

AN ABSTRACT OF THE THESIS OF

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Title: EFFECTS OF SELECTED MATHEMATICAL COMPUTER GAMES ON ACHIEVEMENT  
AND ATTITUDE TOWARD MATHEMATICS IN UNIVERSITY ENTRY-LEVEL  
ALGEBRA

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Abstract approved: \_\_\_\_\_

Howard L. Wilson

Two mathematical computer games, POE and EQUATIONS, were used to test the effects of games as learning aids in a university entry-level intermediate algebra course. Specifically, this study investigated whether use of these games would significantly increase student achievement in the course and improve student attitude toward mathematics.

EQUATIONS is a nonsimulation mathematical game in which the algorithms of dealing with fundamental operations of mathematics are incorporated into the rules of the game. The computer version of EQUATIONS provides an opportunity for the student to play against a computer rather than another student. POE is a computerized strategy game designed to aid the student in learning to use the computer and to learn the rules for EQUATIONS.

The hypotheses for this study, in condensed form, stated the following: Mathematical computer games, POE and EQUATIONS, will significantly increase student achievement in the university entry-level

intermediate algebra course, will improve student attitude toward mathematics, and will significantly increase student achievement in predetermined specific skill areas.

One hundred forty-three students who were enrolled in the large lecture-recitation section of Mth 95: Intermediate Algebra I at Oregon State University, winter term, 1980, were randomly assigned to the four Solomon groups. Following the expected student withdrawal in the first three weeks of classes, 89 students remained. Students in the experimental groups were trained to use the computer and play POE and EQUATIONS in two short training sessions. After playing POE for two weeks, students played EQUATIONS for the remaining six weeks of the term.

Students in the two pretest groups were pretested with Dutton's Attitude Scale and one form of the course final examination. All students were posttested with Dutton's Attitude Scale and an equivalent form of the course final examination. Scholastic Aptitude Test (SAT) scores were available for approximately two-thirds of the sample.

The results of the analysis of the achievement posttest scores, after adjustments for initial differences with the achievement pretest scores, indicated the games treatment did not significantly increase student achievement at the .05 level. However, this analysis did suggest a games treatment trend ( $p=.10$ ). SAT data, obtained for a subset of the sample, provided additional investigation of this apparent trend. Analysis of the achievement posttest scores of the SAT subgroups, after initial adjustments for achievement pretest and SAT scores, indicated the mathematics portion of SAT was a significant

( $p=.005$ ) predictor of posttest achievement. These data did not support the games treatment trend. Additional descriptive analysis using SAT data, suggested the initial withdrawal of students may have influenced the achievement posttest means. This bias may have created the appearance of a games treatment trend. In conclusion, the data in this study suggested the mathematical computer games, POE and EQUATIONS, did not significantly increase student achievement in this sample at the .05 level.

Analysis of subscores from the achievement posttest did not find significant (at the .05 level) increases in student achievement in the predetermined specific skill areas.

The results of the analysis of the attitude data showed no significant (at the .05 level) improvement in attitudes toward mathematics. The attitude pretest score was found to be a significant ( $p=.003$ ) predictor of the attitude posttest score.

Investigation of the amount of computer time used per week by students in the treatment groups indicated only 12 of 41 students worked with the computer games more than four weeks. The achievement of these 12 students was highly correlated with their time spent on the computer. These data illustrated the student response in this sample to the games as an additional assignment.

Effects of Selected Mathematical Computer Games on  
Achievement and Attitude Toward Mathematics in  
University Entry-Level Algebra

by

Margaret Louise Moore

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EFFECT OF SELECTED MATHEMATICAL COMPUTER GAMES  
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IN UNIVERSITY ENTRY-LEVEL ALGEBRA

I. INTRODUCTION

Mathematics education in the past fifteen years has experienced tremendous changes in pedagogical techniques. Inspired by new developments in technology and by current psychological theories that encourage active student involvement in learning, a wide variety of materials have been created by educators as well as manufacturers. Presently, teachers are deluged with the volume of new and varied materials and with the concomitant promotional claims for assimilation of the materials.

Among these materials created as learning tools are a wide range of educational games. Games are generally characterized as activities in which the player or players are bound by a set of predetermined rules in order to reach a predetermined goal. As such, games offer a unique avenue for aiding students in learning.

Zoltan P. Dienes, expanding on the cognitive psychology of Jean Piaget, presents a theoretical basis for the use of games in learning mathematics. In Dienes' conception learning mathematics is an evolutionary process which must begin with each student's existing understandings. Learning progresses as the student relates his/her own understandings to new structures. The process requires the active involvement of the student, at least mentally if not physically, as well as a motivating environment for the student. As the student interacts with new and diverse materials, or concrete embodiments of

mathematical structures, he redefines "his mathematical life space to permit the processing of new environmental stimuli" (Reys and Post, 1973, p. 40).

To create a highly motivating environment in which each student is encouraged to explore, organize, and abstract mathematical structures requires a large number of mathematically structured materials. Dienes (1972) suggests the materials include a large number of games:

These games would be ordered in a certain way, because some games would be too difficult to play without some previous games having been played. Most mathematical structures can be learned by playing skillfully contrived and excitingly motivating games of a mathematical nature (p. 64).

One of the fastest developing technologies with potential impact for education is computer technology. Innovations in both hardware and software are giving impetus to the development of educational games as aids in individualizing education.

Computer games offer distinct advantages in gaming. For games to be most effective all players should be "at about the same level of skill in game rules and understanding the subject-matter content being dealt with in the games" (Allen, 1972, p. 69). If this situation is achieved, game problems are more apt to be at the appropriate level of difficulty to sustain interest and curiosity as well as provide the necessary rewards. In computer games the computer, acting as the opponent, can be programmed to meet these objectives.

As a result of the influences of the cognitive psychology on learning mathematics and the improvements in technology, such as the computer technology, more and improved games are available for classroom use. Currently, many documents contain annotations of available games

complete with descriptions, objectives, suggested age levels, suggested ability levels, suggested uses, and anecdotal claims for the uses.

Although educational game theory and classroom experiences suggest games have positive affective effects in mathematics education, good research evidence does not exist to substantiate the claim. Achievement effects are, also, unsubstantiated as noted by Bright, Harvey and Wheeler (1978):

Teachers have been enthusiastically encouraged to use an almost bewildering array of mathematical games. The empirical research reporting positive cognitive effects on games in mathematics learning, however, is virtually nonexistent (p. 5).

#### The Problem

The purpose of this study is to investigate some aspects of the educational value of two mathematical computer games, POE and EQUATIONS, in university, entry-level algebra courses.

The entry-level mathematics course at the university is typically an intermediate algebra course rather than a first course in algebra. The ten- to twelve-week course provides a broad survey of the algebraic concepts taught in first- and second-year algebra courses at the secondary level. The course content includes linear, fractional, radical, and quadratic equations, graphical interpretations of equations, operations on polynomials and rational expressions, and word problems using these equations and expressions. This entry-level course does require previous experiences with these algebraic concepts.

Students enrolled in the entry-level course form a heterogeneous group typified by diverse mathematical exposure, mathematical

achievement, and attitudes toward mathematics. A great variation among these students exists in the number of years elapsed since a previous mathematics course. For the majority of students the number of years ranges, without trend, from zero to three. Differences in the mathematics courses previously completed further compounds the variation in mathematical exposure. A summary of these courses includes basic mathematics, first-year algebra, geometry, and second-year algebra at the secondary school and basic mathematics, technical mathematics, and first courses in algebra at the community college. No single course, school level, or number of years elapsed describes the mathematical exposure of students who enroll in the entry-level intermediate algebra course at the university.

An additional source of variation among these students arises from their achievements in past mathematical experiences. The range of grades received in the previous mathematics courses suggests varied success with the concepts. The variation in time elapsed since the previous course raises the question of retention of the ideas. Additionally, information from the College Entrance Examination Board Scholastic Aptitude Test - Mathematics Section (SAT-M) indicates these students are mathematically weak. Analysis of this information implies many of the students enrolled in the entry-level intermediate algebra course have been previously unsuccessful with their mathematical experiences. (Nelson, 1969).

Students with weak mathematical backgrounds tend to be unsure of themselves in mathematics classes. Frequently, this weakness translates into a more negative attitude toward mathematics (Aiken, 1972). The

negative attitude problem is prevalent in the entry-level mathematics courses at the university. A large majority of the students enter with negative attitudes toward mathematics. They are the students who were previously unsuccessful in mathematics classes. They are frustrated by the large number of rules in mathematics; they fear the symbolization and abstract concepts; and, they are particularly frightened when presented with word problems. They indicate they do not like mathematics because they are "not good at it" and they think they make too many mistakes. In essence these students avoid mathematics if at all possible. They definitely are not interested in majoring in any area which requires mathematics.

The entry-level mathematics course at the university is typically taught using the large-lecture format. Instructors lecture to large groups of students with students rarely speaking or interacting. The classes often lack any personal character. The emphasis is on learning in a passive, information-processing mode with little opportunity for active examination and exploration of the concepts. As King (1978) reports, few student-centered teaching methods are used in university mathematics classrooms.

According to Piaget, the cognitive development of individuals progresses through definite stages. Students who are at the concrete operational stage are limited in their comprehension by a need for concrete, tangible objects. Students who are at the formal operational stage no longer require these concrete representations to reason with concepts. Research on cognitive development indicates that 50% of the college freshmen function at the concrete operational level rather than the formal operational level in their understanding of mathematics

(Chiappetta, 1976; Carmichale, Hassell, Hunger, Jones, Ryan, and Vincent, 1980). Herein lies a serious problem. Most university entry-level intermediate algebra courses are taught in a manner to require formal operational reasoning. Therefore, for a large portion of the students, comprehension of the content is limited.

Essentially, the entry-level intermediate algebra course at the university creates a frustrating learning experience for many of the students. The content is aimed at a higher level of understanding than the students are generally capable of achieving. The students need concrete experiences, active manipulation of the concepts, time to explore the concrete representations of the abstract concepts, and individual attention. Yet, they are taught in a large lecture group in which the emphasis is on passive reception of abstract ideas.

Educational game theory suggests that mathematical games provide a teaching method directed toward the problems in the intermediate algebra courses at the university. Gaming enthusiasts claim that games provide students the opportunities to actively manipulate the ideas and encourage student involvement, individualization, and motivation.

POE and EQUATIONS are nonsimulation mathematical games created by Layman Allen of the University of Michigan to provide these opportunities. The computer version of EQUATIONS is an adapted version of the original student-student game. This version provides an occasion for a student to play against a computer opponent rather than another student. According to Allen, EQUATIONS has two purposes:

One is mathematical: to develop the player's insight into the relations between the arithmetic operations. The other is psychological: to increase the probability that a

player will view himself as competent at rigorous symbol-handling activities and thus will develop a favorable attitude toward such activities (Allen and Ross, 1972, p. 219).

POE is a computer game intended to simplify the learning of the rules to the game of EQUATIONS and to serve as an introduction to the use of the computer.

In essence the problem is to determine the educational potential of two computer games, POE and EQUATIONS, in the entry-level intermediate algebra course at the university. This study seeks answers to the following questions: Do these games aid the student in learning algebra? Does interaction with these games affect attitude and interest toward mathematics? These questions propose the following hypotheses for this study in an attempt to statistically measure certain achievement and attitude effects of the games in university entry-level algebra courses.

#### Statement of the Major Hypotheses

The two major hypotheses stated in the null form are:

$H_1$ : There is no significant difference in the mean achievement of students in the university, entry-level intermediate algebra course that includes interaction with computer games and students in the university, entry-level intermediate algebra course without interaction with computer games.

$H_2$ : There is no significant difference in the mean attitude toward mathematics of students in the university, entry-level intermediate algebra course that includes interaction with computer games and

students in the university, entry-level intermediate algebra course without interaction with computer games.

### Need for the Study

Currently, educators are enthusiastically encouraged to incorporate games as learning aids in the classroom. Yet, amidst the enthusiastic claims for the educational value of games, little systematic research is available. Although learning theory entwines games in the learning of mathematics, valid and reliable empirical data are virtually nonexistent.

The existing research on the use of games in the mathematics classroom concentrates on the game, EQUATIONS, played at the junior high/middle school level. The majority of this research deals with the game in combination with a specified classroom model, teams-games-tournaments. None of this research deals with the computerized version of EQUATIONS.

Review of the research indicates major biases and questionable designs. Pierfy's (1977) summary of the major deficiencies in the research includes the following:

1. Many studies concerning particular games have been conducted by the game designer;
2. Instruments used to measure have been investigation-constructed with a range of reliability coefficients from .800 to .346; and
3. Research has, at best, been quasi-experimental using intact groups of questionable comparability, comparing groups with different teachers, different subjects, and groups with increased potential of Hawthorne effect as a source of bias.

With these major deficiencies in the available research, studies are needed which are not conducted by the game designer, use reliable instruments, apply experimental designs, and deal with other age levels and mathematics classes. Studies are needed to provide more valid and reliable empirical data concerning the affective and cognitive learning effects of games.

### Assumptions

The assumptions inherent in the study are the following:

1. Student achievement in the intermediate algebra course is measured by the final achievement examination for the course.
2. Dutton's Scale for Measuring Attitudes Toward Mathematics is a valid and reliable measure of attitudes toward mathematics.
3. Students introduced to POE and EQUATIONS and given computer time to continue playing resist sharing their computer access with students in the class not given the information and computer time.
4. Computer time is a valid and reliable measure of the amount of time students interact with POE and EQUATIONS.

### Limitations

The limitations applicable to the study include the following:

1. The study is limited to students enrolled in Mth 95: Intermediate Algebra I at Oregon State University winter term.
2. The study is limited by the extent students given computer time use the time to play POE and EQUATIONS.

3. The study is limited by the extent students who have access to computer time seriously participate as players when interacting with POE and EQUATIONS.

#### Delimitations

The delimitations are as follows:

1. The study will evaluate only the concurrent use of the computer games with regular instruction in the algebra class.
2. The study will not attempt to compare the play of the games with the computer (student-computer play) to the play of the games without the computer (student-student play).
3. The study will not attempt to deal with variables associated with student's experiences with computers.
4. The study will not attempt to relate variables such as number of mathematics courses, grades with achievement and attitude in the algebra class except as reflected in SAT-M scores.
5. The study will not attempt to compare the use of computer games with other instructional strategies.

#### Definition of Terms

The following definitions are relevant to this study:

1. Play is a voluntary activity involving one or more persons.
2. A game is an activity in which the player or players are bound by a set of predetermined rules while striving to attain some pre-determined goal.

3. An educational game refers to any game designed primarily to enhance learning rather than for entertainment.
4. A nonsimulation game refers to a game which deals with real problems, situations, and rules rather than modeled imitations of these situations.
5. A mathematical game is an educational game in which mathematical ideas are incorporated in the rules in such a way that the more a player knows about mathematics, the better his play will be.
6. A computer game is a game in which the computer acts as one of the players.
7. POE and EQUATIONS are mathematical computer games created by Layman E. Allen, University of Michigan.
8. The SAT-M scores refer to the mathematics or quantitative section scores on the Scholastic Aptitude Test of the College Entrance Examination Board. The SAT-V scores refer to the verbal or qualitative section scores.
9. Achievement refers to the acquisition of mathematically related knowledge or skills as demonstrated by the scores on the final examination in the algebra course.
10. 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).

