions unit) allowing the experiment to last approximately four weeks. The experimental class received the treatment throughout the entire experiment.

The pretest and posttest consisted of different forms of the Intermediate Algebra portion of the *Descriptive Test of Mathematics Skills* of the College Board and the *Fennema-Sherman Mathematics Attitudes Scales.* The Intermediate Algebra test consists of three subsections: Algebraic Operations; Solving Equations and Inequalities; and the Coordinate Plane and Graphing. The latter was used to determine graphing ability. The scales used from the *Fennema-Sherman Mathematics Attitudes Scales* included: Mathematics as a Male Domain, Confidence in Learning Mathematics, Attitude Toward Success in Mathematics, Effectance Motivation in Mathematics, and Usefulness of Mathematics.

The data collected consisted of pretest and posttest scores of all student who participated in the study. The class sizes in the study ranged from twelve to thirty-three students with an average of twenty-four students. Five hundred twenty-one (521) students participated in the study. After eliminating those students who were absent for pretest or posttest, four hundred twenty-three (423) students took both attitude tests and four hundred twenty-five (425) students took both algebra tests.

Statistical Analysis

The individual tests were scored on a Scan-Tron reader. The resulting data was then analyzed on an IBM Personal Computer using the Number Cruncher Statistical Systems program to perform the multiple regression analysis. The full model included seventeen independent variables (see p. 72). One indicator variable was the use of the educational computer game. Two variables were sex-related (ratio of females in the class and the interaction of this with using the computer game). Four variables were related to the grade-level of the students (ratio of sophomores in the class, ratio of seniors in the class, and the interaction of each of these with using the computer game). The last ten variables were indicator variables for the eleven teachers involved in the experiment. Thus, there were four groups of independent variables: (1) use of the educational computer game, (2) sex-related, (3) grade level-related, and (4) teacher-related. The dependent variable was the change in class means from the pretest to the posttest for each of the hypothesized areas (mathematical achievement, attitudes toward mathematics, and graphing ability). The initial regression analysis using the full model produced p-values which indicated that mathematical achievement and graphing ability were well described by the model. The attitudes toward mathematics showed a weaker relationship ($p=0.105$). An analysis was performed in a stepwise manner to see if any variables could be dropped from the model. Using multiple regression on the variables computer-grade level interaction, grade level, computer-sex interaction, and sex produced F-ratios indicating the strength of each variable in the model. All the F-ratios were non-significant, except the computer-sex interaction in mathematical achievement. A graphical analysis and further analysis on the Number Cruncher revealed that the size of the F-ratio was primarily caused by one class. Thus, the sex-related and grade level-related variables were dropped from the model. Based on the F-ratios, it was evident in the hypothesized areas producing a significant difference that the teacher was the overwhelming factor. The teacher could not be dropped leaving only the computer game in the model. Two types of variables (using the educational computer game and teacher-related) remained in the model and the regression analysis reduced to a paired T-test. Each teacher taught a control class and an experimental class so the teacher was used as the basis for blocking with use of the computer game varying. The paired T-test analysis indicated the following:

(1) there was a significant difference, at the .08 level, in the change of class means on mathematical achievement favoring use of the educational computer game,

(2) there was very little difference in the change of class means on attitudes toward mathematics, and

(3) there was a significant difference, at the .005 level, in the change of class means on graphing ability favoring use of the educational computer game.

A multiple regression analysis was performed using the full model on the change of class means for the other subsections of the Intermediate Algebra and the five more specific attitude scales. F-ratios were calculated for the variables: computer-grade level interaction, grade level, computer-sex interaction, and sex. The only variable which revealed any signifance was computer-sex interaction on the Algebraic Operations and Solving Equations and Inequalities. This was expected since they are subsets of the mathematical achievement test. Further analysis using Number Cruncher revealed that dropping one teacher reduced the F-ratios to non-significant values. Thus, the variables computer-grade level interaction, grade level, computer-sex interaction, and sex were dropped from the model. A paired T-test was performed on each of the parts of the tests using the teacher for blocking and varying the use the educational computer game. All p-values showed no significant difference based on use of the educational computer game. The p-values also revealed that use of the computer game had a negative non-significant effect on Solving Equations and Inequalities portion of the Intermediate Algebra test ($p=0.90$) and Effectance Motivation in Mathematics ($p=0.91$). However, the former result must be tempered by the fact that very little solving of equations and inequalities was included in the unit and the students using the computer game were doing more visualizing and less paper and pencil work.

A paired T-test on the pretest scores with blocks based on the teacher and control vs. experimental varying showed that there was no significant difference between the control class means and the experimental class means in any of the hypothesized areas (mathematical achievement, attitudes toward mathematics, and graphing ability) at the beginning of the experiment. However, there was a significant difference between the posttest means and the difference between posttest and pretest means in the areas of mathematical achievement and graphing ability.

Conclusions

Several past studies have been done about educational computer games in mathematics, this study differed from those studies in several ways: (1) the cognitive level of the subjects, (2) the high school setting, (3) using a computer game which takes advantage of the hi-resolution graphics on the microcomputer, and (4) using the computer game in lieu of in-class homework.

Theoretically, the results present another example of Skemp's ideas on visualization, Bruner's iconic level, and Dienes' levels of learning. The major role played by the teacher is no surprise, it was alluded to many times and was a major point in Amarel's article.

Many of the articles in the literature search indicated that CAI (including games) increased or at the very least did not show a detrimental effect on mathematical achievement. Most of the studies were done using mainframe computers and/or involving lower ability students. Saunders and Bell found no significant difference in the second-year algebra, but

Bitter and Slauchert reported significantly higher achievement levels. The results of this study indicate that those findings are also true for the second year high school algebra classes in this study. There was a significant difference, at the .08 level, in the change of class means on mathematical achievement favoring the use of the educational computer game. The lack of a more significant difference can be greatly explained by observing that the results of the study also indicate a difference, but not a significant difference ($p=0.90$), in the class means on Solving Equations and Inequalities (one third of the Intermediate Algebra test) favoring the students who did not use the computer game. However, the latter conclusion must be tempered by the fact that very little solving of equations and inequalities was included in the unit and the students using the computer game were doing more visualizing and less paper and pencil work.

Most of the articles on CAI and computer gaming mentioned a positive effect or at least no detrimental effect on attitudes toward mathematics. The results of this study indicate that there was very little difference in the change of class means on attitudes toward mathematics between the students who used the educational computer game and the students who did not use the computer game. Further analysis showed that four of the specific attitudes (Mathematics as a Male Domain, Confidence in Learning Mathematics, Attitude Toward Success in Mathematics, and Usefulness of Mathematics) showed the same result. The results on Effectance Motivation show a difference, but not a significant difference ($p=0.91$), favoring the second year high school algebra students in the study who did not use the educational computer game. Some of the results reflect the fact that other studies in the literature covered a longer period of time, four weeks is probably insufficient time to foster a change in attitude. Many of the studies in the literature were based on students voluntarily deciding to use the CAI or the computer game; in this study not only were the students assigned to work on the computer game, but a teacher was supervising to make sure they were carrying out the assignment.

The literature produced no research studies on graphing ability, only observations and a few case studies were cited. The results of this study indicate that there was a significant difference in the change of class means on graphing ability favoring the second year high school algebra students who used the educational computer game. While this result is encouraging, one must guard against over optimism. Graphing was the thrust of the unit being studied and there is no doubt that the educational computer game did an excellent job of helping the students learn those topics covered on the graphing portion of the tests. The educational computer game is one tool among many available to the teacher of mathematics, while it did an excellent job on this unit it cannot be generalized to other units. The results on mathematical achievement from this study indicate there are other areas for which the computer game could be a very useful tool for the learner in mathematics.

Recommendations for Further Study

The literature review indicated that there are many unanswered questions dealing with CAI and educational computer gaming. As a result of this study and the review of the research, the following recommendations are made for further study:

1. This study dealt with classes, but one needs to investigate how the use of educational computer games affects an individual's learning of mathematics. Further study is recommended to identify what personality traits make a student more or less receptive to learning via an educational computer game.
2. Several articles mentioned that the method of

measuring (paper and pencil) may not reflect what the student is learning. Since this study used a traditional test to collect data, it is recommended that further studies include an observational component where someone watches and records the data. This would take into account: (1) the student's intensity level, (2) student's motivation, and (3) remarks made by the student. Valuable data would also be gained by using on-machine time as a variable. This method has the advantage of using an impartial observer rather than relying on data only provided by the student.

3. It is recommended that future studies include interviewing techniques to gather data. The study would involve gathering data from the student, but not in written form.

4. The catalogues indicate many games that the manufacturers and designers say promote mathematical learning. This study only looked at one such game, replication of this study is recommended using other mathematical computer games. The studies should include research at various levels. One of the many simulation games that purport to increase one's logical thinking ability would be a good starting point.

5. The choice of measuring instruments may provide further insight into mathematical achievement, attitudes toward mathematics, and graphing ability.

Therefore, replication of this study is recommended using different measuring instruments.

6. The mathematical achievement results in this study indicate that educational computer games can have a positive effect on learning in other units in mathematics. This unit contained graphing quadratic functions, it is recommended that future studies be conducted using other units in the curriculum to test the effects of educational computer games.

7. This study involved total immersion in the sense that there was no break from playing the computer game for four weeks. Further study is recommended where the educational computer game is used intermittently over a longer period of time.

8. This study differed in that it involved total immersion rather than intermittent treatment. This study was four weeks long, it is recommended that this study be replicated using the total immersion method for different lengths of time.

9. This study involved second year high school algebra students. The teacher is already dealing with a more select group of students. A study involving first year algebra would have ramifications on more students. Therefore, it is recommended that this study be replicated using first year algebra students. It is further recommended that the study center around the

graphing of linear functions unit.

10. Intrinsic motivation was frequently cited in the literature as the reason a student plays computer games. Further studies are recommended in which the student use of the educational computer game is more optional on the student's part.

11. A common argument found in the literature for using CAI was whether it increased retention. This study did not deal with retention of the learning, it is recommended that this study be replicated with retention being among the major concerns of the study.

12. Using the educational computer game in lieu of in-class homework was the strategy for using an educational computer in this study. Further studies are recommended which investigate what effects other strategies have on learning mathematics. Some examples might include class tournaments or strictly using the game as a demonstration tool.

13. The literature indicates that no conclusive research has been done on the side effects computer gaming has on an individual, either psychologically or physically. Further studies are recommended which investigate the effects educational computer gaming has on an individual in the above areas.

14. Many articles in the literature mentioned interactivity as a valuable part of the process of

learning mathematics through a computer. Further research is recommended to ascertain whether one or two person games are more beneficial to the learner.

15. The results of this study indicated that teacher-related variables played a major role in all the areas revealing a significant difference (mathematical achievement and graphing ability). Further studies are recommended that investigate the different aspects of the teacher variable and the possible interaction between it and using the computer.

16. In the mathematical achievement analysis of this study, the computer-sex interaction was significant. Graphical analysis and further analysis on the Number Cruncher demonstrated that dropping one teacher from the model reduced the variable to non-significance. It is recommended this interaction be further investigated in future studies.

17. There is a consensus among futurists that more learning will take place in the home via computers. Thus, it is recommended that future studies investigate the home use of educational games and their effect on the learning of mathematics.

BIBLIOGRAPHY

Aiken, L.R. Attitudes in mathematics. _Review of Educational Research,_ 1970, _40,_ 551-96.

Aiken, L.R. Two scales of attitude toward mathematics. _Journal for Research in Mathematics Education,_ 1974, 5(2), 67-71.

Amarel, S. Classrooms and computers in instructional settings. _Theory Into Practice,_ 1983, 22(4), 260-6.

An agenda for action: recommendations for school mathematics of the 1980's. Reston, Virginia: National Council of Teachers of Mathematics, 1980.

Armstrong, J.M. Achievement and participation of women in mathematics: results of two national surveys. _Journal for Research in Mathematics Education,_ 1981, 12(5), 356-72.

Badger, M.E. Why aren't girls better at maths? A review of research. _Educational Research,_ 1981, 24(1), 11-23.

Barstow, D. Computers and education: some questions of values. _The Journal of Computers in Mathematics and Science Teaching,_ 1983, 3(1), 8-12.

Bear, G.G. Microcomputers and school effectiveness. _Educational Technology,_ 1984, 24(1), 11-15.

Begle, E. G. _Critical variables in mathematics education._ Washington, D.C.: Mathematics Association of America and National Council of Teachers of Mathematics, 1979.

Bell, A.W., and others. _A review of research in mathematics education. Part A: research on learning and teaching._ 1983. (ERIC Document Reproduction Service No. 241 280).

Benbow, C.P., and Stanley, J.C. Consequences in high school and college of sex differences in mathematical reasoning ability: a longitudinal perspective. _American Education Research Journal,_ 1982, 19(4), 598-622.

Bork, A. Computers & learning: a compendium of papers. (ERIC Document Reproduction Service No. ED 239 591).

Bork, A. Computers in education today- and some possible futures. _Phi Delta Kappan,_ 1984, 66(4), 239-43.

Boraiko, A.A. The Chip. _National Geographic,_ 1982, 162(4), 421-57.

Bowman, R.F. A "Pac-Man" theory of motivation: tactical implications for classroom instruction. _Educational Technology,_ 1982, 22(9), 14-16.

Bowman, R.P., and Rotter, J.C. Computer games: friend or foe? _Elementary School Guidance and Counselor,_ 1983, 18(1), 25-34.

Braun, L. The impact of computers on mathematics. Madison: Proceedings of the conference entitled School Mathematics: Options for the 1990's (T.A. Romberg and D.M. Stewart, Eds.), 1984 (ERIC Document Reproduction Service No. 250 196).

Bright, G.W., Harvey, J.G., and Wheeler, M.M. Cognitive effects of games on mathematical learning. Madison: University of Wisconsin, 1977. (ERIC Document Reproduction Service No. ED 166 007).

Bright, G.W., Harvey, J.G., and Wheeler, M.M. Incorporating instructional objectives into the rules of a game. _Journal for Research in Mathematics Education,_ 1979, 10(5), 356-9.

Bright, G.W., Harvey, J.G., and Wheeler, M.M. Game constraints, player verbalizations, and mathematics learning. _Journal of Experimental Education,_ 1980, 49(1), 52-55.

Broadbooks, W.J., Elmore, P.B., Pederson, K., and Bleyer, D.R. Construct validation study of the Fennema-Sherman Mathematics Attitudes Scales. _Educational and Psychological Measurement,_ 1981, 41(2), 551-557.

Bruner, J.S. _The process of education._ Cambridge, Mass.: Harvard University Press, 1960.

Bruner, J.S. Toward a theory of instruction. Cambridge: Belknap Press of Harvard University, 1966.

Bruner, J.S., Jolly, A., and Sylva, K. (Eds.). Play - its role in development and evolution. New York: Basic Books, 1976.

Burns, P.K., and Bozeman, W.C. Computer-assisted instruction and mathematics achievement: is there a relationship? Educational Technology, 1981, 21(10), 32-39.

Camp, J.S., and Marchionini, G. Computer enhanced mathematics. Viewpoints in Teaching and Learning, 1981, 57(2), 1-12.

Campbell, D., and Stanley, J. Experimental and quasi-experimental design for research on teaching. In N. Gage (Ed), Handbook of research on teaching. Chicago: Rand McNally, 1963.

Carpenter, T.P., et. al. Students' affective responses in mathematics: secondary results from national assessment. Mathematics Teacher, 1980, 73(7), 521-39.

Chambers, J.A., and Sprecher, J.W. Computer-assisted instruction: current trends and critical issues. Communications of the ACM, 1980, 23(6), 232-243.

Clement, F.J. Affective considerations in computer-based education. Educational Technology, 1981, 21(4), 28-32.

College Entrance Examination Board. Intermediate Algebra. In Descriptive Tests of Mathematics Skills of the College Board. 1978.

College Entrance Examination Board. Guide to the use of the Desciptive Tests of Mathematics Skills. 1979.

Computers in Mathematics Education. Reston, Virginia: National Council of Teachers of Mathematics, 1984.

Dalton, D.W., and Hannafin, M.J. The role of computer-assisted instruction in affecting learner self-esteem: a case study. Educational Technology, 1984, 24(12), 42-4.

Davis, P.J., and Hersh, R. The mathematical experience. Boston: Birkhauser, 1980.

DeBono, E. New think: the use of lateral thinking in the generation of new ideas. New York: Harper & Row, 1970.

DeBono, E. Lateral thinking: creativity step by step. New York: Harper & Row, 1970.

Deken, J. The electronic cottage. New York: Bantam Books, 1980.

Dekkers, J., and Donatti, S. Integration of research studies on use of simulations as an instructional strategy. Journal Educational Research, 1981, 74(6), 422-7.

Dewey, J. Experience and education. London: Collier-Macmillan, 1963.

Diem, R.A. Education and computer technology: some unresolved issues. Educational Technology, 198, 22(6), 19-21.

Dienes, Z.P. Building up mathematics. London: Hutchinson, 1960.

Dienes, Z.P. An experimental study of mathematical learning. London: Hutchinson, 1963.

Dienes, Z.P. The power of mathematics. London: Hutchinson, 1964.

Dienes, Z.P. Mathematics through the senses: games, dance, & art. Atlantic Highlands, New Jersey: Humanities, 1973.

Dienes, Z.P. The six stages in the process of learning mathematics. Atlantic Highlands, New Jersey: Humanities, 1973.

Dienes, Z.P., and Holt, M. Let's play math. New York: Walker & Co., 1973.

Dreyfus, T. How to use a computer to teach mathematical concepts. Madison: Proceedings of the sixth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education (J.M. Moser, Ed.), 1984. (ERIC Document Reproduction Service No. ED 253 432).

Dreyfus, T., and Eisenberg, T. Intuitive functional concepts: a baseline study of intuitions. Journal for Research in Mathematics Education, 1982, 13(5), 360-380.

Driskell, J.E., and Dwyer, D.J. Microcomputer videogame based training. Educational Technology, 1984, 24(2), 11-16.

Dugdale, S. GREEN GLOBS: A microcomputer application for graphing of equations. Urbana: University of Illinois, 1981. (ERIC Document Reproduction Service No. ED 208 876).

Dugdale, S. GREEN GLOBS: a microcomputer application for graphing of equations. Mathematics Teacher, 1982, 75(3), 208-14.

Dugdale, S., and Kibbey, D. Prototype microcomputer courseware for teaching high school algebra. Urbana: University of Illinois, 1983. (ERIC Document Reproduction Service No. ED 232 846).

Dunne, J.J. Gaming approaches in educational software: an analysis of their use and effectiveness. New York: Columbia University, 1985. (ERIC Document Service No. ED 253 207).

Dutton, W.H., and Blum, M.P. The measurement of attitudes toward arithmetic with a Likert-type test. Elementary School Journal, 1968, 68, 259-264.

Ediger, M. Philosophy of microcomputer use in the mathematics curriculum. 1985. (ERIC Document Reproduction Service No. ED 253 415).

Educational computing software: state of the art in 1984. An interview with Dr. Michael W. Allen. Educational Technology, 1984, 24(2), 7-10.

Ethington, C.A., and Wolfle, L.M. Sex differences in a causal model of mathematics achievement. Journal for Research in Mathematics Education, 1984, 15(5), 361-77.

Evans, C. The micro millennium. New York: Washington Square Press, 1979.

Fennema, E. The sex factor. In E. Fennema (ed.), Mathematics Education Research: Implications for the 80's. Alexandria: Association for Supervision and Curriculum Development, 1981.

Fennema, E., and Sherman, J. "Fennema-Sherman Mathematics Attitude Scales." JSAS Catalogue of Selected Documents in Psychology 6(1976): 31 (Ms. No. 1225).

Fennema, E., and Tartre, L.A. The use of spatial visualization in mathematics by boys and girls. Journal for Research in Mathematics Education, 1985, 16(3), 184-206.

Fennema, E., Wolleat, P.L., Pedro, J.D., and Becker, A.D. Increasing women's participation in mathematics: an intervention study. Journal for Research in Mathematics Education, 1981, 12(1), 3-14.

Ferguson, M. How and why the computer gives power back to people. Forecast for Home Economics, 1983, 229(3), 41.

Fey, J.T. (Ed.) Computing & mathematics: the impact on secondary school curricula. College Park: University of Maryland, 1984.

Fishbein, E., Tirosh, D., and Melamed, U. Is it possible to measure the intuitive acceptance of a mathematical statement? Educational Studies in Mathematics, 1981, 12(4), 491-512.

Forman, D. Search of the literature. The Computing Teacher, 1982, 9(5), 37-51.