### Design of the Study

At Oregon State University the entry-level mathematics course is Mth 95: Intermediate Algebra I. This class is taught in large lecture sections with smaller recitation sessions. As such, the emphasis in learning the algebraic concepts is by passive reception with little opportunity for active examination and exploration of the concepts. On the whole the class is characterized by students who have been unsuccessful in mathematics and who have negative attitudes toward mathematics. To study the effect of the computer games, POE and EQUATIONS, in the entry-level mathematics course at the university, students enrolled in Mth 95, during winter term, 1980, constitute the sample population.

The experimental design selected for the study is the Solomon Four-Group Design described by Campbell and Stanley (1963). Although random assignment theoretically controls for initial differences between the experimental and control groups, the pretesting in this design provides a statistical control for initial differences. Furthermore, this design controls for the effects of pretesting as well as the treatment effects. By paralleling pretest experimental and pretest control groups with unpretested experimental and unpretested control groups, measurements are made of the effect of the treatment variable, the main effect of pretesting, and the interaction of pretesting with the treatment variable.

Each student in the sample population is randomly assigned to one of the four groups. Students in the experimental groups are trained to use the computer and play POE in a short session. After interacting

with POE for two weeks, these students are trained in the play of EQUATIONS in a second session. For the remainder of the term, six weeks, the students continue to play EQUATIONS. This treatment therefore, consists of play of computer games supplemented by an initial introduction. Students in the experimental groups interact with the games concurrently with instructions, assignments, and tests for the algebra class. Students in the control groups experience the same instruction, assignments, and tests for the class with no additional assignments.

Data consist of pretest scores for students in the pretest groups (experimental and control) and posttest scores for all students. Dutton's Scale for Measuring Attitudes Toward Mathematics is used for measuring attitude. Equivalent forms of the final achievement examination for the course are the instruments for measuring mathematical achievement.

The Solomon Four-Group Design suggests initial measurement of the pretest effect using a two-by-two analysis of variance. This test treats the pretest as another treatment coordinate with the computer games treatment. Negligible interaction effects of pretesting allows an analysis of covariance using the pretest scores as the covariate.

#### Organization of the Remainder of the Study

The remainder of this study is separated into four chapters. Chapter II reviews the literature related to educational games. This chapter describes in detail the process of acceptance of educational gaming, the educational games paradigm, the implementation of games in

education, and evaluation of educational gaming. Detailed reviews of the studies involving the use of mathematical games is presented. Chapter III details the design of the study including descriptions of the games used. Chapters IV and V present and discuss the results of the study. Chapter IV analyzes the data and discusses the results relative to the hypotheses. Results not directly related to the hypotheses are included. Chapter V contains a summary, conclusions, and recommendations for further study.

## II. LITERATURE REVIEW

A review of the literature on educational games reveals strong roots from fields outside education. The concept of learning from games is not new. Yet, acceptance and implementation of games as instructional aids in formal education is relatively new. To describe the growth, acceptance, and implementation of educational games, the literature review is divided into the following sections: (1) Introduction, (2) Evolution of the Theory of Educational Games, (3) The Educational Games Paradigm, (4) Implementation of Educational Games, (5) Evaluation of Educational Games, and (6) Summary.

### Introduction

A famous scientist, Dimitri Mendeleev, faced the problem of understanding the relationships among the atomic elements. He created a card game, which his friends called Patience, to help solve the problem. Each card contained an element with its one distinguishing property, its characteristic atomic weight. He claimed he made friends with the elements from the shuffling and reshuffling, arranging and rearranging of the elements throughout the games. Eventually, he discovered the elements grouped themselves in families as displayed in the Periodic Table of Elements and provided new impetus in the field (Bronowski, 1973).

Aldous Huxley (1962) expressed recognition of Mendeleev's experience and envisioned a formal educational system in a utopic society to emphasize learning through games. In Island a cynical British newsman,

Farnaby, visited a local school and received the following explanation of the educational policy in Pala, Huxley's utopia:

"From about five onwards, practically any intelligent child can learn practically anything, provided always that you present it to him in the right way. Logic and structure in the form of games and puzzles. The children play and, incredibly quickly, they catch the point. After which you can go on to practical applications...Or consider another field where one can use games to implant an understanding of basic principles. The old eternal verities are merely a high degree of likeliness; the immutable laws of nature are just statistical averages. How does one get these profoundly unobvious notions into children's heads? By teaching them all kinds of games with cards and boards and dice."

"Evolutionary Snakes and Ladders -- that's the most popular game with the little ones," said Mrs. Narayan. "Another great favorite is Mendelian Happy Families."

"And a little later," Mr. Menon added, "we introduce them to a rather complicated game played by four people with a pack of sixty specially designed cards divided into three suits. Psychological bridge, we call it. Chance deals you your hand, but the way you play it is a matter of skill, bluff, and cooperation with your partner" (pp. 245-246).

Although Mendeleev's game demonstrated an effective mode of learning, the educational value of games was recognized many centuries prior to his work. According to Johnson (1958), Plato claimed "games of various kinds such as a game played with different kinds of coins mixed together" provided for some learning of arithmetic (p. 69). Not until the 1960s did educators capitalize on the potential in any form. Within the past twenty years, educators have increasingly accepted and implemented games in instruction. Initially, games were applied at the elementary and secondary levels; now games have become part of the teaching techniques at the university level. Concerning this acceptance, Jacobson (1979) commented: "Many academic gamers think that nothing

short of an educational revolution could be in the making" (p. 1). How close has the current educational system come to Huxley's ideal?

### Evolution of the Theory of Educational Games

#### Evolving Attitudes Toward Play

For the work-oriented society of the nineteenth century, play was considered as the antithesis of work. Play held connotations of foolish, phony, wasteful, perverted, evil, insignificant, a luxury item or unnecessary activity after the necessary work was completed. Play was not considered as having value in human development.

Yet, since the beginning of the twentieth century, explanations of the role of play in human development have undergone transformations. Scholars, particularly psychologists and sociologists, have more carefully observed and sought to explain the play phenomenon. Initially, the explanations of play reflected the influence of the attitudes of the work-oriented society and the influence of the Darwinian era. As one theory revised another and accounted for a broader or different perspective, an evolution in the attitude toward the function of play was apparent.

The prevailing notion of play as a wasteful activity was expressed in the surplus energy theory. Herbert Spencer (1873) captured the essence of the idea of play as a release of excess energy in The Principles of Psychology. Play was considered nonproductive. For the "more-evolved creatures" play consumed excess time and discharged accumulated energy of "faculties unused in the provision for immediate needs...and

energy in excess of immediate needs...a superfluous and useless exercise of faculties"(pp. 629-630).

An obvious flaw in the surplus energy theory was the failure to account for the actual forms of play of children, specifically the imitative play of children. Karl Groos (1919) interpreted play as a kind of biological function. He claimed play was "an instinctive activity, existing for the purposes of practice or exercise, with serious intent" (p. 19). In his "practice theory of play" he interpreted play as preparation for the serious work of life; childhood was that portion of the life cycle set aside for this practice activity. Later, to account for "mischievous and unapplied energy" during childhood, Groos added a "catharsis concept." He analyzed spontaneous, unrestricted play as having a cathartic effect, a purging of that energy which had "anti-social possibilities" (Lehman and Witty, 1927, p. 17).

Whereas Groos claimed the future held the key to all play activities, G. Stanley Hall (1920) explained play as a function of the past. According to Hall's recapitulation theory, the child repeated in play the activities of his ancestors; in this respect ontogeny repeated phylogeny (Lehman and Witty, 1927, p. 20).

McDougall (1918) centered his thinking on the rivalry aspect in many play activities. He interpreted rivalry as an instinct needed for survival. When the rivalry instinct ripened prematurely, play was the means of exercising the instinct until it was needed for "serious use" (p. 113).

While these theories focused on an explanation of the play of the child, Patrick (1916) attempted to account for the play activity of the

adult in a work-oriented society. He considered the play of an adult arose as a need for relaxation of "cerebral functioning...put under severe strain in our modern strenuous life" (p. 49).

All of these theories developed from the conception that play was the antithesis of work or serious activity. However, the works of Freud and Piaget established play as more than a frivolous activity. Freud (1922) described a relationship of imaginative play to emotional development. The reenactment of unpleasant events through play was encouraged as a technique to aid disturbed children and, thus, was considered a serious activity. The notion was that play allowed the child to "work through" internal tensions and conflicts by "playing them out" (Millar, 1968, p. 58).

For Freud play held little significance for intellectual development except as it aided in reducing the amount of tension that was impeding intellectual activity. However, more recently, Piaget (1962) proposed a more direct relationship between play and the growth of intelligence. He depicted intellectual development in terms of two complementary processes, assimilation and accommodation. Assimilation defined the process in which the individual modified incoming information to fit his own needs. Accommodation described the adjustment the individual made to the external world in order to assimilate the information. Piaget claimed intellectual development was due to the continual, active interplay between the processes of receiving and adjusting to information. Growth, or adaptation, occurred when the processes complemented each other (considered to be in equilibrium). He proposed that play occurred when assimilation dissociated from and predominated

over accommodation. On the other hand, imitation occurred when accommodation or adjustment to the world's demands, predominated over assimilation. Reintegration of the processes resulted in equilibrium representing intellectual growth. Play, then, was considered an integral part of the development of intelligence.

Since the turn of the century, sociologists have debated the value of play to the social development of the individual and of a culture. In his essay on sociability at the turn of the century, Georg Simmel (1950) observed that people repeatedly played games which mirrored real-life situations or problems. These play experiences provided practice at real life with relative safety from real-life consequences. Simmel's conceptualization was similar to Groos' practice theory; yet, where Groos focused on the activity itself, Simmel focused on the social situation in which the activity was performed.

George Herbert Mead (1934) claimed play was an invaluable teaching aid in the development of the social self. He proposed the "self" was not present at birth but developed from the social experiences of the child. Stages of development of the self were described sequentially in terms of imitation, play, and, finally, the organized game. Of these activities Mead valued the organized game because the games represented "the passage of the life of the child from taking the role of others in play to the organized part essential to self-consciousness in the full sense of the term" (p. 152). In other words, the game provided the opportunity for the child to view himself through the eyes of a variety of "individual others" and eventually through the collective eyes of others as an entire system ("generalized others"). In this respect the

child learned to anticipate the actions of others and, also, to perform as others expected.

Mead's work characterized play as important in the social development of the individual. Meanwhile, Huizinga (1938/1955) described a close relationship between play and the development of a society. Recognizing the universality of play and games in all human societies, Huizinga proposed play as a civilizing agent. In what many consider a classic work on games, Homo Ludens, he claimed play taught man respect for rules, a spirit of curiosity and inquiry, and the ability to create and use strategies. Man, having acquired these abilities, was able to understand the "cultural rules of the game." Huizinga concluded: "To the degree that he is influenced by play, man can check the monotony, determinism, and brutality of nature. He learns to construct order, conceive economy, and establish equity" (p. 57).

Acceptance of a relationship between societies and their forms of play led Caillois (1961) in Man, Play and Games to attempt to classify societies by their play activities and games. Yet, in his work he did not conceive these activities in a contributing role, only that the activities characterized the societies. His expressions of games as nonproductive and wasteful connotated his feelings as to their usefulness.

This changing attitude toward play and its role in development was evidenced by the increased amounts of literature since 1900. Some of the highly recognized works from the current expanse of literature were two volumes dealing specifically with the role of play in human development, i.e., The Psychology of Play by Millar (1968) and Why People Play

by Ellis (1973). A recent compilation of 71 articles, Play-It's Role in Development and Evolution, edited by Bruner, Jolley, and Sylva (1976), provided a sampling of the prime literature: historical, literary, clinical, introspective, anthropological, sociological. Bruner indicated this volume represented "a body of literature emphasizing the crucial role of play in the development of the individual human child" (p. 1).

### Evolving Learning Theories

Concurrent with the changes in theories of play were changes in learning theories. Recognition of a role for play and games in learning has been a slow process in American education.

Early American education was a product of deep religious convictions and old world educational beliefs. Strongly influenced by Calvinism, the early American school emphasized self-denial and self-control, particularly in play. This attitude toward play which dominated the schools was evidenced in the statement by the Methodist Church in America in 1792: "The students shall be indulged with nothing which the world calls play. Let this rule be observed with the strictest nicety; for those who play when they are young, will play when they are old" (Lehman and Witty, 1927, p. 2).

John Dewey was the first American educational reformer to strongly challenge this attitude toward play in schools. His work was the culmination of learning theories offered by such reknowned educators from the old world as Comenius, Rousseau, Pestalozzi and Froebel.

Comenius (1649/1953), a seventeenth century Czechslovakian educator, likened the need of outdoor games for physical activity of the human

body to the need of indoor games for activity of the human mind. In The Analytical Didactic he claimed the competitive aspect of games delighted students as well as maintained their enthusiasm for a task.

During the eighteenth century, Rousseau vigorously expressed a belief in education through experience. He claimed the most important part of a boy's education was acquired through the activity of first-hand experience. In particular he valued play activities for he felt, through them, the child learned without any consciousness of learning. Rousseau's support for an active approach to education was so strong that he adamantly opposed the use of books. Concerning books, he asserted, "They only teach us to talk about what we do not know. They are of doubtful use for men. They are worse than useless for children" (Boyd, 1963, p. 313).

Like Rousseau, Pestalozzi, a Swiss experimental educator of the late eighteenth century, approached education from the interests of children rather than the logic of adults. An originator of the modern concept of readiness, Pestalozzi emphasized the importance of individual differences and the value of active rather than passive involvement. His certainty that knowledge progressed from concrete to abstract caused him to stress the need for concrete representations, including simulation exercises and games (Mayer, 1960).

Froebel, a nineteenth century German educator, recommended the education of the child center on experience rather than instruction. He believed children learned by doing rather than by more abstract methods involving reading and listening. Recognizing that children, left unattended, invariably played some kind of game, Froebel characterized

games as an "educational phenomenon" (Usova, 1963, p. 29). In his learning theory he promoted a wise and thoughtful choice of games to encourage the translation of the abstract into the actions of the child while still maintaining the "spontaneous delight of play" (Bowen, 1894, p. 101).

Writings of these European educational reformers reached American students of education. Thought-provoking discussions ensued which led to a gradual acceptance and appreciation of the importance of play in learning. Experimentation with the ideas in the classrooms gave credence to the active learning approach.

The discussions of American educational methods in light of the influential foreign learning theories culminated with the work of John Dewey (1916, 1938). Dewey proposed a learning theory based on an active approach to learning, an approach he claimed promoted good habits of thinking. Play methods were treated as active ways of learning, not relaxation or diversion from so-called real study. Dewey recognized the need for work activities in learning, but he denied that these activities necessarily excluded play. Noting that enticing a student to work usually required external rewards, Dewey valued the motivational power of play. In fact, he considered work permeated with play was "art" (Dewey, 1916, p. 206). Use of play activities, particularly games, provided the opportunity for students to be actively involved in learning, to test their ideas by application, to personally discover the consequences without emphasis from external rewards of teacher domination.

Dewey's analysis of a functional role of play and games in learning instigated dynamic dialogue among educators. Pragmatism and progressive

education strongly influenced translations of Dewey's principles into classroom practices. Typically, the translations were interpreted for the elementary level and often proved tentative, crude and inconsistent. Not until the late 1950s and the early 1960s did Dewey's work receive a more accurate interpretation in classroom activities in preschool through graduate school. Boocock (1968) declared that while defense of games and play in learning culminated with Dewey, the educational innovations of the sixties represented "a second and more accurate translation" of Dewey's ideas into classroom practices (p. 57).

Learning theories of the sixties were essentially extensions of Dewey's theory of learning influenced strongly by Piaget's interpretations of cognitive development. Piaget (1963) proposed that the cognitive development of a child proceeded through four main stages: the sensori-motor stage dominated largely by motor activity; the preoperational stage characterized by the development of language and socialization of behavior; the concrete stage in which the child developed the ability to apply logical thought to concrete problems; and the formal stage in which the child no longer relied on concrete structures to think logically and was able to apply logic to all classes of problems.

Bruner (1966) extended Dewey's message on the active involvement of students in the learning process in Toward a Theory of Instruction. Bruner asserted learning was a discovery process. Students, investigating problems, searching for regularities or patterns through manipulation of the problem, trying to reconcile the patterns to ideas already known, were actively involved in the process of learning. Furthermore, he assessed activities involving play and games providing "a superb

means of getting children to participate actively in the process of learning, as players rather than spectators" (p. 95).

With the emphasis on active involvement in the learning process, consideration broadened to the learning process involved in specific disciplines. Zoltan P. Dienes (1972), strongly influenced by Piaget's interpretation of cognitive development, defended Bruner's thesis in the learning of mathematics. As a mathematician turned psychologist, he recognized learning mathematics was not a "spectator sport." In fact he insisted learning mathematics required the active physical as well as mental involvement of the students. A strong proponent of play, and particularly of games, he claimed, "Most mathematical structures can be learned by playing skillfully contrived and excitingly motivating games of a mathematical nature" (p. 64).

Dienes' theory of learning mathematics revolved around four principles, each principle incorporating game-like activities. The major principle, the dynamic principle, suggested the cyclical nature of the learning process in three ordered stages. The first stage, free play, while relatively unstructured, provided actual student experience to which later experiences were related. The second stage, slow realization, was characterized by the structuring of the informal play stage with simple concrete ideas or experiences which were isomorphic to the abstraction to be learned. The third stage, awareness, involved the moment of insight and understanding as the student suddenly understood the abstraction. This stage served as a

play stage for the next concept to be learned. The cycle repeated as the concepts of mathematics were learned by the student (Reys and Post, 1973).

The remaining three principles clarified the framework established by the dynamic principle in Dienes' theory. The perceptual variability principle provided for differences between students in concept formation. Through this principle, Dienes insisted a broad variety of conceptual forms, represented in a concrete manner, were needed to help students abstract the mathematical concept. The mathematical variability principle spoke to the problems of generalization. This principle required the experiences to vary as many irrelevant mathematical variables as possible while at the same time keeping the relevant variables intact. The constructivity principle stated that constructive thinking necessarily preceded analytical thinking. The student's own experiences allowed for the construction of an idea after which he subjected the idea to logical tests or analysis.

These four principles identified the criteria for effective mathematics learning. Dienes considered play and game activities essential to the learning process. In particular he defended the value of rule-bound play, the game, as an instigator of higher-order cognitive activities (Dienes, 1963).

#### The Educational Games Paradigm

Influences from multiple disciplines shaped the development of educational gaming. Acceptance by educators was slow while

psychologists, sociologists, scientists and military leaders actively applied the theory to their particular fields. However, communications among varied fields created an inconsistency in the terminology used in the educational games paradigm. Terms, such as simulation games, gaming simulations, game/simulation, instructional games, teaching games, learning games, as well as educational games, confused communications through the literature. Haney (1971) noted, "the field...has its share of semantic quicksand, but anyone interested in questions of how humans learn should take a running jump into it anyway" (p. 1).

#### Fundamental Terms

An understanding of some fundamental terms used in educational game theory - play, game, and simulation - is required in an attempt to remove the confusion in terminology.

Play. Euclid began his geometry with point, line and plane as undefined terms in order to prevent circular definitions. Apparently, the term play has served a similar purpose in educational game theory. Scholars, describing and discussing play, have not defined it. Sutton-Smith (1967) noted the nonexistence of a "generally accepted definition of what play really is or what it does" (p. 362).

Although attempts to describe play included such ideas as fun, opposite of work, and important for human existence, the concept of a voluntary activity was used most consistently. For example, Huizinga (1938/1955) described play as

...a voluntary activity or occupation executed within certain fixed limits of time and place, according to rules freely accepted, absolutely binding, having its aim in itself and accompanied by a feeling of tension, joy and consciousness that it is different from ordinary life (p. 28).

Caillois (1961) considered play to be free, make-believe activity.

He also indicated that while rules were involved with play, play was characterized by uncertainty as to the direction of the activity and the terminating of the activity. Bower (1968) discussed the idea of voluntary activity but, further, stated that play was "a relationship with oneself or others which requires the skill of creating and becoming involved in illusions, of being able to step out of the real world and back again" (p. 12). Avedon and Sutton-Smith (1971) identified play as an "exercise of voluntary control systems" (p. 6). And, Allen (1972) depicted play as a "free, spontaneous activity which cannot be prescribed and in which there is no predictable outcome; problems, goals, and rules may change as play progresses" (p. 62).

Synthesis of these definitions indicated an agreement on the voluntary aspect of play but presented another important concept. During play, rules, once accepted, were binding; however, these rules were allowed to be changed within the activity.

Game. Throughout the literature, professionals from various fields discussed the term game. They communicated definitions of games from their philosophical stances by way of descriptions. Whereas this sort of intellectualization with the concept of play retained a philosophical emphasis, the work dealing with the concept of games

attained a more scientific direction with the work of von Neumann and Morgenstern (1944). Probability theory was available for analysis of pure chance games before this work. Yet, this work provided the analysis of games involving a mixture of chance and strategy, or even those involving pure strategy, devoid of chance. In this work the authors provided a mathematically rigorous definition of games from which they were able to develop ways to form best strategies.

Von Neumann and Morgenstern claimed a game was the "totality of the set of rules which describe[d] it" (p. 49). The term play indicated each instance in which the game was played from beginning to end. A move referred to the opportunity to choose among various alternatives; choice was the specific decision made. Furthermore, they recognized the relationship between moves and choices to be the same as the relationship between game and play: "The game consists of a sequence of moves, and the play of a sequence of choices" (p. 49).

Another important distinction dealt with rules and strategies. Strategies referred to the player's plan, regardless of what principles were used to guide his choices. Strategies were viewed in degrees, some good, some bad. Within the game, the player was allowed to freely accept or freely reject a particular strategy. However, the player was not allowed the choice of acceptance or rejection of the rules. Within the definition of game, rules were required to be absolute commands: "If they are ever infringed, then the whole transaction by definition ceases to be the game described by those rules" (von Neumann and Morgenstern, 1944, p. 49).

From this explanation of the terminology, the games of strategy were defined in terms of the actions of at least two players with conflicting interests. While allowed to freely choose his own actions within the rules of the game, each player was not allowed to choose his opponents' actions, nor those of chance, such as the roll of the dice. The resulting problem from this model was twofold: Was there a "best" strategy, and, if so, how was it determined (Richardson, 1958)?

These questions were complicated by an additional allowance. Besides the problems of decisions creating many possible outcomes, the problem of different pay-off values was added to the model, creating more possible outcomes. If the decisions created the situation where the sum of all pay-offs at the end of the game was zero, the game was interpreted to be a "zero-sum-game." What one or more players won, other players lost. On the contrary, "non-zero-sum games" allowed players to receive pay-offs without cost to other players' pay-offs. Conceptually, the non-zero-sum game allowed the possibility for some or all players to win or lose.

Since von Neumann and Morgenstern's work, professionals from different fields have prepared descriptions of games to more concretely characterize games within their particular fields and for their particular purposes. A representative sampling of these descriptions were:

1. Suits (1967) offered a philosopher's response:

To play a game is to engage in activity directed toward bringing about a specific state of affairs,

using only means permitted by specific rules, where the means permitted by the rules are more limited in scope than they would be in the absence of the rules, and where the sole reason for accepting such limitation is to make possible such activity (p. 148).

2. In Serious Games Abt (1971) claimed that "reduced to its formal essence, a game is an activity among two or more independent decision-makers seeking to achieve their objectives in some limiting context" (p. 6).
3. Fletcher's (1971) definition consisted of a list of characteristics required in a game: a set of players, a set of rules explaining what the players were permitted and forbidden to do during the game, conflict of interest among players, resources and information within which the player acted, a set of possible outcomes (goals) which were specified or determinable.
4. Inbar and Stoll (1972) emphasized that the game must have a formal winner. They considered games in terms of three features:
  1. A structure of more or less explicit rules about constraints under which a goal is to be achieved within certain resources;
  2. Player's psychological orientation that the goal is valueless in itself;
  3. Social consensus that the activity is inconsequential for the serious business of life (p. 10).
5. Avedon and Sutton-Smith (1971) required the game to be a free-choice activity. Their description suggested a game as "an exercise of voluntary control systems, in which there is a contest between powers, confined by rules in order to produce a disequilibrium outcome" (p. 7).

Haney (1971) summarized most of these definitions or descriptions by requiring a game to have "players, rules, uncertainty, terminating situations, and payoffs for the players" (p. 4).

More current definitions involved a slightly different orientation. Dunathan (1978) claimed that "one could easily get the impression there is no consistent definition of game" (p. 14). He proposed that a game was more appropriately defined by three essential principles: competition, abstraction, and power. Included with the competition with self, other participants, and uninvolved others was the competition attributed with risk, chance, and scoring. He considered the game to be an abstraction. To play a game, he claimed the player was required to comprehend the whole game package, then to decide the game's merit in his own terms (thus, deciding to play or not to play), and if the decision was to play, to internalize the game (or, the effort of playing the game was worthless). Power provided the reason for the player to compete. According to Dunathan, the players were allowed to exercise talent, skill, physical prowess, or intelligence at a low cost within the game whereas in the real world the stakes were probably perceived as being higher.

Thiagarajan and Stolovitch (1978) defined game using a similar technique. From their perspective the game contained conflict, control, closure, and contrivance. Conflict included the struggle among players, against chance, and between teams; control referred to the rules; closure required the game to terminate in a finite time, thus, distinguishing a game from mere play; and, contrivance alluded to the separation of the game from real life.

Simulation. The third fundamental term in the paradigm, simulation, also was abused throughout the literature. Probably, the most common misuse considered simulation equivalent to a simulation game. The variety of definitions stimulated confusion as to whether games were subsets of simulations, whether simulations were subsets of games, or whether the terms represented partially intersecting sets.

As the field dealing with simulations matured, more accurate definitions were offered amidst other less accurate ones. Seidner (1976) referred to simulations as "the dynamic execution or manipulation of a model of some object system... They are abstractions and simplifications of the real world. They focus upon particular aspects of the referent system rather than all of its elements" (pp. 221-222). Hounsell and Trollinger (1977) more succinctly summarized a simulation as an "operational activity which represents an actual situation that could occur in real life" (p. 235).

Attempting to deal with the confusion in the terminology, Spannus (1978) characterized rather than defined simulation. He felt that three characteristics were essential for a simulation: simulations must be based on a model of reality; objectives of the simulation activity must be at the participants' level of application; and, consequences of the participants' actions must be dealt with in the simulation.

The simulation model of reality received a great deal of attention in the literature. In essence the model was described as the midpoint between the complex, uncontrollable and nonreproducible real

world phenomena and the distorted, ungeneralizable, more controlled laboratory experiments. The extracted model was regarded as a static system, representing the structure of the real-world system under consideration. When the functional relations and processes were added to the model, the model became a dynamic representation of a real-world system - a simulation (Haney, 1971).

To create the simulation, however, the dynamic representation of the real-world system was placed in an active situation guided by information and data (not necessarily rules as with games) and was combined with a clearly defined objective. Participants (not necessarily human) were required to accept the posed situation as if it were real, to assume a role which may or may not be accepted by them in a real situation, and yet, to interact as expected in that role. In this manner the simulation presented a probable replication of the behavior of a phenomenon (Kerr, 1977).

Dennis (1979) offered a taxonomy of simulations in terms of their objectives:

1. Replicable Performance Simulations: The learning outcome is an expected replication of a specifiable performance.
2. Information Retrieval Simulations: The learning outcome is information in the form of facts, principles, or understandings, all of which are specifiable and/or quantifiable.
3. Encounter Simulations: The learning outcome is the "experiencing of a situation." One is expected to become aware of (perhaps) vaguely defined possibilities or probabilities of the situation. The learning goal is awareness of variability among the consequences, and procedures for assessing the magnitude of this variability (p. 3).

Barton (1970) described simulations by the techniques involved in the manipulation of the model. He used the term, analysis, for those simulations which used only mathematical analysis (thus, not displaying the dynamic aspects of the model) because the results of different trials remained the same. Man-model simulations (or all-man simulations) referred to those simulations using only human participants as decision-makers. Man-computer simulations (or man-machine simulations) referred to those simulations in which both human and computerized decisions were made. Finally, all-computer simulations (or all-machine simulations) referred to those simulations in which all defined parameters were contained in the computer program.

Obviously, from the differentiation of simulations via the techniques involving implementation of the computer into the model, the impact of computer technology was significant. The computer, a machine based on logic and symbol manipulation, extended the potential of human problem solving by several orders of magnitude. Thus, computers increased the potential for simulations by several orders of magnitude. The computer simulation required human thought to analyze the general problem and to adapt the solution to a computer language. After this human input, different data and different circumstances processed and interpreted in light of the general problem was possible by the computer. In this manner the computer provided humans the capability of extensively studying highly complex and detailed problems such as those suggested by simulations attempting to model real-world situations.

Another distinction often made in the field of simulations, stochastic versus nonstochastic simulations, arose from mathematical developments of the Monte Carlo techniques. According to McLean (1978), mathematicians working with probability theory, were able to simulate patterns of chance that were previously considered as independent, random events. Without the use of Monte Carlo techniques, the only simulations possible were nonstochastic. Nonstochastic simulations were based solely on probability theory, such that trial after trial using identical inputs into the model resulted in identical outputs. However, as Barton (1970) noted, more accurately modeled real-world simulations required chance processes in which identical parameters, starting conditions, and input time-path values likely produced different outputs trial-to-trial. By combining chance processes with probability theory to determine outputs of simulations, the capability for handling stochastic simulations was created.

#### Types of Educational Games

The descriptions of games and simulations throughout the literature did not depict two mutually exclusive groups but, more accurately, intersecting groups or possibly points in a continuum. As the ideas of games and simulations were inserted within the context of teaching and learning strategies, a new level of terminological confusion erupted: educational games, games, instructional games, simulated games, gaming simulations, game-simulations, nonsimulation games. Overall, the emphasis intended by the new terms was to

indicate subgroups of games, simulations, and educational teaching-learning strategies.

Haney (1971) described the term educational game as "a competitive cooperative exercise which teaches something other than merely the rules of the game" (p. 7). Essentially, educational games were conceived as activities which allowed students, acting as players, to employ a body of knowledge as a resource within the rules of the game and in competition with other players in order to achieve the stated goal(s). Within the set of educational games, two major disjoint subsets were termed simulation games and nonsimulation games.

Simulation Versus Nonsimulation Games. Simulation games originated from a merger of the concept of simulation with the concept of game. Therefore, this activity combined the basic characteristics of games and the basic characteristics of simulations. The elements of the game - players, rules defining the range and nature of actions, goals or winning criterion - combined with the essence of a simulation - a model representing another situation - to form the simulation game. Zuckerman and Horn (1973) claimed that simulation games "differ from ordinary games only in that their elements compose a more or less accurate representation or model of some external reality with which the players interact in much the same way they would interact with the actual reality" (p. 1).