Gallitano, G.M. The effects of a computer based approach to teaching trigonometry on student achievement and attitudes (Doctoral Dissertation, Columbia University Teachers College, 1983). Dissertation Abstracts International, 1984, 44, 3311-A.

Gamewomanship. Science '84, 1984, 5(1), 7.

Gawronski, J.D. Computers in school mathematics. In S. Hill (Ed.), Education in the 80's. Washington: National Education Association, 1982.

Getman, G.N. Optometric problems causes by computers in the classroom. Academic Therapy, 1983, 18(5), 517-524.

Gleason, G.T. Microcomputers in education: the state of the art. Educational Technology, 1981, 21(3), 7-19.

Glickman, C.D. Play and the school curriculum: the historical context. Journal of Research and Development in Education, 1981, 14(3), 1-10.

Grady, D. What every teacher should know about computer simulations. Learning, 1983, 11(8), 34,39,42,46.

Hadamard, J. An essay on the psychology of invention in the mathematical field. Princeton: Princeton University Press, 1949.

Heinich, R. The proper study of instructional technology. Educational Communication and Technology, 1984, 32(2), 67-88.

Henry, K.M. The effect of games on cognitive abilities and attitudes toward mathematics. Unpublished doctoral dissertation, Oregon State University, 1974.

Heuston, D.H. Computers in elementary and secondary education. Orem, UT.: WICAT Systems, Inc., 1983. (ERIC Document Reproduction Service No. ED 246 845).

Hirschbuhl, J.J. Hardware considerations for computer based education in the 1980's. Journal of Research and Development in Education, 1980, 14(1), 41-56.

Hoben, T. Sex differences in high mathematical reasoning ability: a theory to fit the facts. 1984. (ERIC Document Reproduction Service No. ED 245 881).

Hoffman, J.L., and Waters, K. Some effects of student personality on success with computer-assisted instruction. Educational Technology, 1982, 22(3), 20-21.

Into the electronic learning era: implications for education and psychological research. An interview with Mary Alice White. Educational Technology, 1981, 21(9), 9-13.

Isaac, S., and Michael, W.B. Handbook in research and evaluation. San Diego: EdITS, 1981.

Kelman, P., Bardige, A., Choate, J., Hanify, G., Richards, J., Roberts, N., Walters J., and Tornrose, M.K. Computers in teaching mathematics. Reading, Mass.: Addison-Wesley, 1983.

Kirschner, V. Females and mathematics. ERIC/SMEAC Mathematics Education Fact sheet, No. 1, 1981.

Kline, M. The ancients versus the moderns, a new battle of the books. Mathematics Teacher, 1958, 1(6), 418-427.

Koehler, M.S., and Fennema, E. Women and mathematics: is there a problem? In S. Hill (Ed.), Education in the 80's. Washington: National Education Association, 1982.

Komoski, P.K. Educational computing: the burden of insuring quality. Phi Delta Kappan, 1984, 66(4), 244-48.

Kulik, J.A. Synthesis of research on computer-based instruction. Educational Leadership, 1983, 41(1), 19-21.

Kulik, J.A., Bangert, R.L., and Williams, G.W. Effects of computer-based teaching on secondary school students. Journal of Educational Psychology, 1983, 75(1), 19-26.

Kulm, G. Research on mathematics attitude. In R.J. Shumway (Ed.), _Research in Mathematics Education._ Reston: National Council of Teachers of Mathematics, 1980.

Leder, G. Bright girls, mathematics and fear of success. _Educational Studies in Mathematics,_ 1980, 11(4), 411-22.

Lesgold, A.M., and Reif, F. Computers in education: realizing the potential. Pittsburgh: Report of a Research Conference, 1983. (ERIC Document Service No. ED 235 783).

Mathematics for the middle grades. Reston, Virginia: National Council of Teachers of Mathematics, 1983, pp. 35-49.

McClave, J.T., and Dietrich, F.,III. _Statistics._ San Francisco: Dellen Publishing Company, 1985.

Minato, S., and Yanase, S. On the relationship between students' attitudes toward school mathematics and their levels of intelligence. _Educational Studies in Mathematics,_ 1984, 15(3), 313-20.

Mirabelli, A. Beware of the microcomputer...and why. _Forecast for Home Economics,_ 1983, 29(3), 41.

Moore, M.L. _Effects of selected mathematical computer games on achievement and attitude toward mathematics in university entry-level algebra._ Unpublished doctoral dissertation, Oregon State University, 1981.

Morris, J.P. Microcomputers in a sixth grade classroom. _Arithmetic Teacher,_ 1983, 31(2), 22-24.

Naisbitt, J. _Megatrends._ New York: Warner Books, 1984.

National Council of Teachers of Mathematics. The impact of computing technology on school mathematics: report of an NCTM conference. _Journal of Computers in Mathematics and Science Teaching,_ 1984-5, 4(2), 19-23.

National Council of Teachers of Mathematics. Mathematics education research: 1984 in review. Journal for Research in Mathematics Education, 1985, 16(4), 316-9.

Needham, N.R. Thirty billion quarters can't be wrong- or can they? Today's Education, 1982-83 annual, 53-55.

Neter, J., and Wasserman, W. Applied linear statistical models. Homewood, Illinois: Richard D. Irwin, Inc., 1974.

Nugent, G.C. Pictures, audio, and print: symbolic representation and effect on learning. Educational Communication & Technology Journal, 1982, 30(3), 163-174.

O'Brien, T.C. Wasting new technology on the same old curriculum. Classroom Computer Learning, 1983, 4(4), 24-27,30.

Ohanian, S. Beware the rosy view! Classroom Computer Learning, 1983, 4(3), 20-21, 23-24, 26-27.

Overton, V. Research in instructional computing and mathematics education. Viewpoints in Teaching and Learning, 1981, 57(2), 23-36.

Overview and analysis of school mathematics, K-12. A report of the National Advisory Council on Mathematics Education, 1976.

Parsons, J.B. The seductive computer: can it be resisted? The Education Digest, 1983, 49(3), 46-49.

Papert, S. Mindstorms. New York: Basic Books, 1980.

Piaget, J. Play, dreams, and imitation in childhood. (C. Gattegno and F.M. Hodgson, trans.) New York: Norton, 1962.

Piaget, J. The psychology of intelligence. Paterson, New Jersey: Littlefield, Adams, 1963.

Ploeger, F.D. The effectiveness of microcomputers in education. Austin: Southwest Educational Development Lab, 1983. (ERIC Document Reproduction Service No. ED 246 876).

Poincaré, H. Mathematical Creation. In James R. Newman (Ed.), The world of mathematics, vol. 4. New York: Simon and Schuster, 1956.

Polya, G. How to solve it. Princeton, New Jersey: Princeton Universtiy Press, 1945.

Polya, G. Mathematical Discovery. New York: John Wiley & Sons, Inc., 1962.

Polyani, M. The tacit dimension. Garden City, N. Y.: Anchor Books, 1967.

Popham, W.J. Educational Statistics. New York: Harper & Row, 1967.

Position paper on basic mathematical skills. National Council of Supervisors of Mathematics, January, 1977.

Powers, S., Douglas, P., and Choroszy, M. A reliability and validity investigation of the mathematics attribution scale [algebra]. Educational and Psychological Measurement, 1984, 44(3), 733-7.

Priorities in school mathematics: executive summary of the PRISM project. Reston, Virginia: National Council of Teachers of Mathematics, 1981.

Reyes, L.H. Attitudes and mathematics. In M.M. Lindquist (Ed.), Selected issues in mathematics education. Chicago: National Society for the Study of Education, 1980.

Roberts, F.C., and Park, O. Intelligent computer-assisted instruction: an explanation and overview. Educational Technology, 1983, 23(12), 7-12.

Salisbury, D.F. How to decide when and where to use microcomputers for instruction. Educational Technology, 1984, 24(3), 22-4.

Samples, B. The metaphoric mind. Reading, Mass.: Addison-Wesley, 1976.

Samples, B., Charles, C., and Barnhart, D. _The wholeschool book._ Reading, Mass.: Addison-Wesley, 1977.

Saunders, J., and Bell, F.H. Computer-enhanced algebra resources: their effects on achievement and attitudes. _International Journal of Mathematics Education in Science and Technology,_ 1980, 11(4), 465-73.

Schonberger, A.K. Sex-related issues in mathematics education. In M.M. Lindquist (Ed.), _Selected issues in mathematics education._ Chicago: National Society for the Study of Education, 1980.

Shay, C. Simulations in the classroom: an appraisal. _Educational Technology,_ 1980, 20(11), 26-31.

Sherman, J. Predicting math-performance in high school boys and girls. _Journal of Educational Psychology,_ 1979, 71(2), 242-7.

Sherman, J. Mathematics, spacial visualization, and related factors: changes in girls and boys, grade 8-11. _Journal of Educational Psychology,_ 1980, 72(4), 476-82.

Shostak, A.B. The coming systems break: technology and schools of the future. _Phi Delta Kappan,_ 1981, 62(5), 356-9.

Signer, B.R. A formative and summative evaluation study of a project integrating the microcomputer with second year high school algebra instruction. (Doctoral Dissertation, University of South Florida, 1982). _Dissertation Abstracts International,_ 1982, 43, 711-A.

Skemp, R.R. _Intelligence, learning, and action._ New York: John Wiley & Sons, 1979.

Skemp, R.R. _The psychology of learning mathematics._ Middlesex, England: Penguin Books, 1973.

Skinner, B.F. _The technology of teaching._ New York: Appleton-Century-Crofts, 1968.

Smith, I.D. Impact of computer-assisted instruction on student attitudes. _Journal of Educational Psychology,_ 1973, 64(3), 366-72.

Snedecor, G.W., and Cochran, W.G. Statistical methods. Ames, Iowa: Iowa State University Press, 1980.

Steffin, S.A. Come in and play with me computer simulations: a key to divergent thinking. Media & Methods, 1981, 18(2), 12-13.

Stevens, D.J., and Sybouts, W. Computers in the classroom. Clearing House, 1982, 56(2), 82-85.

Stolker, B. Your microcomputer future (in basic English). Forecast for Home Economics, 1983, 29(3), 38-40.

Stowitschek, J.J., and Stowitschek, C.E. One more time with feeling: the absence of research on teacher use of microcomputers, Exceptional Education Quarterly, 1984, 4(4), 23-39.

Suydam, M.N. Microcomputers and mathematics instruction. ERIC/SMEAC Mathematics Education Fact Sheet No. 4, 1981.

Taylor, R. The computer in the school: tutor, tool, tutee. New York: Teachers College Press, 1980.