Livingston and Stoll (1973) emphasized some important distinguishing characteristics of simulation games. They indicated that players must assume roles and make decisions within that role. However, they noted the simulation game provided motivation other

than that in simple role-playing exercises. Encompassed in the rules, a scoring mechanism for determining winners, necessarily affected the players' decisions while playing the simulation game. Hence, Livingston and Stoll perceived players being more externally motivated than in mere role-playing exercises. Another aspect of the incorporation of game rules was that rules (and scoring rewards) likely discouraged particular player actions which were options in a real situation. Stadsklev (1975) consolidated this aspect of role-taking in his summary of simulation games as "a sophisticated technique involving role-taking within the context of a comparatively complex social model of an actual or hypothetical process instilled into game form" (p. 8).

The impetus for educational simulation games rested in the use of rules to confine and direct the players' role-playing actions in order to create a specified experience. Barton (1970) commented that simulation games were designed "to enable participants to understand better the complex and subtle processes of behavior within the system modeled" (p. 206). Haney (1971) added that simulation games in the social sciences gave "students personal experience in solving problems of cooperation and conflict implicit in a variety of real-world social systems" (p. 9).

The distinction between simulation and nonsimulation games focused on the imitative aspect of simulation games. Since only some of the elements and relationships operant in the real system were considered for a simulation game, the game was more realistically viewed as an imitation of a real system. On the other hand, non-simulation games were created to incorporate the totality of all

functional relationships of a real system. Goodman (1973) expressed the distinction in this manner:

If the principles incorporated by reference in game rules are in fact an explicitly developed set of rules, indeed a set of rules such as mathematics which constitute a body of subject matter, the exercise is usefully termed a non-simulation game. The rules by which such a game is played--in addition to the special game rules added--are the rules of mathematics; they do not simulate the rules of mathematics. The implications of this set of rules incorporated by reference in the game rules are not like the implications of the rules of mathematics, they are the implications of the rules of mathematics (p. 929).

Free-, Rigid-, and Open-Form Games. Another classification of educational games was made on the basis of problem solving behavior required in the game. The forms discussed in the literature were free-form, rigid-form, and open-form. Dennis, Muiznieks, and Stewart (1979) claimed free-form games involved general, context-related problem solving behavior; rigid-form games involved specific, context-related problem solving behavior; and, open-form games involved general, context-free problem solving behaviors.

More specifically, free-form games were identified by Shubik and Brewer (1972) as those games in which a scenario provided a context within which the play progressed. The characteristic feature of this form was that within the play, participants were allowed to challenge, create and improve the rules, positions, and goals. This freedom required player imagination and innovation in decision-making affecting other players. Yet, while the problems represented typical problems, the problems were not identical to the real problems. Within the context of the game, the problem solving behaviors required were

not identical to real-life behaviors, only similar to them. The behaviors exhibited were general rather than specific. Often, games in sociology, political science and social psychology were applicable to this form, where the objective was to have the student experience general political and social decision-making strategies within certain representative problem areas.

Shubik and Brewer (1972) referred to rigid-form games as those games in which all of the rules were completely specified and well-defined in advance of the game. Changing the rules during the play of the game was not tolerated since these rules were identical to the rules in the real-life content. For example, arithmetic games designed to teach addition were included in this category since the rules of the game incorporated the rules of addition. Addition problems represented real addition problems and the problem solving behaviors needed were real addition problem solving skills. Behaviors learned and practiced in the game were precisely those needed and used in the real setting. Playing the game permitted development and practice of the solution algorithms. Contrary to free-form games, rigid-form games were not considered robust since they did not "tolerate flights of fantasy and explorations beyond what is inherent in the defined and in principle knowable solution space" (p. 335). Therefore, rigid-form games were considered more amenable to computerization.

Dennis, Muiznieks, and Stewart (1979) defined open-form games as those games in which "neither the problems solved nor the behaviors employed are congruent to any real-life counterparts" (p. 5). Pure

strategy games, such as chess and tic-tac-toe, were included in this category. Within the open-form games the relationship of the game strategies to real-life problem solving strategies were clearly not obvious, defined or described; however, claims were made connecting the strategies to real-life problem solving.

Computer Games. The accelerated pace of technological development in the computer industry during the past twenty years improved the cost, reliability, and performance of computing. The impact of this increased sophistication and accessibility affected not only education but made a significant contribution to the emergence of educational games.

The application of computers in education included learning about computers, learning through computers, learning with computers, and computer-managed instruction. Learning with computers was termed computer-augmented learning (CAL) and learning through computers was termed computer-assisted instruction (CAI). Educational games were included within the domain of computer-augmented learning (Braun, 1977).

Computerized educational games utilized the computer in varying roles during the play of the game. Umpley (1971) assigned the term "man-machine" to games using only humans as players and the computer as referee. In man-machine games, the computer kept track of the score, made sure rules were not violated, reminded players of rules, and visually displayed the progress of the game. The term "machine-player" referred to games in which the computer served not only as referee, but, also, replaced one or more human players. Within this

mode, a computerized decision-making model replaced a human player. This more complex role for the computer introduced the concept of the computer as an opponent in the game. Replacing all players by computerized decision-making models created games referred to as "all-machine" games (p. 5).

Until advances were made in the field of artificial intelligence, the application of computers to educational games was limited to man-machine games. Work in artificial intelligence succeeded in simulating intelligent behavior of human players in games. In fact, research summarized by Shubik, Wolf, and Lockhart (1971) attested to the success of these artificial players in a game situation. The improved programming capabilities resulting from this work created the possibility of computer games in which both human and artificial players were involved; additionally, within each play the artificial player(s) could be programmed to match the competitive level (i.e., intelligence) of the human players.

The present state of artificial intelligence has allowed adequate programming of artificial players in rigid-form games. Since players in rigid-form games generally expected to exhibit specific problem solving skills and information-processing abilities within a set of well-defined rules, the simulation of an artificial player was more quantifiable. In other words, the intelligence to be simulated represented an individual intelligence rather than a social intelligence. As Shubik (1975) indicated, "The problems in the construction of a good problem-solver or a socially intelligent player differ inasmuch as the criteria for the performance of the former are

relatively easy to construct, whereas there are no such easy criteria that can be constructed to judge group or social rationality" (p. 39). In essence, then, an artificial player for a rigid-form game may be created mainly with efficient searching and calculating techniques.

The more free-form or open-form the game, the more the game has rebuffed computerization. Within these forms, players are required to display a more general problem solving strategy, a social intelligence taking into account the social interaction among players. With this less quantifiable intelligence, simulating artificial players to display social, political or economic behavior has been difficult. Currently, the sophistication in artificial intelligence has not adequately produced an artificial player to compete successfully against a human player in open-form and free-form games.

#### Implementation of Educational Games

During the past twenty years, games were popularized as an instructional technique in education. This rise of educational gaming was a product of several complex factors. Certainly, the growing appreciation by educators of a link between play and learning was one of these factors. The advent of game theory and the development of the computer technology were, also, forces in the creation. However, the military employed gaming techniques far more than education and for a much longer time. Basically, the military used games in preparing for war. Military gaming arose from a long rich history of war games dating to 3000 B.C. and the Chinese game Wei-Hai

(Encirclement). Chess was a product of Middle Ages' waring adapted from an Indian game Chaturanga. Military officers, lacking opportunities to practice waring strategies, developed war games from their experience with chess. By World War II, war games were widely used by military branches in many different countries. As Fleet Admiral Nimitz recognized, "The war with Japan had been re-enacted in the game rooms...by so many people in so many different ways that nothing that happened during the war was a surprise--absolutely nothing except the Kamikaze tactics toward the end of the war" (Carlson, 1969, p. 5). More currently, war games were considered indispensable aids to military planners for training and operational studies.

The emergence of games in the classroom coincided with the curriculum reforms and the learning theory reforms of the early 1960s. Inspired by developments in technology and by learning theories that encouraged active student involvement in learning, a diverse variety of materials were created. Game designers began to create more and more games specifically for educational purposes. By the 1970s, games were enthusiastically recommended as learning aids in the classroom.

Boocock and Schild (1968) claimed the implementation of gaming as a teaching technique passed through three phases during the sixties. The first phase, lasting until 1963, was termed "acceptance on faith." The initial discovery of gaming as an instructional technique created an enthusiasm and a wave of acceptance without concern for rigorous evidence. During this phase, researchers developed, rather than evaluated, games. Many unsubstantiated claims were

made for the use of games in the classroom. Additionally, the involvement of students observed during game sessions was often reported as evidence of learning.

The years 1963-1965 comprised the second phase described as the "post-honeymoon period." During this time, some controlled experiments were conducted attempting to substantiate some of the claims made for gaming. While the results of many of the experiments were generally inconclusive with questionable validity, the summative effect provided a sobering force in the implementation of games in education. Boocock and Schild summarized the research conclusions as follows: games were not a panacea for all educational ills; many games in their present form had serious flaws; and neither standard tests nor the relatively crude instruments designed specifically to evaluate a particular game or games were adequate or sufficient measures for the impact of games.

The third phase at the end of the decade was referred to as a time of "realistic optimism." To indicate a renewed faith tempered by a more realistic approach, Boocock and Schild noted that games were being field tested in a wide variety of educational settings. This optimism directed alterations to make the games more valuable for particular kinds of students, increased the pool of data on the learning effects of specific games (in many cases by researchers other than the game's designer) and aided researchers to revise and clarify claims as to what games do in the classroom.

Within this more realistic, yet still optimistic, atmosphere, games were designed and produced in increasing numbers. Evidence of the growing number of educational games was found in the many publications devoted to annotated listings of the available commercial games (i.e., Zuckerman and Horn (1973); this work was a second edition expanded from the first edition). In addition to commercially prepared games, more and more teachers, convinced of the educational value of games, developed and designed games for specific purposes in their classrooms.

An outgrowth of the interest was a large amount of literature dealing with the implementation of games in education. Review of this literature has been separated into three areas: rationale for implementing games, claims for games in education, and limitations of games in education.

#### Rationale for Implementing Games

One statement repeatedly appeared in the literature to state succinctly the rationale for implementing games in education.

I hear and I forget;  
I see and I remember;  
I do and I understand.

The statement, a product of ancient times, aptly expressed the common theme in contemporary learning theories - experience. Experiential learning was considered the best way for students to learn because they were allowed to experience the consequence of their actions "by coping with their environment rather than by being

taught" (Stadsklev, 1975, p. 31). The rationale for learning through games grew from this learning theory coupled with changing educational philosophy. Carl Rogers summarized the changing philosophy by suggesting education needed to develop "learners not learneds," people who were able to solve problems, make decisions, and find answers rather than people merely full of information (Stadsklev, 1975, p. 5).

Duke (1974) discussed the rationale of learning through games within this process-oriented philosophy. Initially, he recognized a similarity in the rise in gaming with the increase in societal complexity. His conception of societal changes led him to remark, "Humankind is a little harried of late. The naked ape barely blinked only to discover that his animal being has moved from the cave to the moon with little time for adjustment" (p. 3). Duke interpreted the change in complexity of the society resulted from combined efforts of technology and knowledge. Preceding the industrial revolution, complexity plotted against time increased linearly with small slope. From 1900 to 1940 the rate of change increased dramatically, but, after World War II, the curve became exponential. Duke's projection of the plot maintained the exponential growth in complexity. By superimposing on this graph a plot of the development of new games since 1940, Duke noted the similarity of the curves with perhaps a ten-year difference in placement. He interpreted this similarity to be more than coincidental. As new information was generated exponentially and the problems of the world grew more complex, Duke saw the rise of the need for communicating holistic thought, or

gestalt. His conclusion was "The simultaneous invention of games of a wide diversity of subject matter and technique is a response to a felt need for an improved communication form to deal with problems of gestalt or holistic thought" (p. 40).

To clarify this rationale, Duke referred to the work of Moore and Anderson (1969/1975). In their thesis Moore and Anderson pinpointed a similar dramatic change in society during the 1940s. The dawn of human history to the 1940s was considered the primitive period; the post-forties were considered modern. Their study of this division emphasized the transition in the society from a "performance" society to a "learning" society (p. 58). In a performance society the youth practiced skills required in adulthood. However, the learning society called for a transformation of the educational philosophy of the performance society. No longer was it reasonable to assume that skills taught were needed in the future because of the tremendous technological advances. Thus, preparing students for the future required the emphasis to be on the learning process. Moore and Anderson described four underlying principles needed for this environment for learning. Duke (1974) succinctly summarized these principles as follows:

1. Perspectives principle. A given environment is more productive if it permits and facilitates the taking of more perspectives towards the problem than another environment.
2. Autotelic principle. The environment must be safe for experimentation of even the most outrageous or improbable sort without high personal risk.
3. Productive principle. This implies the ability of the learner to deduce or make probable inference within the context of the educational environment. This requires an environment which is logically and

coherently structured, permitting the learner to make leaps of faith to some other perspective or level of thought.

4. Personalization principle. That environment is most productive which permits the greatest responsiveness to the learner's activities; it is an environment that encourages the learner first to find a question and then find an answer (p. 62).

Duke proposed that these principles provided the underlying design of a good educational environment and that most existing games were constructed with the concept of an "environment for learning as an underlying rationale" (p. 62). Furthermore, he rationalized

We learn through games, then because it is a relatively safe environment which permits the exploration of many perspectives chosen by the individual, expressed in the jargon of the individual and subject to fairly prompt feedback in "what-if" contexts (p. 40).

During the sixties, the Academic Games Program at The Johns Hopkins University Center for Social Organization of Schools was organized to study a central question: How do games create and influence learning? Coleman, Livingston, Fennessey, Edwards and Kidder (1973) described the rationale for implementing games in the classroom through an emphasis on learning theory. In short they suggested that games employed experiential learning. The distinction between traditional classroom learning and learning through games was seen as a distinction between an information-processing mode (via lectures, textbooks) and an experiential learning mode. Analysis of the differences in the two modes revealed different sequences of learning. The information-processing mode, a deductive paradigm, involved, first, the reception of the information through a symbolic

medium such as lecture or book; second, the general principle was "understood" or "assimilated" where the individual was said to have "learned the meaning of the information"; third, the individual was able to see how the general principle applied to specific situations ("particularizing"); and, finally, at some point the individual acted upon the general principle by personally using it. The experiential mode, an inductive paradigm, began with the last step of the information-processing mode with the student acting in a particular situation and observing the results; from these actions an understanding of the specific case emerged so that the individual was able to anticipate actions over a wide range of situations. Coleman et al. commented that this generalized understanding did not imply, in this sequence, "an ability to express the principle in a symbolic medium"; the sequence was completed by the individual actively applying the general principle to a new, specific situation (p. 5).

In essence this group rationalized that learning through games provided a means of learning other than passive, information processing with reliance on a symbolic medium. Learning through games provided direct activity, emerging from the student's experiences, proceeding at the student's direction and pace. Coleman (1972) suggested this process of learning was that which was encouraged in the current learning theories.

#### Claims for Games in Education

With the increased pool of data on the learning effects of games, the claims on the educational effectiveness of games were revised and

clarified. However, data used to support the current claims consisted of an accumulation of anecdotal data, data from one-game samples, and data derived heavily from simulation games. Thus, the resultant claims proposed descriptive rather than definitive statements of the educational effectiveness of games. Possibly, G. Shirts terminology more aptly described the state of the claims as "hunches" about games as educational tools (Stadsklev, 1975, p. 33).

Reviewing the vast number of claims for games, Greenblat (1975) organized the claims into six general categories: motivation and interest; cognitive learning; changes in the character of later course work; affective learning with respect to subject matter; general affective learning; and changes in classroom structure and relations.

Perhaps the most consistently acclaimed purpose for implementing games in instruction dealt with the motivational value. Many reports claimed that games significantly increased the motivation and interest level of students. Heitzmann (1974) noted that "Conclusions from experimentation indicates that they (games) are powerful motivators, have been reached by many researchers with diverse games in several settings" (p. 17). Orbach (1979) condensed the many reasons given for the capacity of games to arouse motivation to learn into three basic explanations. Essentially, the explanations indicated that students were more motivated to learn through games because (1) games were relevant and realistic, (2) games provided for students to actively manipulate the ideas rather than merely

contemplate over them, and (3) games provided fun and enjoyment. However, Orbach noted that often in the motivational claims, involvement, enthusiasm, interest and satisfaction were used interchangeably with motivation. He warned that these terms were, in fact, external expressions of the motivation to learn, not sources of it, as the explanations indicated.

Many game advocates claimed that games experientially taught specific terms, facts, concepts, and procedures. Implicit in the claims was the feeling that games were as effective or more effective in teaching this information. Hounshell and Trollinger (1977) noted that advocates indicated students learned the factual information through opportunities to utilize the information in an active manner and from the immediate reward structure within the game.

Other claims within the cognitive domain included the assertion that game playing required critical thinking, decision-making skills, and other problem solving strategies. Referring to the analytic approach required of the participants in a game, Taylor and Walford (1972) stated "issues must be treated on their merits, alternative strategies must be devised and attempted, results observed, and conclusions drawn, on the basis of direct experience" (p. 18). Ryan (1968) concluded that involving students in such a process helped them to transfer the knowledge of concepts and principles.

Claims that games created changes in the character of later course work included notions that games made the later work more meaningful, that games led students to more sophisticated and relevant inquiry, and that games involved greater participation by class

members who shared experiences. However, Rosenfeld (1975) noted no research evidence was available to either support or refute these claims.

Numerous references were made to the potential of games in affective learning with respect to subject matter. Greenblat (1975) consolidated the literature in this area to include claims that participation in games led to changed perspectives and orientations, to increased empathy for others, and to increased insight into the predicaments, pressures, uncertainties, and moral and intellectual difficulties of others. Basically, these claims arose from consideration of simulation games that involved interaction among students through role-playing. More recent evidence has been inconsistent in this area. Heitzmann (1974) claimed games could change the attitudes of participants. However, some research suggested a lack of permanency of the attitudinal change (for example, Livingston's 1971 study dealing with games and attitudes toward the poor). Seidner (1976) further tempered the claims for attitudinal changes by emphasizing that the change was not always in the direction desired.

More general affective learning from games was, also, claimed. Arguments were made that participants gained increased self-awareness and a greater sense of personal efficacy and potency. Reports, such as that of Lee and O'Leary (1971), noted increased tolerance for ambiguity and uncertainty as well as increased confidence in ability to make decisions. However, Taylor and Walford (1972) cautioned that students who lacked the ability to do well in a game

or who were oversensitive to the disapproval of others might be negatively affected by the game.

A number of claims were made about the learning environments when games were implemented. Fletcher (1972) insisted the self-judging aspect of games, where the outcome of the game decided the winner(s), shifted classroom relationships. He analyzed games "provide(d) feedback which (was) from the players' perspectives at once more lucid, less arbitrary, and probably faster than that provided in other instructional settings, particularly by a teacher in an ordinary classroom" (p. 433).

Skemp (1973) noted that within the classroom, teachers assumed two authority roles. He discussed one role as equivalent to establishing and maintaining discipline and obedience to instructions. The second role, however, was equivalent to an authority resulting from superior knowledge. Teachers exercising the second kind of authority encouraged students to question, interact, and debate with the ideas presented. Clearly, as Skemp suggested, "these two roles are not only different but in conflict" (p. 120). Yet, teachers are expected to exhibit both kinds of authority.

Boocock and Coleman (1966) considered games a means by which the conflicting roles were minimized:

The dual role of the teacher as both teacher and judge is a structural defect of the school. A teacher has not only the task of teaching students, but also the task of giving them grades, grades that can greatly affect the students' futures. As a result, students develop attitudes toward the teachers that can interfere greatly with learning: hostility, servility, alienation, and other reactions to an authority figure.

(With games) the teacher can escape from the role of judge, and return to his original function, that of a teacher, helper for the student (pp. 217-219).

Stadsklev (1975) indicated that the game rather than the teacher became the source of learning. Thus, students learned what they wanted to learn and what they needed to learn rather than what they were told to learn.

Gaming enthusiasts proclaimed that numerous changes in the classroom environment resulted from the transformation in the teacher's role. Greenblat (1975) considered the use of games encouraged students to recognize more freedom to explore ideas, to become more autonomous, to perceive teachers more positively, to maintain more natural and relaxed exchanges with other students and with teachers, to maintain greater acceptance and increased knowledge of other students; use of games, also, encouraged teachers to perceive students more positively. However, Rosenfeld (1975) reported an absence of studies analyzing these claims but an abundance of anecdotal accounts suggesting that games led to better student-teacher relations and an improved learning environment.

Claims for Games in Mathematics Education. Application of gaming was strongly promoted for mathematics education. As Abt (1970) indicated the "study of mathematics alone (could) be enriched by the use of games" (p. 40). Within the mathematics discipline, games were designed for an entire class, for an individual student, and for small groups; additionally, games were designed for varying age levels as well as ability levels.

Many claims were found about the implementation of these games in mathematics education. Reys and Post (1973) claimed that games were helpful in achieving many objectives in mathematics instruction including:

1. making practice periods pleasant and successful;
2. teaching mathematical concepts or ideas;
3. teaching mathematical vocabulary;
4. motivating effective study habits;
5. providing for individual differences;
6. favorably affecting the attitudes of children toward mathematics;
7. improving reading in mathematics;
8. providing an enjoyable means of summarizing or reviewing;
9. adding to the enjoyment of classwork and homework (p. 251).

At the annual meeting of the National Council of Teachers of Mathematics, Wheeler (1980) presented a comprehensive list of claims made for games in mathematics instruction found throughout the literature:

1. Games should be considered an integral part of the school curriculum and as more than relief from the strain and tedium of regular school work.
2. Games provide a superb means of getting children to participate actively in the process of learning--as players rather than spectators.
3. Games are tremendously useful devices for developing skill in mathematics.
4. Most mathematical structures can be learned by playing skillfully contrived and excitingly motivating games of a mathematical nature.
5. Games may be an effective means of making practice of computational skills palatable.
6. Many mathematical games can be used to lead students to formulation and testing of hypotheses as they strive to discover a winning strategy.
7. Games can be an effective way to retrain skills with basic facts.
8. Games can be an effective way to maintain skills with basic facts.

9. Games need to be played frequently in order to maintain basic mathematics skills.
10. To modify a game by incorporating instructional objectives into the rules of a practice game affects mathematics achievement.
11. When used subsequent to formal instruction, changing the game constraints to increase the verbalization of players increases the mathematical achievement of the players.
12. Games can be used to increase the accuracy of mathematical descriptions.
13. Games can be used to develop meaningful mathematical descriptions.
14. A game can promote formal logical reasoning skills.
15. Homogeneous achievement grouping of players affects learning through mathematical skill and concept games.
16. Heterogeneous achievement grouping of players affects learning through mathematical skill and concept games.
17. A game played prior to explicit instruction in the mathematical content of the game enhances learning.

#### Limitations of Games in Education

The numerous optimistic claims for implementing games in education were tempered by a certain amount of pessimism as to the value of games as educational tools. The negative attitudes toward games prevalent around the turn of the century never completely disappeared. Caillois (1961) reiterated the same feelings expressed by Spencer in 1873: games were a wasteful activity. In reference to this negative attitude, Boocock (1968) alerted that "this is the view of games still held by many educators" (p. 54). Abt (1968) also indicated that this attitude provided a serious limitation of implementing educational games. Teachers' negative attitudes towards games transferred to students. Therefore, if the teacher considered a game as a wasteful activity, students were likely to respond by not taking the game seriously.

DeVries (1976) discussed a limitation which almost directly counteracted an assertion made for implementing games in education. In The Adolescent Society Coleman (1961) expressed the need for students who excelled academically to be rewarded much as the athletes were. He felt a change in the allocation of rewards and prestige was needed in order for schools to perform their educational functions. He claimed the implementation of games would sufficiently alter the reward structure away from the competition for grades toward more appropriate academic competition. Yet, as DeVries recognized, students have not accepted games as a legitimate part of the activities in the classroom. He reasoned this nonacceptance was related to the non-incorporation of game activities into the classroom reward structure. In other words, games were implemented as a peripheral activity in the classroom and not associated with the serious business of grading. Thus, the effectiveness of games in the classroom was limited by the acceptance of students as a legitimate part of the classroom technique.

Observations of limitations as a result of the competitive aspects of games were made in the literature. Zieler (1969) considered possible negative psychological effects. His concern was that losing in a game had the potential of negatively affecting student morale, motivation, and concentration span. Dennis, Muiznieks, and Stewart (1979) noted that students simply resisted playing games because they were threatened by the competition of games. Also, they recognized that the competitive nature of games tended to reward those who thought like the designer of the

particular game and tended to punish those who developed innovative strategies. And, as previously mentioned, Taylor and Walford (1972) warned that students who lacked the ability to do well in a game or who were oversensitive to others' disapproval might be negatively affected by the game.

Coleman et al. (1973) recognized that using educational games was extremely time consuming. Learning from games was an experiential learning process, and, therefore, involved actions which needed to be repeated enough times and in enough circumstances to allow the development of a generalization from the experience. Furthermore, they asserted that the emphasis on the experience often by-passed the symbolic medium and produced learning which was not measurable on a paper-pencil test. "In learning through games, a form of experiential learning, it is a common observation that some players are able to pursue a strategy of play very well, but when asked to describe the strategy they used, can't begin to do so" (p. 5).

Limitations to implementation of educational games resulted from the myriad of games created within the past fifteen years. Stadskev (1975) indicated one serious limitation dealt with applications of games in the classroom. Games were not applicable in all situations, for all groups of students, at all levels of understanding. Hounshell and Trollinger (1977) recognized not only the need for the skill of the teacher in selecting the appropriate game but in administering and organizing the activity.

## Summary

Coleman (1967) in defending the implementation of games in education commented that

...games are clearly not a self-sufficient panacea for education although they are more than simply another educational device. They can be used in many ways ranging from merely inserting them into an existing curriculum to transforming the curriculum by using games and tournaments to replace quizzes and tests (p. 70).

With the enthusiasm for a new and exciting means of learning, many unsubstantiated claims were made for implementing games in education. Livingston and Stoll (1973), commenting on the claims, were reminded of a statement which appeared in Media and Methods (October, 1970):

Simulation games will revolutionize teaching (what won't?). Students will freak out on them (thus solving the drug problem), low tracks will suddenly become hypermotivated, teachers will become guides (referees, one supposes), and we will lock-step toward Nirvana with a pair of dice in hand (p. 31).

Yet, in spite of the cynicism, games were enthusiastically implemented in the classroom, experimented with in different situations, created and revised for specific experiences. Fletcher (1977) surveying the claims and the manner of implementation insisted that games have failed to become a significant force in education and have remained largely as add-ons to the curriculum.

### Evaluation of Educational Games

Within the past two decades the field of educational gaming expanded from an initial emphasis on elementary education, to include secondary education, and, currently, to include more and more activities aimed at higher education. Many claims were made about application of games in these classrooms. Yet, as Jacobson (1979) recognized:

Whether games and simulations actually lead to better acquisition of cognitive skills than do lectures and other traditional forms of instructions has not been demonstrated conclusively. Even on the "affective" or emotional side of learning, where games are thought to have their greatest value, the evidence is far from overwhelming (pp. 1; 19).

Speaking of the data that have been collected, Shirts (1973/1975) issued a statement to the National Gaming Council: "I think the studies that have been done are not all that good. The results are ambiguous. The methodology is suspect. I am just not very impressed at all with what has been going on" (Stadsklev, 1975, p. 13). Greenblat (1975) delineated weaknesses of games research to include poor research design and sampling, poor operationalization of concepts, generalizations from one game to another or to all games, and lack of control for relevant sample characteristics in the analysis. Pierfy (1977) specified the following three major deficiencies he found in the research:

1. Many studies concerning particular games have been conducted by the game designer;

2. Instruments used to measure have been investigation-constructed with a range of reliability coefficients from .800 to .346; and
3. Research has, at best, been quasi-experimental using intact groups of questionable comparability, comparing groups with different teachers, different subjects, and groups with increased potential of Hawthorne effect as a source of bias.

Aside from the methodological difficulties of the available research, Greenblat (1975) was concerned with the treatment of simulations and games as homogeneous. Current research has tended to consider one game the same as all games; thus, generalizations were made from one game to all games. Furthermore, the results from research dealing with simulation games have been generalized to all games, including nonsimulation games.

Some of the generalizations which were made resulted from the findings of the Academic Games Program. Coleman et al. (1973) summarized the conclusions from seven years of research:

1. The most consistent finding which held true for students from elementary to high school and for both simulation and nonsimulation games was that students preferred games to other classroom activities.
2. Research showed that nonsimulation games produced superior student performance on the specific skills students needed to use in playing the game.
3. Results dealing with simulation games were:
  - a. Simulation games can teach factual information, though not more effectively than other methods of instruction.
  - b. They can improve students' performance on tasks similar to those the students practice in the game.
  - c. They can change students' attitudes toward the real-life persons whose roles they take in the game; these changes are likely to be in the positive direction but may be short-lived.

- d. Neither unstructured role-playing nor a highly abstract simulation game seems to be as effective at producing this type of change as a more concrete simulation game in which the identification of role is explicit.
  - e. They tend to be more effective with students of high academic ability. Low ability students seem to be as good as their brighter classmates at learning to use winning strategies in the game, but they often fail to grasp the analogies by which the game represents a real-life situation.
  - f. The amount of time students spend playing can make a substantial difference in the effects of the game. On the other hand, class discussion following the game may make very little difference.
4. In general, the effectiveness of a simulation or game for producing changes in either attitudes or behavior depends on the degree to which it requires the players to employ knowledge or skills related to the attitude or behavior (pp. 6-7).

However, Coleman et al. did make a final comment which was important when considering their studies:

These findings bring the field of simulation and gaming one step closer to understanding the special and perhaps unique value of games, but they cannot and should not be directly generalized to all games. As a result of the variety of available games and game structures and the diverse conditions under which they may be used, the conclusions reached by the Hopkins Games Program's research can be applied directly only to a fraction of the possible learning environments (p. 7).

#### Review of Related Research

Research on the use of games in mathematics education has been, generally, directed toward the junior high school student population. The majority of game treatments involved the student-student version of EQUATIONS. A substantial number of the studies were conducted by the game designer.