Teaching statistics and probability. Reston, Virginia: National Council of Teachers of Mathematics, 1981, pp. 220-233.

TECHnically Speaking an occasional column of editorial opinion. Educational Technology, 1983, 23(2), 6.

The agenda in action. Reston, Virginia: National Council of Teachers of Mathematics, 1983, pp. 131-153.

Thomas, D. The effectiveness of CAI in secondary schools. AEDS Journal, 1979, 12, 103-16. (ERIC Document Reproduction Service No. ED 204 144).

Toffler, A. The third wave. New York: Bantam Books, 1980.

Von Neumann, J., and Morgenstern, O. Theory of games and economic behavior. Princeton, New Jersey: Princeton University Press, 1944.

Wagschal, P.H. A last chance for computers in the schools? Phi Delta Kappan, 1984, 66(4), 251-4.

Watson, J.M. The Aiken attitude to mathematics scales: psychometric data on reliability and discriminant validity. Educational and Psychological Measurement, 1983, 43(4), 1247-53.

Weller, D.L. The teacher and computerized technology: a teaching partnership in the cognitive and affective domain. The Clearing House, 1983, 57(4), 149-52.

White, M.A. Synthesis of research on electronic learning. Educational Leadership, 1983, 40(8), 13-5.

White, R.W. Motivation reconsidered: the concept of competence. Psychological Review, 66(5), 1959, 297-333.

Why are boys' scores higher? Higher math aptitude, says John Hopkins duo. Phi Delta Kappan, 1981, 62(6), 463-4.

Wilkinson, J.D. The computer- a tool for instruction? Mathematics Teacher, 1984, 77(6), 404-5.

Winn, W. Visualization in learning and instruction: a cognitive approach. Educational Communication & Technology Journal, 1982, 30(1), 3-25.

Wittman, E. The complementary roles of intuitive and reflective thinking in mathematics teaching. Educational Studies in Mathematics, 1981, 12(4), 389-97.

APPENDICES

Appendix A

Class Data Achievement and Graphing Ability

Class	Number of Students pre	post	both	Female Ratio	Sophomore Ratio	Senior Ratio
C 1	11	10	9	.333	.000	.778
E 1	17	18	17	.706	.000	.529
C 2	15	14	13	.538	.077	.462
E 2	17	14	12	.667	.083	.250
C 3	26	21	19	.263	.368	.211
E 3	24	21	19	.579	.053	.105
C 4	24	21	19	.632	.000	.000
E 4	27	26	25	.480	.000	.000
C 5	29	29	25	.800	.240	.080
E 5	23	26	23	.609	.217	.087
C 6	20	18	18	.556	.056	.056
E 6	16	14	13	.615	.154	.154
C 7	21	24	18	.444	.000	.111
E 7	22	17	17	.294	.059	.118
C 8	31	28	27	.704	.222	.185
E 8	23	20	19	.579	.421	.053
C 9	27	27	26	.385	.192	.154
E 9	23	23	22	.545	.136	.136
C 10	24	23	22	.591	.227	.273
E 10	24	25	23	.565	.217	.087
C 11	18	18	16	.563	.188	.063
E 11	23	23	23	.826	.043	.217

Appendix A

Class Data Attitude

Class	Number of Students pre	post	both	Female Ratio	Sophomore Ratio	Senior Ratio
C 1	11	8	7	.286	.000	.857
E 1	17	18	17	.706	.000	.529
C 2	15	14	13	.538	.077	.462
E 2	19	14	13	.615	.154	.231
C 3	26	21	19	.263	.368	.211
E 3	24	21	19	.579	.053	.105
C 4	24	21	19	.632	.000	.000
E 4	27	26	25	.480	.000	.080
C 5	29	29	25	.800	.240	.080
E 5	23	26	23	.609	.217	.087
C 6	20	16	16	.500	.063	.063
E 6	16	14	13	.615	.154	.154
C 7	20	24	17	.471	.000	.118
E 7	22	17	17	.294	.059	.118
C 8	32	28	27	.741	.185	.185
E 8	24	21	21	.571	.381	.048
C 9	27	27	26	.385	.192	.154
E 9	23	23	22	.545	.136	.136
C 10	24	23	22	.591	.227	.273
E 10	24	25	23	.565	.217	.087
C 11	18	18	16	.563	.188	.063
E 11	23	23	23	.826	.043	.217

Appendix B

Form A Intermediate Algebra Skills
Descriptive Tests of Mathematics Skills
of the College Board

Time—30 minutes

30 Questions

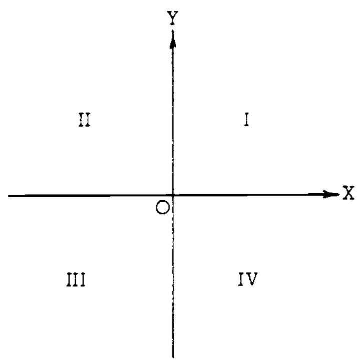
Directions: Solve each problem in this test using the paper provided by your test administrator if needed. Then indicate the answer by darkening the appropriate space on the answer sheet. Do not write in this test booklet.

1. $4x^2 - 49 =$

   (A) $(2x - 7)(2x + 7)$
   (B) $(4x - 49)(x + 1)$
   (C) $4(x - 7)(x + 7)$
   (D) $(4x - 7)(4x + 7)$

2. $(-3x^3)^2 =$

   (A) $-6x^6$ (B) $9x^5$ (C) $9x^6$ (D) $9x^9$



3. Which quadrant contains the points that satisfy both $x < -2$ and $y > 1$?

   (A) I (B) II (C) III (D) IV

4. $7x^2 + 18xy + 8y^2 =$

   (A) $(7x + 2y)(x + 4y)$
   (B) $(7x + 4y)(x + 2y)$
   (C) $(7x^2 + 4)(1 + 2y^2)$
   (D) $(x + y)(7x + 8y)$

5. $\frac{x^2 - 3x + 2}{3x - 3} =$

   (A) $\frac{x^2 + 2}{-3}$
   (B) $\frac{x - 2}{3}$
   (C) $x + 1$
   (D) $\frac{x + 2}{3}$

6. $(a - 3b)^2 =$

   (A) $a^2 - 9b^2$
   (B) $a^2 + 6b^2$
   (C) $a^2 - 3ab + 9b^2$
   (D) $a^2 - 6ab + 9b^2$

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$$\begin{cases} x + y = 7 \\ 3x - y = 5 \end{cases}$$

7. In the solution of the system of equations above, what is the value of x ?

(A) 6 (B) 4 (C) 3 (D) $\frac{8}{3}$

8. $x^3y - xy^2 =$

(A) $xy(x^2 - y)$
(B) $x^2y^2(x - y)$
(C) $x^3y(1 - y)(1 + y)$
(D) $x^2y(x - y^2)$

9. If $\frac{x-2}{4} = \frac{2x+1}{3}$, then $x =$

(A) 2 (B) $\frac{3}{5}$ (C) $-\frac{3}{5}$ (D) -2

10. $(8a^6)^{\frac{1}{3}} =$

(A) $2a^2$ (B) $\frac{8}{3}a^2$ (C) $2a^3$ (D) $\frac{8}{3}a^3$

11. The values of x for which $|x - 3| = 12$ are

(A) 9 only
(B) 15 only
(C) -9 and 15
(D) 9 and 15

12. $\sqrt{27} + \sqrt{12} =$

(A) $\sqrt{39}$
(B) $13\sqrt{3}$
(C) $6\sqrt{3}$
(D) $5\sqrt{3}$

13. If $y = mx + b$ and $m \neq 0$, then $x =$

(A) $\frac{y-b}{m}$ (B) $\frac{b-y}{m}$ (C) $\frac{y}{m} - b$ (D) $b - \frac{y}{m}$

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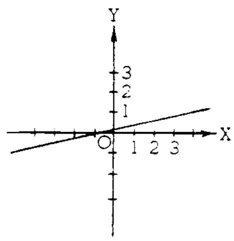
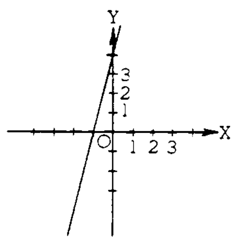
Descriptive Tests of Mathematics Skills
of the College Board

14. Which of the following is the graph of $y = 4x - 1$?

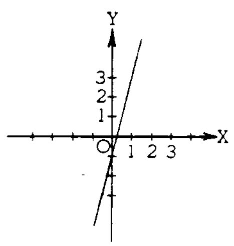
(A)



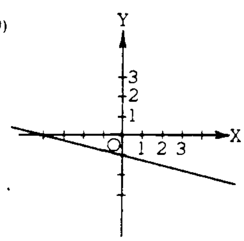
(B)



(C)



(D)



15. Which of the following is equivalent to $3x + 4 > x - 1$?

(A) $x > -5$ (B) $x > -\frac{5}{2}$ (C) $x > \frac{5}{4}$ (D) $x > \frac{3}{2}$

16. What is the slope of the line that contains the points $(-3, 2)$ and $(0, 0)$?

(A) $-\frac{3}{2}$ (B) $-\frac{2}{3}$ (C) $\frac{2}{3}$ (D) $\frac{3}{2}$

17. What are the roots of $3x(x + 1)(x - 2) = 0$?

(A) -1, 0, and 2

(B) -1, $-\frac{1}{3}$, and 2

(C) -2, 1, and 0

(D) -1 and 2 only

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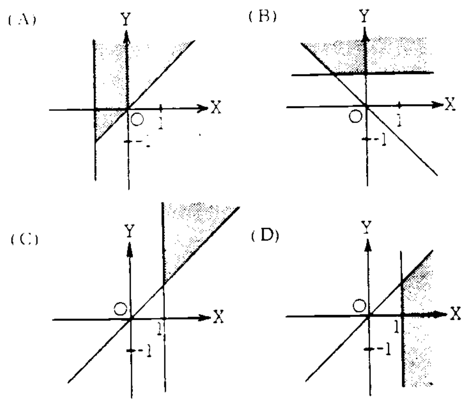
18. Which of the following shaded regions is the graph of the set $\{(x, y) : y \geqq x \text{ and } x \geqq 1\}$?



19. $\frac{7x^2 - 14x}{3xy} \div \frac{xy - 2y}{y^2} =$

(A) $\frac{7(x-2)^2}{3y^2}$

(B) $\frac{7(x-2)}{3y}$

(C) $\frac{7}{3y}$

(D) $\frac{7}{3}$

20. The roots of the equation $x^2 + 13x - 30 = 0$ are

(A) −15 and 2
(B) −10 and −3
(C) −2 and 15
(D) 3 and 10

21. The distance between the points (2, 3) and (5, 7) is

(A) $\sqrt{149}$ (B) 7 (C) $\sqrt{47}$ (D) 5

22. $\frac{1}{z-1} - \frac{1}{z+1} =$

(A) 0 (B) $\frac{1}{z}$ (C) $\frac{2}{z^2-1}$ (D) $\frac{2z}{z^2-1}$

23. The y-intercept of the graph of $2x - 3y = 8$ is

(A) 8 (B) $\frac{2}{3}$ (C) $-\frac{4}{3}$ (D) $-\frac{8}{3}$

24. What are all values of x for which $x^2 - 9x \geqq 0$?

(A) $x \geqq -9$
(B) $x \geqq 9$
(C) $0 \leqq x \leqq 9$
(D) $x \leqq 0$ or $x \geqq 9$

25. Which of the following is an equation of the line with slope −2 that contains the point (−2, 1) ?

(A) $y + 1 = -2(x - 2)$
(B) $y - 1 = -2(x + 2)$
(C) $y + 1 = 2(x - 2)$
(D) $y - 1 = 2(x + 2)$

26. If $\frac{1}{x} + \frac{2}{x} = \frac{5}{4}$, then x =

(A) $\frac{5}{12}$ (B) 2 (C) $\frac{12}{5}$ (D) 4

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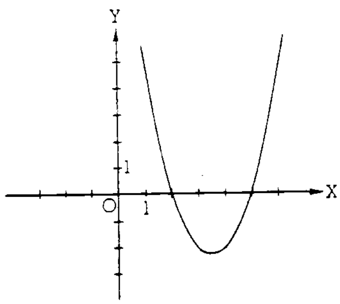
27. An equation of the line that is parallel to $3x + 2y = 7$ and that passes through the point $(0, 0)$ is

(A) $y = -\frac{3}{2}x$

(B) $y = -\frac{2}{3}x$

(C) $y = \frac{2}{3}x$

(D) $y = \frac{3}{2}x$



28. Which of the following could be an equation of the graph above?

(A) $y = x^2 + 7x + 10$
(B) $y = x^2 - 7x + 10$
(C) $y = x^2 - 7x$
(D) $y = -x^2 + 7x - 10$

29. The roots of $2x^2 - 5x - 5 = 0$ are

(A) $\frac{5 \pm \sqrt{15}}{4}$

(B) $\frac{5 \pm \sqrt{65}}{4}$

(C) $\frac{5 \pm \sqrt{35}}{2}$

(D) $\frac{5 \pm \sqrt{65}}{2}$

30. Which of the following is an equation of a line that is perpendicular to a line with a slope of $\frac{2}{5}$?

(A) $y = \frac{2}{5}x + 3$

(B) $y = -\frac{2}{5}x + 3$

(C) $y = \frac{5}{2}x + 3$

(D) $y = -\frac{5}{2}x + 3$

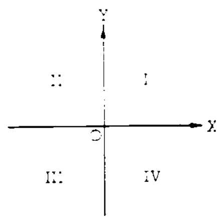
IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK ON THIS TEST.

Appendix C

Form B Intermediate Algebra Skills
Descriptive Tests of Mathematics Skills
of the College Board

Time—30 minutes
30 Questions

<u>Directions</u>: For this test solve each problem. Then indicate the <u>best</u> answer in the appropriate space on the answer sheet.



1. In which quadrant in the figure above would the point (5, −2) be located?

   (A) I (B) II (C) III (D) IV

2. $(-2t^2)^3 =$

   (A) $-8t^6$ (B) $-6t^5$ (C) $6t^6$ (D) $8t^5$

3. $(5r + s)^2 =$

   (A) $10r^2 + 2s^2$
   (B) $25r^2 + s^2$
   (C) $25r^2 + 5rs + s^2$
   (D) $25r^2 + 10rs + s^2$

4. $\dfrac{x^2 - 3x - 4}{2x + 2} =$

   (A) $x - 2$

   (B) $x^2 - x - 2$

   (C) $\dfrac{x - 4}{2}$

   (D) $\dfrac{x^2 - 3x - 2}{2x}$

5. If $P = 2L + 2H$, then $L =$

   (A) $\dfrac{P - H}{2}$

   (B) $P - 2H$

   (C) $2(P - 2H)$

   (D) $\dfrac{P - 2H}{2}$

6. $9x^2 - 64 =$

   (A) $(3x - 8)^2$
   (B) $(9x - 8)(9x + 8)$
   (C) $(9x - 64)(x + 1)$
   (D) $(3x - 8)(3x + 8)$

7. Which of the following is equivalent to $6x - 7 < x + 4$?

   (A) $x < \dfrac{11}{5}$

   (B) $x > \dfrac{11}{5}$

   (C) $x < -\dfrac{1}{2}$

   (D) $x > -\dfrac{1}{2}$

8. $\sqrt{45} - \sqrt{20} =$

   (A) 1 (B) $\sqrt{5}$ (C) 5 (D) $5\sqrt{5}$

GO ON TO THE NEXT PAGE.

Appendix C

Form B Intermediate Algebra Skills Descriptive Tests of Mathematics Skills of the College Board

9. If $\frac{3}{x} - \frac{4}{x} = \frac{1}{2}$, then $x =$

(A) -2 (B) $-\frac{1}{2}$ (C) $\frac{1}{2}$ (D) 2

10. The values of x for which $|4 - x| = 15$ are

(A) -11 only
(B) 19 only
(C) -11 and 19
(D) -11 and -19

11. $x^2y - xy^3 =$

(A) $xy(x - y^2)$
(B) $xy(x + y)(x - y)$
(C) $x^2y(1 - xy^2)$
(D) $x^2y^2(y - x)$

12. The roots of $4x(x - 5)(x + 2) = 0$ are

(A) -5, 0, and 2

(B) -2, 0, and 5

(C) -2, $\frac{1}{4}$, and 5

(D) -2 and 5 only

13. $\frac{9x^2 + 18x}{2xy} \div \frac{xy + 2y}{x^2} =$

(A) $\frac{9(x + 2)}{2x}$

(B) $\frac{9(x + 2)^2}{2x^2}$

(C) $\frac{9x^2}{2y^2}$

(D) $\frac{9}{2}$

14. What is the slope of the line that contains the points $(4, -5)$ and $(2, 3)$?

(A) 1 (B) $-\frac{1}{4}$ (C) -1 (D) -4

15. Which of the following points is on the graph of $x - 2y = 6$?

(A) $(-4, -2)$
(B) $(-2, 2)$
(C) $(2, -2)$
(D) $(4, -2)$

16. The roots of the equation $2x^2 - 5x + 3 = 0$ are

(A) $-\frac{3}{2}$ and -1

(B) $-\frac{3}{2}$ and 1

(C) -1 and $\frac{3}{2}$

(D) 1 and $\frac{3}{2}$

17. Which of the following is a factor of $2x^2 + xy - 6y^2$?

(A) $(x - 3y)$
(B) $(x - 2y)$
(C) $(2x + 3y)$
(D) $(2x - 3y)$

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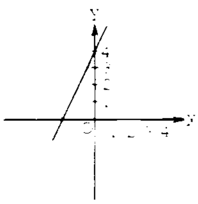
Appendix C

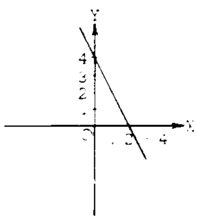
Form B Intermediate Algebra Skills
Descriptive Tests of Mathematics Skills
of the College Board

18. Which of the following is the graph of $y = -2x + 4$?

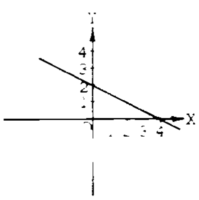
(A)



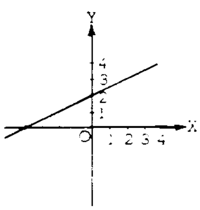
(B)



(C)



(D)



19. In the solution of the system of equations

$$\begin{cases} 5x + y = 2 \\ x - y = 10, \end{cases}$$

what is the value of y ?

(A) -12 (B) -8 (C) 8 (D) 12

20. The slope of the line with equation $6x - 7y = 10$ is

(A) $-\frac{7}{6}$ (B) $-\frac{6}{7}$ (C) $\frac{6}{7}$ (D) $\frac{7}{6}$

21. What are all values of x for which $x^2 + 4x \leq 0$?

(A) $x \leq 0$
(B) $0 \leq x \leq 4$
(C) $-4 \leq x \leq 0$
(D) $x \leq -4$ or $x \geq 0$

22. $\dfrac{1}{y-2} - \dfrac{1}{y+2} =$

(A) $\dfrac{-4}{y^2 - 4}$ (B) $\dfrac{4}{y^2 - 4}$ (C) $-\dfrac{1}{y^2}$ (D) 0

23. An equation of a line that is perpendicular to a line with slope $-\frac{3}{8}$ is

(A) $y = \frac{8}{3}x$

(B) $y = \frac{3}{8}x$

(C) $y = -\frac{3}{8}x$

(D) $y = -\frac{8}{3}x$

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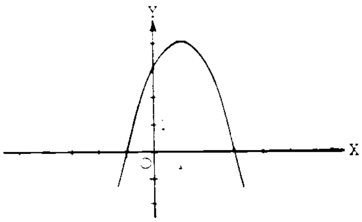
Appendix C

Form B Intermediate Algebra Skills Descriptive Tests of Mathematics Skills of the College Board

-6-

24. The distance between the points (−3, 4) and (6, 2) is

(A) $\sqrt{13}$ (B) $3\sqrt{5}$ (C) $\sqrt{85}$ (D) $3\sqrt{13}$



25. Which of the following could be an equation of the graph above?

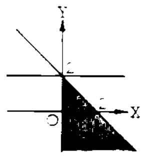
(A) $y = -x^2 + 2x + 3$
(B) $y = -x^2 + 2x - 3$
(C) $y = x^2 + 2x + 3$
(D) $y = x^2 + 2x - 3$

26. Which of the following is true about the graph of $2x - 3y - 6 = 0$?

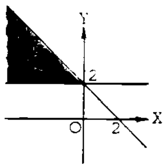
(A) The x-intercept is −3.
(B) The y-intercept is −2.
(C) The slope is 2.
(D) The point (0, 0) is on the graph.