Allen, Allen, and Miller (1966) investigated possible changes in problem solving skills of junior high students resulting from play of WFF'N PROOF, a game of mathematical logic designed by Layman Allen. The experimental group was composed of 23 junior high students enrolled in a six-week summer session program; the control group was composed of 22 junior high students enrolled in the regular fall classes. The treatment consisted of play of WFF'N PROOF for 45 minutes of a two hour class per day, five days a week for the 29 days of the summer session program. The remaining time was devoted to reading and discussing the rules of the game and the underlying concepts. The experimental group was pretested and posttested with the California Test of Mental Maturity (Junior High Level, 1957 S-Form). Fall term, the non-comparable control group was given the same test twice with a six-week interval between the pretest and the posttest. The comparison of the change in non-language I.Q. score over the two administrations for the two groups using the t-test indicated a significant difference ( $p=.02$ ) favorable to the experimental group. Use of the pretest score for a covariate increased the significance ( $p < .001$ ). Variables competing with the treatment for significant difference effects included a classroom situation unlike an ordinary classroom situation, teacher differences, and variability in the administration of the tests. However, the fact that no significant difference was found in the language I.Q. score gains led the researchers to conclude the difference was due to learning from the game.

Allen, Allen, and Ross (1970) conducted a similar study comparing 43 junior and senior high school students playing WFF'N PROOF with 34 students enrolled in a pre-algebra course held during that same summer session. The treatment group played WFF'N PROOF exclusively for three weeks, four hours a day, five days a week in a tournament style. Tournaments were begun with a hierarchy of game tables in which students were matched initially by the teacher. As the games were played, losers were bumped down one table and winners up one table after each session of play. The control group, a pre-algebra class taught by a different teacher, was pretested and posttested on the same dates as the experimental group using the California Test of Mental Maturity. As with the previous study, the t-test yielded a significant difference for the non-language gain scores ( $p < .01$ ) and no significant differences in the language gain scores. The researchers claimed the combination of these two studies pointed toward justified optimism about the efficacy of nonsimulation games.

Henry (1974) used EQUATIONS and TAC-TICKLE to determine if use of mathematics games in a seventh grade classroom significantly improved attitudes toward mathematics and cognitive abilities. Nine intact classes from three different junior high schools constituted the sample. One class from each school played EQUATIONS; one class from each school played TAC-TICKLE; and, one class from each school provided the control. At each school only one teacher was involved with the three classes from that school. Treatment consisted of playing the games for half the class period, every other day for six

weeks; conventional instruction was used during the remaining time. All classes were pretested and posttested using Dutton's Attitude Scale and the Quantitative and Nonverbal Batteries of the Cognitive Abilities test. Analysis of the gain scores revealed no significant differences among the games and non-game groups.

Allen and Ross (1974) used the game EQUATIONS and Instructional Math Play (IMP) Kits when studying student's ability to solve computation and reasoning problems. Eighth grade students who had played EQUATIONS during the prior two years as part of their regular instruction intensively worked for two weeks with the IMP kits. Effects were measured by two different forms of investigator-designed problems; one form was directly related to the game EQUATIONS. Skills in applying mathematical ideas had significantly improved for the students using the combination of EQUATIONS and the IMP kits.

Teams-Games-Tournament Model. The game EQUATIONS has been studied extensively in a classroom model entitled Teams-Games-Tournament (TGT). The TGT Model was structured around simple nonsimulation games. Students were assigned to four-member teams so that intra-team variability with respect to achievement was maximized and inter-team variability was minimized. The game-tournament procedure was structured so that students competed only with classmates of comparable achievement levels. Game playing tables were established according to the hierarchy of abilities; a game was played at each table by students from each of the different teams at that level. After the game session, losers were bumped down one table and winners up one table. At the end of each day of the tournament, points were

awarded to each student according to his standing during that day's play. The sum of team member's points represented the team's standing in the tournament.

Edwards, DeVries, and Snyder (1972) studied mathematical achievement effects of the combined TGT structure and the nonsimulation game EQUATIONS. The sample consisted of four intact seventh grade general mathematics classes (two low ability and two average ability, n=96) taught by the same instructor. The control group, one low- and one average-ability class, was exposed to the traditional instruction of lectures, drills and quizzes for nine weeks. The matched experimental group played EQUATIONS twice a week in the TGT structure along with the traditional instruction for the same nine-week period.

Both groups were pretested and posttested with the computations subtest of the Stanford Achievement Test in Mathematics and a divergent solutions test designed by the researchers. The divergent solutions test required a skill similar to that used in playing EQUATIONS. A subset of the items on the computation subtest related to the content of the game was also used.

Results of the three measures of achievement indicated significantly greater gains for the experimental group on all three. Additionally, a treatment-by-ability analysis on the divergent solutions test revealed the low ability experimental group gained significantly more than the low ability control.

Edwards and DeVries (1972) used 117 seventh grade students in a 2x2x3 randomized block design to investigate the independent and combined effects of a learning game, EQUATIONS, and TGT procedures on

students' attitudes and achievement in mathematics. The three factors of the design were task (game versus quiz), reward (team versus individual), and ability (low, middle, high). Students were stratified according to ability and then randomly assigned into the four other treatments. The treatments lasted four weeks, two days per week, one period per day.

For mathematics achievement the computations test showed a main effect for student ability. Results of the divergent solutions test indicated the games classes scored significantly ( $p < .05$ ) higher than the quiz classes although no significant difference was found on the mathematics computation test.

Four attitude measures, math class interest, attending class, receiving newsletters, and working with others, revealed game classes were more positive towards their classes than quiz classes. Low and average ability students in the TGT classes were more positive toward their classes than students in the individual reward classes; however, the reverse was true for the high ability students.

DeVries and Edwards (1973) used classroom observation data to assess effects of the game, EQUATIONS, student teams, and the games-teams combination in seventh grade mathematics classes for four weeks. They reported both the games treatment and teams treatment resulted in greater peer tutoring. Students in the games treatment perceived the classroom as satisfying, less difficult and less competitive. However, the teams created more competition but with greater perceived mutual concern. The games-teams combination resulted in greater peer tutoring than either games or teams alone.

Edwards and DeVries (1974) again using the game EQUATIONS examined the effects of a scoring variation and a noncompetitive form of the TGT model. Better players received more points than poorer players to provide the scoring variation. These weighted scores were used in the TGT model without the competition among teams. The sample consisted of 128 seventh grade students. For twelve weeks the treatment group practiced two days a week and played the game one day a week. Students playing the game scored significantly better than the control on the divergent solutions test whereas there was no significant difference on a typical computations test. The TGT variations produced no significant effects.

Allen and Main (1973) focused on the affective domain of instructional gaming. Using the game EQUATIONS and the TGT structure, they measured the students' attitudes towards the class by the absentee rate. The mean absentee rate in the nongame classes was significantly higher than that in the games classes. The researchers assumed absenteeism was directly related to students' attitudes towards the class in an inner city urban school in Detroit.

DeVries (1976) summarized the research using the TGT model. He claimed the results consistently showed more positive effects on achievement than on attitudes. However, achievement effects were most often measured by divergent solutions tests which were biased in favor of students playing EQUATIONS. Attitude effects of EQUATIONS were also viewed as more positive for the games students but were essentially investigated at the seventh and eighth grade levels.

EQUATIONS Variations. Variations with the game EQUATIONS have also been studied. Allen, Jackson, Ross, and White (1978) investigated the effect of a scoring variation on achievement in learning mathematics. The 4+ Scoring Method was used to channel attention upon specific mathematical concepts in conjunction with EQUATIONS. The sample consisted of two intact eighth grade classes at a suburban school and two intact seventh grade mathematics classes at an urban school. Both the control group and the experimental group at each school engaged in an EQUATIONS tournament once a week and had regular classes the other four days. However, the experimental classes used the 4+ Scoring Method. The effects of the scoring method were measured by four specially designed pretests and posttests (easy C-test, easy R-test, hard C-test, hard R-test). The differences in gain scores between the 4+ Scoring classes and the control classes were weakly significant on the easy tests ( $p < .10$ ); but, they were strongly significant ( $p < .003$ ) on the hard tests which were content specific to the 4+ Scoring Method.

Allen, Bangert, and Rycus (1979) proposed another variation for evaluation. They suggested a snuffing version of EQUATIONS might produce more achievement gains than the standard version. The snuffing version encouraged players throughout the course of the game to reveal to other players the mathematical ideas being considered in seeking to win. The game designers have currently designed and scheduled research with this version.

Computer Games. Layman Allen created a computerized version of EQUATIONS. However, no research has considered this variation of the

game. In fact little research has considered mathematical computer games. What research has been completed with computerized gaming in mathematics has studied computer-assisted learning where the game was used for motivation and not teaching. For computer-augmented learning where mathematical concepts are interwoven within a game, no studies were found.

Peelle (1971) used two NIM variants which were adapted to an interactive computer system. Fifth and sixth grade students selected the game-playing level for the machine opponent and then competed with that opponent. Comprehensive performance data were gathered on-line in order to measure differences in the effectiveness of the games. No significant differences were found.

Weusi-Puryear (1975) investigated whether the motivational effect of computerized games in mathematics practice was enough to significantly increase student achievement. Eight- to eleven-year old students ( $n=258$ ) were randomly assigned in equal numbers to three treatments; computerized tutorial interwoven with a simulated Tic-Tac-Toe game, and a control. Mathematics concepts were elementary arithmetic. Students in the games/tutorial group were given arithmetic problems to solve. Problems solved correctly resulted in the opportunity to make a move on a tic-tac-toe board; incorrect answers resulted in a lost turn. Analysis of pretest and posttest data identified the achievement of the games/tutorial group to be significantly better than the other two groups even though they needed fewer exercises to achieve the results.

McCann (1977) explored the use of two games designed for the PLATO IV system in teaching mathematics skills to students at a naval electronics school. The games were used as a motivational technique as in the Weusi-Puryear study. A comparison of two games, speedway and tug-of-war, to conventional computer-assisted mathematics drill and practice sessions was made on a random assignment of 48 students into two of the six combinations of games and regular practice. No significant differences were found in achievement or training time between conventional practice and game practice. However, questionnaire data indicated students experiencing both conventional practice on one task and game practice on another task preferred the game practice.

#### Summary

The literature review revealed several forces directing the rise of educational gaming. Recognition of the value of play in human development and cognitive development, promotion of learning theories conducive to game learning, developments in game theory and computer technology, plus a long and rich history of war games helped to shape the current educational games paradigm.

The educational games paradigm suffered from misconceptions and inconsistencies in terminology; but, understanding of fundamental terms - play, game, and simulation - gave meaning to the different types of educational games. Rationale for implementing games in the classroom emphasized the need for active involvement in the learning process, a need for experiential learning, a need for more process-

oriented education than product-oriented training. Implementation of games as learning aids created biased enthusiasm based on anecdotal, optimistic, and impressionistic data. Few considerations of the limitations of the paradigm were available. Two problems were identified as needing further consideration, the psychological effects of losing and the over-emphasis on winning.

Review of the research on games in the mathematics classroom suggested mathematical games, such as EQUATIONS, improved attitudes toward mathematics and increased achievement. However, much of the research was directed by the game designer, dealt with middle school age students, considered student-student play of the game. No research evidence was found dealing with computer games in the computer-augmented learning mode.

### III. THE STUDY

This chapter presents the methods and design of the study in the following main sections: (1) The Games, (2) The Hypotheses, (3) The Measuring Instruments, (4) The Experiment, (5) Statistical Analysis of the Data, and (6) Summary.

#### The Games

The problem was to determine if mathematical computer games, included as a teaching aid in addition to regular instruction in a university entry-level intermediate algebra course, would significantly (1) increase student achievement in algebra, and (2) improve students' attitudes toward mathematics. Two games, POE and EQUATIONS, were selected as the mathematical computer games for the study.

Layman Allen, Professor of Law and Research Scientist at The University of Michigan, originally created the game EQUATIONS for student-student play. In 1978 and 1979 he completed a computer version of EQUATIONS and created an accompanying game, POE. The games were programmed in the BASIC computer language for a Prime 300 mini-computer located at the Mental Health Research Institute at the University of Michigan.

In January 1979, Allen granted permission to transfer the computer programs to Oregon State University for use in research with the entry-level intermediate algebra course.

Preparation of POE and EQUATIONS to run on the Oregon State University CDC CYBER 73 computer required a considerable language conversion. The Research and Instruction Group at the Oregon State University Computer Center converted these programs to the CYBER with financial support from Unsponsored Research Funds awarded by the Dean of Research. Conversion was completed January 1980.

EQUATIONS is a nonsimulation mathematical game in which the algorithms of dealing with the fundamental operations of mathematics are incorporated into the rules of the game. Throughout the game, students are encouraged to explore the mathematical operations by experimenting with alternative solutions. Playing the game also requires attention to the mathematical rules in order to successfully complete (win at) the game.

The computer version of EQUATIONS provides an occasion for a student to play against a computer opponent rather than another student. The program contains 19 progressive units designed to give the student experiences in a game setting in dealing with fundamental mathematical operations - addition, subtraction, multiplication, division, involution, and evolution. A comprehensive outline of the 19 units is in Appendix A. Each unit contains several playing kits dealing with a specific set of mathematical concepts.

Before playing any kits in a unit, the student responds to a set of ten diagnostic questions. The first five questions are referred to as C-type items. For these items, students apply the operations to a given problem. The remaining five problems are of the R-type, more representative of the skills needed in playing the

game. For these items the student is given a set of resources including numerals and operational signs. Using all of these resources, the student must devise an arithmetic expression which equals a given goal. A comparison of each type of item is made in Figure 1.

	C-TYPE	R-TYPE
ITEM	$6 \times 9 + 5 = \underline{\quad}$	Goal = 9 Resources: + x 0 3 3
SOLUTION	59	$3 \times 3 + 0$

Figure 1. C-type and R-type items and solutions for diagnostic questions.

Student's responses to these questions determine the playing kits the student is to play from that particular unit. The student records the suggested kits on a Diagnostic Summary Sheet. Appendix B contains a sample set of diagnostic questions and a Diagnostic Summary Sheet.

In playing a kit the student may not encounter the concepts intended in that kit. In that case the computer program prompts the player to replay that kit using a different strategy. Therefore, students may replay certain kits several times and other kits only once.

In the student-student version of EQUATIONS, a throw of special dice-like cubes indicates the resources (numerals and operational symbols) available in a particular game. However, in the computer

program students are presented with predetermined resources which may be used to attain a specified goal. The computer program begins the game by displaying these resources, the mat, and the goal. Figure 2 depicts a sample initial display which begins the play of the game.

RESOURCES; + - X X 0 0 3 4 5 7 9		
FORBIDDEN	PERMITTED	REQUIRED
-----		-----
	SOLUTION	GOAL = 28

Figure 2. Sample display for beginning play of EQUATIONS.

Resources moved to the forbidden area of the mat may not be used in the solution. Resources moved to the permitted area may or may not be used in the solution; players are allowed to use those resources in their solution, but they do not necessarily have to use them. Resources moved to the required area must be used in any solution to the goal. The goal represents one side of the equation; the solutions represent the other side of the equation and, thus, must equal the goal.

The student begins play of the game in one of two possible ways:

1. Declaring a resource as permitted, forbidden, or required.
2. Challenging that the set goal is not attainable from the resources or the set goal is attainable in the next move.

In the event the student does not challenge (i.e., declares a resource), the play turns to the computer opponent. The computer opponent makes a play in a similar manner by either declaring a resource or challenging. Play continues until a challenge is made or a Force-Out is declared.

The following four types of challenges may be made:

1. P-Flub: challenges that the last move made the goal impossible;
2. A-Flub: challenges that the last move allowed a solution in one more move;
3. CP-Flub: challenges that the last player failed to challenge a prior P-Flub; and
4. CA-Flub: challenges that the last player failed to challenge a prior A-Flub.