27. Which of the following shaded regions is the graph of the set $\{(x, y): x + y \leq 2 \text{ and } y \geq 2\}$?

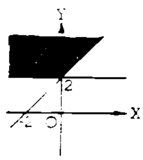
(A)



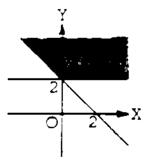
(B)



(C)



(D)



GO ON TO THE NEXT PAGE.

Appendix C

Form B Intermediate Algebra Skills
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28. If $\frac{2x+5}{7} = \frac{x+3}{6}$, then $x =$

(A) -9 (B) -2 (C) $-\frac{9}{5}$ (D) $-\frac{2}{5}$

29. $(16c^{16})^{\frac{1}{4}} =$

(A) $4c^2$ (B) $4c^4$ (C) $2c^2$ (D) $2c^4$

30. The roots of $x^2 - 5x + 1 = 0$ are

(A) $\frac{5 \pm \sqrt{21}}{2}$

(B) $\frac{5 \pm \sqrt{29}}{2}$

(C) $\frac{-5 \pm \sqrt{21}}{2}$

(D) $\frac{-5 \pm \sqrt{29}}{2}$

IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK ON THIS TEST.

Appendix D

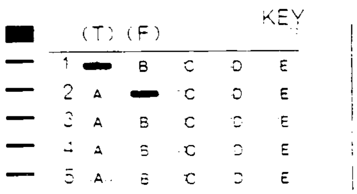
Mathematics Attitude Scales

On the following pages is a series of statements. There are no correct answers for these statements. They have been set up in a way which permits you to indicate the extent to which you agree or disagree with the ideas expressed. Suppose the statement is:

Example 1. I like mathematics.

As you read the statement, you will know whether you agree or disagree. If you strongly agree, blacken circle A opposite Number 1 on your answer sheet. If you agree but with reservations, that is, you do not fully agree, blacken circle B. If you disagree with the idea, indicate the extent to which you disagree by blackening circle D for disagree or circle E if you strongly disagree. But if you neither agree nor disagree, that is, you are not certain, blacken circle C for undecided. Also, if you cannot answer a question, blacken C. Do the same for example No. 2. See the sample answers below.

Example 2. Math is very interesting to me.



Do not spend much time with any statement, but be sure to answer every statement. Work fast but carefully.

There are no "right" or "wrong" answers. The only correct responses are those that are true for you. Whenever possible, let the things that have happened to you help you make a choice. Do not mark on the booklet.

THIS INVENTORY IS BEING USED FOR RESEARCH PURPOSES ONLY AND NO ONE WILL KNOW WHAT YOUR RESPONSES ARE.

Appendix D

Mathematics Attitude Scales

1. I like math problems.
2. Being regarded as smart in mathematics would be a great thing.
3. Math puzzles are boring.
4. Winning a prize in mathematics would make me feel unpleasantly conspicuous.
5. Being first in a mathematics competition would make me pleased.
6. I would rather have someone give me the solution to a difficult math problem than to have to work it out for myself.
7. Most subjects I can handle O.K., but I have a knack for flubbing up math.
8. I don't understand how some people can spend so much time on math and seem to enjoy it.
9. I have a lot of self-confidence when it comes to math.
10. I'd be proud to be the outstanding student in math.
11. Taking mathematics is a waste of time.
12. It's hard to believe a female could be a genius in mathematics.
13. I'm no good at math.
14. The challenge of math problems does not appeal to me.
15. I see mathematics as a subject I will rarely use in my daily life as an adult.
16. I don't think I could do advanced mathematics.
17. In terms of my adult life it is not important for me to do well in mathematics in high school.
18. When a question is left unanswered in math class, I continue to think about it afterward.
19. I'll need a firm mastery of mathematics for my future work.
20. I do as little work in math as possible.
21. Figuring out mathematical problems does not appeal to me.
22. I can get good grades in mathematics.
23. Females are as good as males in geometry.
24. Mathematics is of no relevance to my life.
25. I think that I could handle more difficult mathematics.

Appendix D

Mathematics Attitude Scales

26. Knowing mathematics will help me earn a living.
27. I would trust a woman just as much as I would trust a man to figure out important calculations.
28. Math has been my worst subject.
29. People would think I was some kind of a grind if I got A's in math.
30. For some reason even though I study, math seems unusually hard for me.
31. I will use mathematics in many ways as an adult.
32. I'll need mathematics for my future work.
33. I am challenged by math problems I can't understand immediately.
34. Girls who enjoy studying math are a bit peculiar.
35. Studying mathematics is just as appropriate for women as men.
36. Women certainly are logical enough to do well in mathematics.
37. Girls can do just as well as boys in mathematics.
38. It would make me happy to be recognized as an excellent student in mathematics.
39. Mathematics is for men; arithmetic is for women.
40. It would make people like me less if I were a really good math student.
41. When a math problem arises that I can't immediately solve, I stick with it until I have the solution.
42. Mathematics will not be important to me in my life's work.
43. If I got the highest grade in math I'd prefer no one knew.
44. When a woman has to solve a math problem, it is feminine to ask a man for help.
45. If I had good grades in math, I would try to hide it.
46. I am sure that I can learn mathematics.
47. Mathematics is a worthwhile and necessary subject.
48. Males are not naturally better than females in mathematics.
49. I like math problems.

Appendix D

Mathematics Attitude Scales

50. I'm not the type to do well in math.

51. Generally I have felt secure about attempting mathematics.

52. I study mathematics because I know how useful it is.

53. Mathematics is enjoyable and stimulating to me.

54. I'd be happy to get top grades in mathematics.

55. I expect to have little use for mathematics when I get out of school.

56. I don't like people to think I'm smart in math.

57. I would expect a woman mathematician to be a masculine type of person.

58. I am sure I could do advanced work in mathematics.

59. Once I start trying to work on a math problem, I find it hard to stop.

60. I would have more faith in the answer for a math problem solved by a man than a woman.

Appendix E

Creative Computing Article

Algebra Arcade

In our opinion, the best package of those we reviewed is *Algebra Arcade*, a new program from Wadsworth Electronic Publishing Company. This program was created by four mathematics professors under a National Science Foundation grant to develop computer programs for use in the classroom and illustrates how the computer can be creatively programmed to help make learning less tedious and more fun. The package combines the mathematical skills of graphing equations in algebra with the excitement of an arcade game.

Algebra Arcade is designed to teach students to plot equations on a coordinate system. The user can choose which type of equation "family" to practice: lines, quadratic equations, third degree equations, or equations involving the sine, cosine, tangent, exponent, logarithm, integer, absolute value, and arctangent functions. The user builds the equation he wants, and the computer graphs the equation on the display screen.

What distinguishes this program from those previously described is the way in which the topic is presented. After being shown a set of coordinates, a group of creatures called "algebroids" scurry onto the screen, scattering to various locations on the grid.

It is the user's task to come up with an equation which, when plotted, will pass through as many algebroids as possible. After the graph is plotted, a "whirlwind" follows the path of the graph, "knocking off" any algebroids through which it passes. Points are earned for each algebroid hit: 200 for the first, 400 for the second, and so on. However, the graph plotted must not hit the "shifty-eyed ghost" who also appears on the grid; if it does, the ghost turns into the dreaded Graph Gobbler who munches the equation, leaving the player scoreless.

The game can be played alone, or one-on-one. If, when playing against an opponent, the Graph Gobbler appears, the offending player is sent to "The Committee" which decides, randomly, if he should be penalized one turn, three turns, or if he can get off without losing a turn.

Each player (in both the one- or two-player games) starts off with ten turns; an extra turn is added by scoring 10,000 points, clearing all ten algebroids, or by finding the invisible Graph Gobbler. (Oh yes, we forgot to mention that when the tenth algebroid is eliminated, the Graph Gobbler "has a fit and disappears.")

At that time, the player has up to three tries to find the invisible Graph Gobbler by graphing equations. If one graph finds the hiding place, the player scores an additional 1000 points and earns an extra turn. But, if the player misses after all three attempts, he is sent to The Committee. When both players have used up all their turns, the one with the highest score is named the Algebra Arcade champion.

The program has several features which make it more enjoyable and challenging.

The program has several features which make it more enjoyable and challenging. It can be played either under keyboard control or by using a joystick; this is the first question asked after the program is loaded. The program includes a Features Menu which can be used to change the characteristics of the game. Specifically, this menu includes the following options:

- Saving the current game on disk to continue it at a later time.
- Changing the coordinates of the grid: They are preset at -5 to the left and bottom and +5 to the right and top. They can be reset to any values, seven characters or less in length, which may include a decimal point or π.
- Selecting certain equation families. The families include: the linear equation Y = MX + B, three different representations of a quadratic equation, a third degree equation, and an equation containing a sine function. An additional option allows you to build your own equation, using allowable symbols and functions which appear in a table on the display screen.
- Playing the game with or without the Graph Gobbler.
- Testing the length of a graph, to help determine the use of long, oscillating graphs which could make the game quite easy (although finding such graphs is no easy feat). This length test can be turned on or off.
- Adding an internal timer to encourage quick thinking: if this option is chosen, the regular score is multiplied by a factor, dependent upon how quickly the equation was entered. The timer can be set to several speeds, or not used. If it is used, the algebroids change positions on the screen between turns. In an untimed game, algebroids not eliminated return to the same position at which they appeared during the previous turn.

If desired, these features can be changed as the game progresses. The options of coordinates and types of equations allow for a wide range of difficulty. High school freshmen can use this program to learn to plot straight lines, while seniors and even college students could use it to study the characteristics of higher degree, more complex equations. Thus, the package can be used by a student over a period of years, as his knowledge of mathematical concepts increases.

An additional option of the program is the use of a Practice Field on which equations can be tested before they are actually plotted on the playing field. In this way, a player who is just learning these skills can specify several different equations to be plotted on the practice field. By choosing values wisely, the

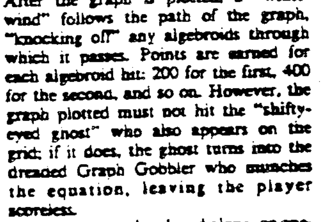
The package can be used by a student over a period of years, as his knowledge of mathematical concepts increases.

player can gain valuable knowledge as t[o] how various equations appear on th[e] grid, so that when he chooses an equa[-] tion to be plotted on the playing fiel[d] the number of points scored can b[e] maximized.

The package includes a 26-page User' Guide that is professionally written an[d] profusely illustrated. Included in th[e] manual are: a quick description of th[e] program, containing enough brie[f] instructions to start a new user at pla[y] immediately; a detailed set of instruc[-] tions, clearly describing all of the vari[-] ous options available to the use[r] (including descriptions of how to ente[r] equations, allowable symbols, and ho[w] the game is scored); suggestions o[n] graphing equations and sample equa[-] tions to try on the practice field; playin[g] tips; and illustrations of some "interes[t-] ing equations." Finally, there is a bri[ef] list of references and a bibliography f[or] further study.

This package demonstrates what goo[d] educational software can and should b[e:] creative, enjoyable, and a valuable lear[n-] ing experience. We recommend *Algeb[ra] Arcade* highly. E

CIRCLE 419 ON READER SERVICE CARD



Algebra Arcade. After two rounds, six algebroids still remain with the ghost (lower left quadrant).

Appendix F

Heller-Turner Article

Algebra program called good learning tool

By SHELLY HELLER
and JUDITH AXLER TURNER
United Feature Syndicate

All About Computers

We found a good educational computer program. That's real news: We're talking about a good use of the computer to help teach.

Education Secretary Terrell Bell recently told Congress that less than 5 percent of all educational software takes advantage of the computer's unique capabilities.

What good is it to put a textbook on a computer so that the computer becomes, in effect, a glorified page-turner? How worthwhile would it be to buy a computer and a stack of "educational" programs, only to find that you've invested in a machine that just looks like your child's workbook up there on the screen? If the computer isn't used for its unique capabilities, there are cheaper — and usually better — ways to do things.

But "Algebra Arcade," a $49.95 program from Wadsworth Electronic Publishing Co., exemplifies everything that's right about educational software. The program gives an exciting, engrossing visual interpretation of algebraic equations.

You remember algebra: It was that stuff where "x" equaled "y," plus, minus or multiplied by something or other. To many of us, it was indecipherable even after we completed the required year of classes. No matter how often our teachers told us that algebra helped us express the relationships between "x" and "y" values, we still thought that it was as impossible to do "x-plus-2" as to add apples and oranges.

But what if we could have SEEN that relationship — if we saw, drawn on a graph, how the numbers on the "y" side of the equation would look as they are related to "x"?

That's what "Algebra Arcade" shows. If "x" equals "y" plus 6, the route between the two is a diagonal line on a graph; the relationship between the two is a constant. If "x" equals "y"-squared, the relationship is a curve: When "x" is 2, "y" is 4; when "x" is 4, "y" is 16.

For the first time, the abstractions our teachers tried to make us understand become real lines and curves.

In "Algebra Arcade," a graph appears on the screen — a graph with positive and negative numbers — and little figures are scattered randomly on the graph. Your job is to devise an equation that would form a line (curved or straight) that will go through as many of these little figures as possible. You type the equation on your keyboard and the computer represents it on the screen. It transcribes exactly what your equation looks like.

The program allows you to use complex equations and logarithmic, exponential and trigonometric functions.

The more little figures you hit with your lines, the higher your score.

This isn't a teaching program. You have to know algebra — such as what a sine is — to be able to use the program. This program reinforces what you've learned. It is, to some extent, drill and practice — the computerized equivalent of having to do 40 algebra problems at home just for practice ... but with a difference.

And what a difference. This program takes full advantage of the unique capabilities of the computer. Sure, it's possible to draw your own graph with lines representing algebraic equations. Maybe your teacher even made you do it once or twice. You probably remember that drawing those graphs and the lines representing the equations is extremely tedious work. Moreover, a little mistake in your arithmetic or your measuring makes your lines horribly wrong and you have no idea of what the problem is.

The computer, however, is a whiz when it comes to counting and measuring, and it draws your lines correctly. Using the computer's abilities and strengths to help teach algebra is a dandy use of the machine.

This program is not only a good example of using the computer's capabilities, but it's well conceived. It's appealing without being condescending: Do a good job and you're properly rewarded with a high score. Do poorly and you have to try again. Too many computer programs give you bells and whistles every time you take a forward step, and boos and hisses — or saccharine regrets — when you miss the mark. In "Algebra Arcade," the reward is built in, which is the way it should be.

If you're going to buy any educational program for your Atari 800, Commodore 64, Apple or IBM PC, it should be "Algebra Arcade." Buy it even if you don't have children old enough to do algebra: It will teach you what to look for in other programs.

Questions about computing? Write to "All About Computers" in care of United Feature Syndicate, 200 Park Ave., New York, NY 10166.

Appendix G

Memo to Teachers in the Study

Thank you for being so patient. The disks came in two days ago. I have checked each disk out to make sure that it works correctly. Dr. Wilson, my advisor, indicated in a phone conversation last week that he saw no real problems with starting the experiment a little later than planned. He felt my committee would like to see the experiment go for about four weeks.

I have enclosed thirty-five Intermediate Algebra exams from the College Board and thirty-five copies of the Fennema-Sherman Mathematics Attitudes Scales along with seventy answer sheets. I will need the College Board booklets returned after the Pretest along with the answer sheets for both Pretests. I will then send you another form of the Intermediate Algebra test to be used as a Posttest along with more answer sheets. The Attitude Posttest will be identical to the Pretest so you can reuse the copies of this. After the Posttest, you will need to return to me the College Board exams and the Posttest answer sheets. You may keep the copies of the Attitude Scales. For all Pretests and Posttests, each answer sheet should contain the following information: name, teacher, sex, and grade level. Since the blanks on the answer sheet do not correspond to this information, have the students put the teacher's name in for the subject, sex in for date and grade level in the blank for hour. (Sorry, the answer sheet was designed for a machine I have access to, not the statistical detail needed in my report.) All four tests-- Attitude Pretest, Intermediate Algebra Pretest, Attitude Posttest, and Intermediate Algebra Posttest-- need all this information. The names will not be used, but further analysis of the data may require linking individual pre and posttests. All tests are to be given to both the control and the experimental group. The Intermediate Algebra test lasts thirty minutes. While there is no timing on the Attitude Scales, the student should not spend too much time on any question (so I would say fifteen to twenty minutes on the Attitude Scales). On the Attitude Scales every question must be answered.

The plan is to use the ALGEBRA ARCADE in lieu of in-class homework. You will need to make a determination each day as to the portion of homework you expect the control group to get done in class and then those problems will not be assigned to the experimental class. This class will then spend the in-class time on the computer playing ALGEBRA ARCADE. Both classes will do the same out-of-class homework. The suggested schedule, which can be modified by the teacher, is the following:

1 day	Pretests;
4-5 days	Using linear functions;
8-10 days	Using various forms of quadratic functions;
4-5 days	Using any function the student wishes; and
1 day	Posttests.

While this schedule may be modified by the teacher, it is imperative that the time elapsing between the Pretest and Posttest is the same for both the control and experimental classes. It is also critical that time allowed for in-class homework in the control group be approximately equal to the time the experimental group spends on the computer. It will be necessary to spend part of the first computer day explaining how the program works and maybe playing a sample game. (Sample games or at least a few moves may also be necessary for the different forms of the quadratic functions.) The program can be locked into linear or the various forms of the quadratic function. Near the end I would turn the family of functions off. In the beginning you may want some of the slower students to turn off the graph gobbler and as students get better you may want to begin using the timer. Games can be saved until the next day; however, I envision the game being used as a two-person game with the teacher making sure that each student varies opponents.

I would also like each teacher to keep an anecdotal record of what they observe during the four weeks. This is not intended to be a log or daily write-up. What I would like are such things as: how many students have already had a formal computer course, how many have a computer in their home, what was the reaction to this particular software package, what was the reaction to this method of learning, and any suggestions or personal feelings on your part.

Finally, thank you for your help! Without your cooperation this experiment would be impossible. No matter what the results are, we all will have made a significant contribution toward the teaching of secondary mathematics. If you have any questions, you may reach me at 414-547-1029 (home) or 414-521-8754 (school). You will be hearing from me.

Appendix H

Class Means Attitudes Toward Mathematics

	Male Domain			Confidence		
Class	Pre	Post	Diff	Pre	Post	Diff
C 1	52.29	49.00	-3.29	45.71	44.86	-0.86
E 1	50.35	52.47	2.12	36.88	36.88	0.00
C 2	53.15	48.38	-4.77	43.15	43.23	0.08
E 2	53.85	55.62	1.77	45.15	43.85	-1.31
C 3	51.95	51.11	-0.84	45.95	43.21	-2.74
E 3	55.37	54.32	-1.05	44.84	43.58	-1.26
C 4	51.89	49.47	-2.42	39.53	41.42	1.89
E 4	51.72	50.44	-1.28	41.88	42.48	0.60
C 5	53.08	52.72	-0.36	43.68	44.24	0.56
E 5	53.04	51.57	-1.48	45.39	44.78	-0.61
C 6	44.50	45.56	1.06	42.56	39.88	-2.69
E 6	55.31	53.31	-2.00	45.92	45.31	-0.62
C 7	49.94	52.00	2.06	42.82	44.94	2.12
E 7	47.53	48.65	1.12	44.35	44.53	0.18
C 8	54.26	53.48	-0.78	41.41	39.22	-2.19
E 8	51.57	50.81	-0.76	47.14	42.71	-4.43
C 9	48.88	47.50	-1.38	43.73	44.15	0.42
E 9	52.05	52.14	0.09	47.36	46.59	-0.77
C 10	51.59	52.64	1.05	42.23	41.23	-1.00
E 10	52.35	52.30	-0.04	44.22	44.61	0.39
C 11	50.56	49.31	-1.25	45.19	43.56	-1.63
E 11	52.04	51.83	-0.22	41.61	43.52	1.91

Appendix H

Class Means Attitudes Toward Mathematics

	Success*			Effectance		
Class	Pre	Post	Diff	Pre	Post	Diff
C 1	44.43	43.29	-1.14	44.00	43.29	-0.71
E 1	42.88	45.94	3.06	39.47	36.82	-2.65
C 2	40.77	41.38	0.62	38.85	41.00	2.15
E 2	45.46	47.54	2.08	37.08	36.92	-0.15
C 3	46.00	45.42	-0.58	42.00	42.32	0.32
E 3	45.58	47.68	2.11	41.37	39.11	-2.26
C 4	45.00	44.16	-0.84	40.16	38.26	-1.89
E 4	42.80	42.32	-0.48	39.68	37.88	-1.80
C 5	45.20	45.32	0.12	40.32	40.40	0.08
E 5	45.65	45.35	-0.30	40.35	40.96	0.61
C 6	39.50	40.19	0.69	35.50	35.19	-0.31
E 6	44.85	43.62	-1.23	42.62	40.15	-2.46
C 7	43.59	44.88	1.29	34.94	35.82	0.88
E 7	43.18	42.29	-0.88	34.35	35.71	1.35
C 8	43.78	42.85	-0.93	37.30	36.63	-0.67
E 8	40.10	39.10	-1.00	39.24	35.19	-4.05
C 9	41.31	41.96	0.65	37.23	36.15	-1.08
E 9	43.68	44.09	0.41	40.64	38.91	-1.73
C 10	42.09	44.45	2.36	38.86	38.18	-0.68
E 10	45.09	45.04	-0.04	41.74	41.91	0.17
C 11	46.00	44.06	-1.94	40.94	37.56	-3.38
E 11	44.22	43.78	-0.43	37.96	36.91	-1.04

*Based on eleven questions.