A Force-Out is declared when a player is "forced" to allow a solution by placing one more resource on the playing mat. If the force-out declaration is correct, the game ends in a draw. When games are perfectly played to the end, they will always end in a draw. Thus, to win a game, a player must correctly challenge the opponent's mistake or be incorrectly challenged by the opponent. In essence, the game is a game of challenges in which strategies involve understanding of mathematical concepts. Appendix C contains a sample EQUATIONS match.

To prepare potential players for EQUATIONS, Allen created POE, a strategy game specifically designed to introduce students to computer game playing and teach them the rules for playing EQUATIONS.

Two versions of POE introduce the student to the rules in a piece-meal fashion. The first version, FP-POE, uses only forbid and permit declarations while the second version, FPR-POE, uses forbid, permit, and require declarations. Play of POE uses the same challenges as EQUATIONS. After the student is sufficiently competent in the play of POE and the use of the computer, EQUATIONS can be played without a large number of initial difficulties created by new rules.

POE is played on a three-by-three mat called a network. Figure 3 displays the network as it appears on the computer terminal. The goal is described in terms of the number of connections. A connection refers to three touching squares which are either permitted or required and which connect the left side of the mat to the right side or the top of the mat to the bottom. The goal may be set as either even or odd, referring to either an even number of connections or an odd number of connections. After the goal is set, the player and the computer take turns placing F's (for Forbidden), P's (for Permitted), or R's (for Required) in the vacant squares until, as in EQUATIONS, either the player or the computer challenges or declares a force-out. Appendix D contains sample matches for each version.

1	2	3
4	5	6
7	8	9

Figure 3. POE network of squares.

Essentially, the games, POE and EQUATIONS, were selected for the following reasons:

1. Most students were not familiar with the computer or the games. With more common games the experiment would have been difficult to control.
2. Both games were designed so that students were able to play with a minimum of assistance in understanding the computer and the play of the games.
3. POE provided an opportunity to learn to use the computer and to learn the rules to EQUATIONS, simplifying the introduction to EQUATIONS.
4. EQUATIONS provided opportunities to actively manipulate the ideas incorporated in the algebra class.
5. EQUATIONS was designed to encourage favorable attitudes toward mathematics.

#### The Hypotheses

The purpose of this study was to investigate some of the educational claims for mathematics games, POE and EQUATIONS, when applied to the university entry-level intermediate algebra course.

The major hypotheses, stated in the null form, were as follows:

- $H_1$ : There is no significant difference in the mean achievement of students in a university intermediate algebra course that includes interaction with computer games and students in a university intermediate algebra course without interaction with computer games.

H<sub>2</sub>: There is no significant difference in the mean attitude of students in a university intermediate algebra course that includes interaction with computer games and students in a university intermediate algebra course without interaction with computer games.

Three minor hypotheses were also tested. Measures for each of these hypotheses were subsets of the achievement test.

H<sub>1.1</sub>: There is no significant difference in the mean achievement in simplifying algebraic expressions of students in a university intermediate algebra course that includes interaction with computer games and students in a university intermediate algebra course without interaction with computer games.

H<sub>1.2</sub>: There is no significant difference in the mean achievement in solving problems with a given equation of students in a university intermediate algebra course that includes interaction with computer games and students in a university intermediate algebra course without interaction with computer games.

H<sub>1.3</sub>: There is no significant difference in the mean achievement in solving problems requiring creation of the algebraic equation of students in a university intermediate algebra course that includes interaction with computer games and students in a university intermediate algebra course without interaction with computer games.

### The Measuring Instruments

Equivalent forms of an intermediate algebra course final achievement examination and Dutton's Attitude Scale were selected as the measuring instruments for this study.

#### The Achievement Examinations

Since the question of achievement concerned achievement in terms of the objectives of the intermediate algebra course at the university, equivalent forms of the final examination for the course were prepared by the instructor for the course, J. Michael Shaughnessey. After the preparation of the examinations, a panel, composed of three additional intermediate algebra instructors, judged the examinations to be consistent with the objectives of the course and judged the two examinations to be equivalent.

The examination which was used as the posttest was subdivided into three areas of questions: simplifying algebraic expressions; solving problems with a given equation; and solving problems requiring creation of the algebraic equation. The scores for each of these subsections were found in order to determine if student abilities in special areas of the course were affected by the games interaction.

#### Dutton's Attitude Scale

The instrument used to measure student's attitude toward mathematics was Dutton's Scale for Measuring Attitudes Toward Mathematics.

Aiken (1970) indicated this scale was used more frequently than any other scale to measure attitudes toward mathematics.

The scale is a 15-item, Likert-type instrument consisting of a variety of statements expressing positive and negative attitudes toward mathematics. Dutton created this scale in 1962 as a revision of the most discriminating items from his earlier Thurston-type scale. Although originally the scale was designed to measure attitudes of prospective elementary teachers, it has been administered to students at all levels, elementary, secondary and post-secondary. Dutton and Blum (1968) reported the scale to have a reliability of 0.90.

Through personal correspondence with Dutton (1979), permission was received to use the scale in this study. Dutton suggested the inclusion of two additional items to serve as a check that students responded seriously to the items. These items requested the students to list two things they liked most about mathematics and two things they liked least about mathematics. Since the word "arithmetic" often depicts a pre-algebra notion, Dutton granted the substitution of the word "math." This substitution was made to eliminate any ambiguity, to connote the entire field of mathematics, and therefore, to provide a more accurate measure of students' attitudes toward mathematics. This substitution has been made repeatedly in studies using the scale which were attempting to measure attitudes toward mathematics (Callahan, 1971; Henry, 1974; Morgan, 1979). Furthermore, the literature indicated that these two words have been used synonymously.

The revised attitude scale is presented in Appendix E. Scale-values for each item have been added to show the weighted values used in scoring the instrument.

### The Experiment

Permission was received from the Mathematics Department at Oregon State University to conduct the study during winter term, 1980.

Detailed descriptions of the design and procedures are presented in the following sections: Population, Experimental Design, Procedure, and Data Collection.

#### Population

The population for the study consisted of students enrolled in the large lecture-recitation section of Mth 95: Intermediate Algebra I at Oregon State University, winter term, 1980. Mth 95 is a four quarter hour credit course described in the 1979-1980 Oregon State University General Catalog as: "Review of elementary algebra. Exponents, simultaneous linear equations and inequalities, factoring quadratics, fractional expressions and equations. This course presupposes some high school algebra" (p. 92). In the large lecture-recitation section of Mth 95, students attended three 50-minute lectures per week (totaling 28 sessions for the term) and one 50-minute recitation class per week (totaling nine sessions for the term). All tests, except the final examination, were administered in the Mathematical Sciences Learning Center (MSLC); students selected their own time for testing within deadlines. Unit tests were of the mastery

type and could be retaken in an alternate form if the student wished to do so. The final examination was administered as a two-hour group final at a specified time during the final week.

One hundred forty-five students enrolled in this course at pre-registration fall term or on registration day of winter term. According to the instructions of the Human Subjects Committee, Oregon State University, students were informed the first day of class that testing of different instructional methods was to be conducted during the term in the large lecture-recitation section of Mth 95. Students who did not wish to participate were allowed to transfer to another section. Two students elected to change sections after the first class; thus, the class list on the first class day contained 143 names. Due to the normal adding and dropping of classes during the first three weeks of the term, only 89 of the 143 students enrolled the first day remained in the class after the third week. These 89 students formed the sample for the study.

Students in the large lecture-recitation section of Mth 95 were specifically selected as subjects for the following reasons:

1. The students were enrolled in the entry-level mathematics course at the university, a course for which many were unprepared but were required to take for graduation.
2. The students enrolled in the only large lecture-recitation section offered for this course, where the instructor was listed as "Staff."

3. One instructor conducted all lectures for these students. One instructor conducted all recitation groups for this course.

### Experimental Design

The experimental design selected for this study was the Solomon Four-Group Design as described by Campbell and Stanley (1963). Within this design, students on the class list were randomly assigned to four groups which varied as follows:

1. The first group received the pretests for attitude and achievement, the games treatment, and the posttests for attitude and achievement;
2. The second group received the pretests and posttests for attitude and achievement but not the games treatment;
3. The third group received the games treatment and posttests for attitude and achievement but not the pretests; and
4. The fourth group received only the posttests for attitude and achievement.

Figure 4 represents a pictorial model of this design.

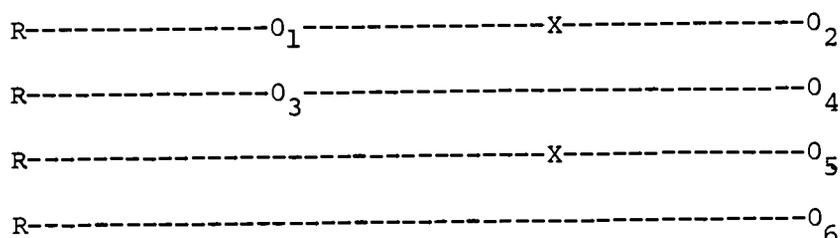


Figure 4. A diagram representing the Solomon Four-Group Design. R refers to randomization; X refers to the mathematical games treatment;  $O_1$  and  $O_3$  represent pretest measures on achievement and attitude;  $O_2$ ,  $O_4$ ,  $O_5$ ,  $O_6$  represent posttest measures on achievement and attitude.

This design was selected since it not only controlled for the effects of pretesting but also measured that effect. By paralleling pretested treatment and pretested control groups with unpretested treatment and unpretested control groups, both the main effect of pretesting and the interaction of pretesting with the treatment were measurable.

Since the university entry-level mathematics course consisted of a heterogeneous population in terms of previous mathematics achievement, information was needed to adjust for initial differences among the groups. Research has shown that aptitude measurements are highly correlated with mathematics achievement. The College Entrance Examination Board Scholastic Aptitude Test (SAT) was an aptitude examination which students took prior to leaving high school and entering college. The mathematics portion of this test provided a measure of the student's accumulated achievement in mathematics.

Approximately two-thirds of the students entering Oregon State University have taken the SAT. To use the scores of those students who had taken the test the sample population was stratified into two groups before randomly selecting the experimental and control groups: (1) students with SAT scores, and (2) students without SAT scores.

From each of these strata two experimental groups (a pretested experimental and an unpretested experimental) and two control groups (a pretested control and an unpretested control) were randomly selected. Initially, the 143 students who enrolled in the course on the first day of class were randomly assigned to the four groups. By the end of the third week of classes, only 89 of these 143 students

remained enrolled in the course. Therefore, the groups contained unequal numbers. Table 1 represents the stratified distribution of the 89 subjects in the four groups.

Table 1. Stratified distribution of subjects in the Solomon groups.

	Students with SAT	Students without SAT	Total
Pretested Experimental	11	8	19
Pretested control	16	8	24
Unpretested Experimental	15	7	22
Unpretested Control	<u>13</u>	<u>11</u>	<u>24</u>
Total	55	34	89

The pretested experimental and pretested control groups were pretested during the first full week of classes. The achievement pretest and Dutton's Attitude Scale were administered in the MSLC. These instruments were not administered to the students as a group. Students selected the times to complete the instruments within specified times.

The experimental treatment began the second full week of classes with introduction sessions to the computer and POE. During the fourth full week of classes, students attended another introduction session for EQUATIONS. Students continued playing the games through the ninth week of classes. Therefore, the treatment time consisted of approximately eight weeks in which the first two weeks were devoted to POE and the remaining six weeks were devoted to EQUATIONS. Students in the experimental group interacted with the games

concurrently with the regular instruction, assignments, and tests for the algebra class. Students in the control group experienced the same instruction, assignments, and tests with no additional assignments.

The attitude posttest, Dutton's Attitude Scale, was administered to all students, control and experimental, in the MSLC during the ninth week of classes. As with all testing in the MSLC, students elected the time, within deadlines, to complete this instrument. All students, control and experimental, were posttested with the final achievement examination during the tenth week of classes. This instrument was administered as a group test in which all students began the test at the same time.

### Procedure

Prior to the beginning of winter term, a tentative class list of 116 students was composed from pre-registration information for Mth 95: Intermediate Algebra I. Available SAT scores were obtained through the Counseling Center. Following the first class meeting, a revised class list of 143 students was prepared. After comparing this list with the previous list, the remaining available SAT scores were obtained. Using the SAT information, the population was separated into two strata, students with SAT scores and students without SAT scores. Finally, experimental and control groups were randomly selected from each stratum.

Since the students were to receive varying assignments, depending upon the random group assignment, a communication file was

created for each student. These files were placed in the MSLC. Students were told to check their file on the third class day to receive their special assignments for the remainder of the term. Samples of the four different assignment sheets are contained in Appendix F.

Students in the experimental group were informed on the assignment sheet that they were to play two mathematical computer games throughout the term. As recommended by many game designers, briefing sessions were held to help the students fully understand what was expected of them while playing the games (Kerr, 1977). During the second full week of classes, three meetings were scheduled in order to provide a time for each student to attend and to keep the number of students per session under fifteen. These 50-minute meetings were conducted by a team composed of the researcher and two other graduate students. The meeting was held in a room containing 16 Infoton computer terminals. At this meeting students were told that they were to play two mathematical computer games at least one and one-half hours per week for the remainder of the term. Also, they were informed that they would receive recitation credit for this activity. The remainder of the meeting was devoted to the following:

1. instructing students in the use of the Infoton computer terminal;
2. instructing students in playing POE;
3. distributing computer time and numbers; and
4. answering any questions concerning the assignment.

Furthermore, as suggested by the game designer, students were given a written copy of the rules for POE clearly expressed in simplified

language. Appendix G contains a sample of the written material provided to the students during this session.

After the students in the experimental group had played POE for two weeks, a second briefing was conducted in an identical manner by the same team as in the first briefing. However, the purpose of this session was to introduce the students to play of EQUATIONS. For reference students were given a simplified written copy of the rules to EQUATIONS. They were also given a Diagnostic Summary Sheet on which they were to record the kits they played throughout the term. The Diagnostic Summary Sheet served as a cross-check with the amount of computer time used by the student to determine the efforts of the students during the term. Appendix H contains a sample of the material given to the students in this briefing session.

For the remaining six weeks students played EQUATIONS concurrently with the regular work for the algebra class. At the end of each week the amount of computer time used by each student was recorded; if students required more time, that amount was added to the account. Each student was allocated ten dollars worth of computer time per week throughout the term. At the end of the ninth full week of classes, the students returned their Diagnostic Summary Sheets to their file in the MSLC.

In summary the treatment in this study was not stand-alone mathematical computer games. As suggested by Layman Allen (1979) in personal correspondence,

Although the ideal would be for the computer program to do the entire job, it seems clear at this stage of

the development, a knowledgeable teacher presenting EQUATIONS at the outset will increase what the students are likely to get out of the experience.

Therefore, the treatment being tested was mathematical computer games supplemented with an initial introduction by a team already familiar with the games.

### Data Collection

As dictated by the Solomon Four-Group Design, two of the four groups were pretested with the attitude pretest and the achievement pretest - the pretest experimental group and pretest control group. The assignment sheet for the students in these groups indicated they were to complete Dutton's Attitude Scale (color-coded blue). They were instructed to request the "Blue Data Check" from their file, complete the check in the testing area of the learning center, and return the completed form to the testing desk. These students were expected to complete this check within two days (Wednesday and Thursday of the first full week of classes). Upon completion of the attitude check, the students were expected to take the achievement pretest (color-coded white). They were told to request the "White Data Check" from their file in the testing area, complete the check in the testing area, and return the completed form to the testing desk. This data check was to be completed within two days (Thursday or Friday of the first full week of classes) after completion of the attitude pretest.