Appendix H

Class Means Attitudes Toward Mathematics

Class	Usefulness Pre	Usefulness Post	Usefulness Diff	Total Attitudes Pre	Total Attitudes Post	Total Attitudes Diff
C 1	50.43	50.14	-0.29	236.86	230.57	-6.29
E 1	48.88	50.24	1.35	218.47	222.35	3.88
C 2	46.31	45.23	-1.08	222.23	219.23	-3.00
E 2	50.23	50.46	0.23	231.77	234.38	2.62
C 3	50.42	49.58	-0.84	236.32	231.63	-4.68
E 3	48.16	48.00	-0.16	235.32	232.68	-2.63
C 4	46.05	46.84	0.79	222.63	220.16	-2.47
E 4	48.20	46.08	-2.12	224.28	219.20	-5.08
C 5	48.92	47.84	-1.08	231.20	230.52	-0.68
E 5	46.61	46.57	-0.04	231.04	229.22	-1.83
C 6	43.50	42.25	-1.25	205.56	203.06	-2.50
E 6	52.08	49.77	-2.31	240.77	232.15	-8.62
C 7	45.76	47.59	1.82	217.06	225.24	8.18
E 7	45.41	45.88	0.47	214.82	217.06	2.24
C 8	47.85	46.56	-1.30	224.59	218.74	-5.85
E 8	47.05	45.29	-1.76	225.10	213.10	-12.00
C 9	43.31	43.81	0.50	214.46	213.58	-0.88
E 9	45.32	46.36	1.05	229.05	228.09	-0.95
C 10	48.36	49.36	1.00	223.14	225.86	2.73
E 10	48.52	48.00	-0.52	231.91	231.87	-0.04
C 11	50.19	45.44	-4.75	232.88	219.94	-12.94
E 11	44.78	45.39	0.61	220.61	221.43	0.83

Appendix I

Class Means Intermediate Algebra

Class	Algebraic Operations Pre	Post	Diff	Solving Equations & Inequalities Pre	Post	Diff
C 1	7.55	7.44	-0.11	7.00	6.11	-0.89
E 1	7.29	7.29	0.00	6.00	5.35	-0.65
C 2	6.92	6.08	-0.84	5.23	5.23	0.00
E 2	6.17	5.75	-0.42	4.83	4.58	-0.25
C 3	7.11	6.95	-0.16	7.37	7.11	-0.26
E 3	8.11	7.95	-0.16	7.42	6.79	-0.63
C 4	6.42	7.21	0.79	6.26	6.37	0.11
E 4	6.80	7.92	1.12	6.64	6.92	0.28
C 5	5.88	5.88	0.00	5.24	5.48	0.24
E 5	5.48	5.83	0.35	5.57	5.43	-0.14
C 6	5.83	5.50	-0.33	5.72	5.61	-0.11
E 6	6.23	6.23	0.00	5.46	5.46	0.00
C 7	5.22	5.83	0.61	3.72	5.11	1.39
E 7	5.65	5.76	0.11	5.12	4.47	-0.65
C 8	8.11	7.07	-1.04	5.00	6.26	1.26
E 8	7.89	7.79	-0.10	5.42	7.16	1.74
C 9	7.12	6.81	-0.31	5.58	4.85	-0.73
E 9	7.14	6.82	-0.32	5.86	4.77	-1.09
C 10	6.77	6.50	-0.27	4.45	5.91	1.46
E 10	8.26	7.35	-0.91	6.17	6.52	0.35
C 11	7.13	5.69	-1.44	5.19	4.81	-0.38
E 11	6.52	5.78	-0.74	5.09	4.87	-0.22

Appendix I

Class Means Intermediate Algebra

	Coordinate Plane & Graphing			Mathematical Achievement		
Class	Pre	Post	Diff	Pre	Post	Diff
C 1	4.44	3.89	-0.55	19.00	17.44	-1.56
E 1	4.47	5.12	0.65	17.76	17.76	0.00
C 2	4.92	4.15	-0.77	17.07	15.46	-1.61
E 2	4.83	4.58	-0.25	15.83	14.92	-0.91
C 3	6.21	5.58	-0.63	20.68	19.63	-1.05
E 3	5.95	6.11	0.16	21.47	20.84	-0.63
C 4	4.58	5.89	1.31	17.26	19.47	2.21
E 4	5.28	6.24	0.96	18.72	21.08	2.36
C 5	4.76	5.16	0.40	15.88	16.52	0.64
E 5	4.35	5.04	0.69	15.39	16.30	0.91
C 6	5.78	4.67	-1.11	17.33	15.78	-1.55
E 6	6.23	5.77	-0.46	17.92	17.46	-0.46
C 7	4.83	4.06	-0.77	13.78	15.00	1.22
E 7	4.29	4.47	0.18	15.06	14.71	-0.35
C 8	4.78	5.26	0.48	17.89	18.59	0.70
E 8	4.84	5.11	0.27	18.16	20.05	1.89
C 9	5.04	5.54	0.50	17.73	17.19	-0.54
E 9	4.82	5.77	0.95	17.82	17.36	-0.46
C 10	3.45	4.14	0.69	15.59	16.55	0.96
E 10	3.65	4.65	1.00	18.09	18.52	0.43
C 11	5.50	5.19	-0.31	17.81	15.69	-2.12
E 11	4.78	4.78	0.00	16.39	15.43	-0.96

Appendix J

Description of the Game

ALGEBRA ARCADE is a challenging, fast moving, and high scoring videogame marketed by Wadsworth, Inc. With a minimum of instructions anyone over nine can play the game. The more sophisticated the function a player uses, the more points scored. The game can be played by one or two players.

The game is played on a coordinate grid set up by the computer. Initially the computer randomly places ten little creatures called Algebroids on the grid. The computer then randomly places the Graph Gobbler in the plane. The Algebroids remain in their initial positions until the screen is cleared, the game is over, or the player(s) ask for a new set of Algebroids to be positioned on the plane. The Graph Gobbler relocates after each turn.

The objective of the game is to type in a function whose graph crosses as many Algebroids as possible. When the function is entered (by pushing the RETURN key), a whirlwind traverses the path from left to right of the function's graph, capturing those Algebroids in its way and leaving a trace of the function's graph. The player receives points based on the number of Algebroids captured. The function (in the form Y = ?)

must use correct BASIC notation (* for multiplication, / for division, and ^ for exponentiation). If the player hits the Graph Gobbler, it gobbles up the graph and the player gets sent to The Committee. The Committee then randomly decides if the player loses one or three turns. A complete game for a given set of Algebroids and Graph Gobbler consists of ten turns for each player.

If a player clears the board before the ten turns expire an extra turn is awarded and the Graph Gobbler's ghost will fly around the screen and disappear. The player then has three opportunities to put in an equation which will locate the ghost. If the player successfully locates the ghost, the player is awarded another turn and 1,000 points; otherwise the player is sent to The Committee. Scoring 10,000 points gets an extra turn, choosing new Algebroids costs a turn.

When entering a function, a player can use any of the ten digits, a decimal point, any of the four basic operations, exponentiation, or parentheses. One can correct a mistake by using the back arrow key unless RETURN has already been pushed. In addition to the constant pi, any of the functions sine, cosine, tangent, inverse tangent, square root, natural logarithm, exponential base e, absolute value, and greatest integer can be entered using a single key.

(Trigonometric functions are in radians.)

Pushing "F" for the features page presents a full page of options available to the player(s). The first option is the ability to save a game. If one or two players are involved in a really exciting game and are out of time to play, it is possible to save the game until the next opportunity to play. When they boot the disk the next time, the player(s) select option 3 and the game can be picked up where it was stopped. One game can be saved for keyboard users and one game for joysticks users. If a second game is saved, it forces the first game to be lost. The game will be saved on the Master ALGEBRA ARCADE disk (not on any other disk).

The second feature, that presents some interesting possibilities, is that of changing the coordinates. The default is letting the ends of the axes be at -5 and +5, but this feature allows the coordinates to be reset to any values the player(s) desire(s). The values do not have to be symmetric about the origin and up to seven characters can be used for each entry. The ten digits, pi, decimal point, subtraction, multiplication, and division can be used as characters. The coordinates may vary on both axes.

The program has a list of equation families which can be locked into a game so that only equations from that family can be used by the players(s). (This option was used extensively by the subjects in this study.) When it is locked into a particular family of equations, the player(s) merely need to supply values for the parameters, not the entire equation. The list of families available are: (1) linear; (2) three forms of quadratic- standard, vertex, factored; (3) factored cubic; (4) sine and (5) a function built by the player(s).

Among the other features, one has an option of: (1) turning the sound off (probably the least favorite option for the students), (2) turning the graph gobbler off (which might be helpful to a beginning player), and (3) a graph length test which is designed to stop people from putting in curves with high amplitude and small period to fill the entire screen.

Finally, one can play the game with or without a timer. Once one is experienced at playing the game, the next challenge is to switch into the timed entry option. The five timing options are: very slow, slow, medium, fast, or very fast. A timing arrow counts down the time and, if a function is not entered on time, you must pay a visit to The Committee. If the speed is medium, fast, or very fast the regular score for the turn is multiplied by the time on the timer. With timed entry, the Algebroids change positions with each turn.

A practice field option allows one to leave the game, go to the practice field and experiment with functions and their graphs without jeopardy of losing points or a turn, and then return to the game. (This option was very underused by the participants in the study.)

If two players are involved, one player has Algebroids with heads up and the other player has Algebroids with heads down. They each have their own playing board and play alternates between them.