The posttest attitude inventory, Dutton's Attitude Scale, was administered during the ninth full week of classes. Students in all

four groups were informed through their assignment sheets that they were to request the "Yellow Data Check" from their file, complete the inventory in the testing area of the learning center, and return it to the testing area. As with the pretest in the learning center, all the students were given a two-day time frame in which to complete this check (Tuesday or Wednesday of the ninth full week of classes).

The achievement posttest was administered as a group examination. All students included in the study took this examination on Wednesday of the tenth full week of the term. Approximately eight weeks elapsed from the pretest to the posttest attitude measures. However, approximately nine weeks elapsed from the pretest to the posttest achievement measures.

The instructor for the large lecture-recitation section prepared the keys and point scale for the pretest and posttest achievement instruments. The researcher used this information to score the pretest. The instructor for the course scored the posttest achievement instrument. The researcher obtained the subtest scores for the posttest achievement instrument by summing the points awarded by the instructor for questions in each subset. The subset questions and possible total score for each subset are indicated in Table 2. Using the weighting scale provided by Dutton, the researcher scored both the pretest and the posttest attitude scales.

In summary, the raw data consisted of six sets of observations for measuring mean achievement difference (hypothesis one), six sets of observations for measuring mean attitude differences (hypothesis two). The data for the four sets of achievement posttest were also

Table 2. Achievement subtest questions and total scores possible.

Subtest identification	Questions from examination	Possible score
Simplifying algebraic expressions	1, 4, 6, 8, 13	30
Solving problems with a given equation	3, 9, 10, 11, 12, 15 16, 17, 18, 23	83
Solving problems requiring creation of the algebraic equation	2, 5, 7, 14, 19, 20, 21, 22	87

subdivided into the three subtest scores: simplifying algebraic expressions, solving problems with a given equation, solving problems requiring creation of the algebraic equation. SAT scores were available for approximately two-thirds of the sample population.

#### Statistical Analysis of the Data

At the conclusion of the experiment the data were summarized and keypunched in preparation for statistical analysis on the CDC CYBER 73 computer at Oregon State University. The Statistical Package for the Social Sciences (SPSS) was used to analyze the data.

Hypothesis one stated that no significant difference existed in mean achievement between the games treatment group and the control group. Hypothesis two stated that no significant difference existed in mean attitude toward mathematics between the games treatment group and the control group. The hypotheses were analyzed separately using the same procedures. The Solomon Four-Group Design was used in order to measure the actual effect of the pretest on the experimental games

treatment. A single statistical procedure was not available to analyze simultaneously all six sets of observations for each hypothesis. Therefore, a two-stage analysis was used.

Initially, the data for each main hypothesis were analyzed using a two-by-two analysis of variance of the posttest scores. This analysis treated the pretest scores as another treatment coordinate with the games treatment. The posttest mean scores were arranged in a two-way classification; using these means, row means and column means (marginals) were calculated. Figure 5 indicates the arrangement of the posttest means for the analysis.

	<u>No games treatment</u>	<u>Games treatment</u>	<u>Row means</u>
Pretested	0 <sub>4</sub>	0 <sub>2</sub>	
Unpretested	0 <sub>6</sub>	0 <sub>5</sub>	
Column means			

Figure 5. Two-way classification of posttest mean scores for calculating column and row means.

In the two-by-two analysis of variance the calculated column means were compared to estimate the main effect of the games treatment; the calculated row means were compared to estimate the main effect of pretesting; and, the cell means were compared to estimate the interaction of pretesting with the games treatment.

Negligible interaction effects of the pretest with the games treatment suggested a second analysis, an analysis of covariance of

$O_4$  versus  $O_2$ . This technique combines the features of analysis of variance and regression to provide adjustments for antecedent differences between groups. The pretest scores served as a covariate accommodating for initial differences. Analysis of covariance was also used to analyze the differences between the SAT pretest-posttest groups. In this case the pretest scores and the SAT scores (both SAT-M and SAT-V) served as covariates in the analysis of  $O_4$  versus  $O_2$ .

The achievement subtest data were analyzed using Students' t-test. These t-tests measured the differences in mean subtest scores between the combined pretested and unpretested experimental groups and the combined pretested and unpretested control groups.

#### Summary

This study was conducted to determine if mathematical computer games included as a teaching method in addition to regular instruction in a university entry-level intermediate algebra course significantly increased student achievement in algebra and improved students' attitudes toward mathematics. POE and EQUATIONS were selected as the mathematical computer games for the study. The Solomon Four-Group Design was chosen for the experimental design. Equivalent forms of the course achievement examination measured the students' achievements; Dutton's Attitude Scale measured the students' attitudes toward mathematics. Students in the large lecture-recitation section of Mth 95: Intermediate Algebra I at Oregon State University, winter term, 1980, were randomly assigned to the four

groups. Students in the experimental groups were trained to use the computer and play POE and EQUATIONS in short training sessions. After playing POE for two weeks, students played EQUATIONS for the remaining six weeks of the term. Analysis of the data included an initial measurement of the pretest effect by a two-by-two analysis of variance. Negligible interaction effects of the pretest with the treatment suggested an additional test, analysis of covariance, in which the pretest scores and SAT scores were used as covariates. This chapter presented detailed discussion of the methods and procedures used in the study.

#### IV. RESULTS OF THE STUDY

This chapter presents the findings of the study. The first section deals with the findings related to the major and minor hypotheses. The second section presents additional findings not directly related to the hypotheses.

##### Findings Related to the Hypotheses

##### Hypothesis One

The null form of hypothesis one stated that no significant difference existed between the mean achievement of students interacting with the mathematical computer games, POE and EQUATIONS, and the mean achievement of students not interacting with the games. Three minor hypotheses dealt with subset scores on the achievement posttest: simplifying algebraic expressions, solving problems with a given equation, and solving problems requiring creation of the algebraic equation. These hypotheses stated, in the null form, that no significant difference existed in these specific skill areas between the experimental and control groups.

The test of the major hypothesis required a two stage analysis. Initially, a two-by-two analysis of variance compared the posttest achievement scores of the four Solomon groups considering the achievement pretest as another treatment coordinate with the games treatment. Table 3 presents the F-values for this test.

As indicated by the probability levels in Table 3, the effects of the games treatment alone and the achievement pretest alone were not

Table 3. Two-by-two analysis of variance measuring achievement effects of pretesting and games treatment.

Source of variation	d.f.	F-values for measurement variables	Probability levels
<b>Main effects</b>			
Games treatment	1	.07	.80
Achievement pretest	1	.72	.40
Interaction effects	1	2.93	.09
Residual	85		

significant at the .05 level. The F-value of 2.93 for the interaction effect of the achievement pretest with the games treatment was not significant at the .05 level but indicated an unexpected trend. The result is discussed in the comparisons of the group means (see page 105).

Since the interaction and main effects of pretesting were not significant at the .05 level, the achievement posttest means for the pretested groups (n=43) were compared using an analysis of covariance. The achievement pretest scores provided the covariate, adjusting the posttest achievement means for initial differences. Table 4 presents the results of this analysis of covariance.

Table 4. Analysis of covariance using achievement pretest scores as the covariate.

Source of variation	d.f.	F-values for measurement variables	Probability levels
<b>Covariate</b>			
Achievement pretest	1	3.56	.07
<b>Main effects</b>			
Games treatment	1	2.88	.10
Residual	40		

Results of the analysis of covariance indicated that after an initial adjustment with the achievement pretest scores (the covariate), the games treatment was not significant at the .05 level. The probability level of .10, however, suggested a trend in these data. The apparent trend was discussed further in the analysis using the SAT data (see page 108). In essence these data failed to show that the mathematical computer games, POE and EQUATIONS, increased student achievement at the .05 level.

The statistical procedure for testing the three minor achievement hypotheses was Students' t-test. As was shown in Table 3, the main and interaction effects for the achievement pretest were negligible. Thus, data from the pretested experimental and unpretested experimental groups were combined to comprise the data for the experimental group for these tests (n=41); data from the pretested control and unpretested control groups were combined to form the data for the control group (n=48). Results of the t-test are presented in Table 5.

Achievement subscore one referred to the student's skill in simplifying algebraic expressions; achievement subscore two referred to the student's skill in solving problems with a given equation; and, achievement subscore three referred to the student's skill in solving problems requiring the creation of the algebraic equation. The differences in means for subscore two and subscore three favored the games treatment group. However, results of the t-tests indicated none of the achievement subscores was significant at the .05 level. Therefore, these data failed to demonstrate that the mathematical computer games, POE and

EQUATIONS, increased achievement in the predetermined specific skill areas.

Table 5. Achievement subscore means and results of individual t-tests for achievement subscores.

Source of variation	Mean	t-value (d.f. = 87)	Probability level
Achievement subscore 1			
Experimental	19.76	-1.01	.31
Control	21.38		
Achievement subscore 2			
Experimental	64.32	.28	.78
Control	63.23		
Achievement subscore 3			
Experimental	57.15	.66	.51
Control	54.15		

### Hypothesis Two

The null form of hypothesis two stated that no significant difference existed between the mean attitude toward mathematics of students interacting with the mathematical computer games, POE and EQUATIONS, and the mean attitude of students not interacting with the games. The analysis for this hypothesis involved two stages similar to the analysis for hypothesis one.

The two-by-two analysis of variance compared the posttest attitude scores of the four Solomon groups considering the attitude pretest as another treatment coordinate with the games treatment. This test involved attitude measurements on 65 students rather than the 89 students considered for hypothesis one. Three students failed to complete

the pretest in the MSLC as instructed; twenty students failed to complete the posttest; one student failed to complete either the pretest or the posttest. F-values resulting from this test are presented in Table 6.

Table 6. Two-by-two analysis of variance measuring attitude effects of pretesting and games treatment.

Source of variation	d.f.	F-values for measurement variables	Probability levels
Main effects			
Games treatment	1	.09	.77
Attitude pretest	1	3.69	.06
Interaction effects	1	.17	.69
Residual	61		

As indicated by the probability levels in Table 6, the main effects of both the games treatment and the attitude pretest were not significant at the .05 level. However, the .06 probability level for the main effect of attitude pretesting was an interesting result. This result is considered in detail with the comparisons of the group means (see page 105).

Lack of significant pretest effects permitted additional testing of the hypothesis using an analysis of covariance. This test compared the attitude posttest means of the pretested control and pretested experimental groups (n=33). The attitude pretest scores provided the covariate, adjusting for initial differences in attitude toward mathematics. The results of this analysis of covariance are presented in Table 7.

Table 7. Analysis of covariance using attitude pretest scores as the covariate.

Source of variation	d.f.	F-values for measurement variables	Probability levels
Covariate			
Attitude pretest	1	10.668*	.003
Main effects			
Games treatment	1	.056	.814
Residual	30		

\*Significant,  $p < .01$

Table 7 indicates that the covariate, the attitude pretest, was significant beyond the .01 level, whereas the main effect of the games treatment was not found to be significant at the .05 probability level. In other words, the attitude pretest was a significant predictor of the attitude posttest score. These data did not provide evidence that the mathematical computer games, POE and EQUATIONS, improved student attitudes toward mathematics.

#### Findings Not Directly Related to the Hypotheses

This section of the chapter presents findings which were not directly related to the hypotheses but helped to more accurately interpret the results of the analysis for the hypotheses. The additional information includes mean comparisons for achievement and attitude, analysis with SAT data, and correlation data.

### Mean Comparisons

According to the design of the study, students were randomly assigned into four groups. Achievement posttest mean scores were obtained from the four groups. A two-way classification of the posttest achievement means was used to calculate the column and row means (marginals) for the analysis of the major achievement hypothesis. The two-way classification including group sizes is depicted in Table 8.

Table 8. Two-way classification of achievement posttest means with marginals.

	No-games treatment		Games treatment		Row means	
	n	mean	n	mean	n	mean
Pretested	24	136.08	19	153.00	43	143.56
Unpretested	24	143.50	22	131.05	46	137.54
Column means	48	139.79	41	141.22		

Comparison of the row means listed in Table 8 favored the pretested groups, suggesting an achievement pretest main effect. However, the statistical analysis (see Table 3) showed this achievement pretest effect was not significant at the .05 level.

Comparison of the column means only slightly favored the games treatment group. Analysis of the comparison yielded no significant games treatment effect at the .05 level (see Table 3).

As indicated in the discussion of the two-by-two analysis of variance of the achievement posttest scores (see Table 3), an unexpected interaction trend was observed. Comparison of the cell means was used to estimate this interaction effect. Comparison of the posttest mean for

the unpretested, no-games group with the other cell means indicated an apparent interaction trend. The pretested, no-games group earned a lower posttest mean (136.80) than the unpretested, no-games group (143.50). These data suggested the pretest, without the games treatment, decreased the achievement posttest score. The unpretested, games group earned a lower posttest mean (131.05) than the unpretested, no-games group (143.50). These data suggested the games treatment, without the pretest, decreased the achievement posttest score. Yet, the pretested, games group earned a higher mean (153.00) than the unpretested, no-games group (143.50). These data suggested that the combination of the pretest with the games treatment increased the achievement posttest score. Thus, the trend for an interaction effect of the games and the pretest was observed.

An additional observation of the cell means presented another important aspect of these data. Comparison of the pretested groups favored a treatment effect. In fact, the statistical analysis (see Table 4), which compared these two pretested groups using the achievement pretest scores as the covariate, supported this trend ( $p=.10$ ). Yet, comparison of the two unpretested groups favored the no-games group. These two sets of data presented conflicting evidence concerning a games treatment effect. Further investigation of these data is presented in the analysis with the SAT data (see page 108).

Attitude posttest mean scores were also obtained from the four groups. A two-way classification of the posttest attitude means was used to calculate the column and row means (marginals) for the analysis of the attitude hypothesis. As previously indicated, the attitude

measurements included only 65 students since 24 students, who completed the achievement measurements, failed to complete either the attitude pretest or the attitude posttest. The two-way classification of the posttest means with group sizes is indicated in Table 9.

Table 9. Two-way classification of attitude posttest means with marginals.

	No-games treatment		Games treatment		Row means	
	n	mean	n	mean	n	mean
Pretested	18	5.93	15	5.64	33	5.80
Unpretested	15	4.97	17	5.02	32	5.00
Column means	33	5.50	32	5.31		

Comparison of the row means in Table 9 showed the mean attitude toward mathematics of the pretested groups was higher than the mean of the unpretested groups. Statistical comparison of these means measured the main effect of pretesting (Table 6). The results of this analysis, though not significant at the .05 level, indicated a strong likelihood ( $p=.06$ ) that the attitude pretest affected responses on the attitude posttest. Additional analysis, using the pretest as the covariate, supported the conclusion that the pretest was a significant predictor of the attitude posttest score (Table 7).

One possible explanation for the observed pretest effect could be that students, taking the attitude pretest, sensed a concern by the instructor for their feelings toward the subject. This feeling may have translated to a more favorable attitude toward mathematics as indicated by the posttest means for the pretested group.

Comparison of the column means favored the no-games groups. The statistical analysis of this comparison indicated the games treatment was not a significant main effect at the .05 level (Table 6).

Comparison of the cell means did not display an interaction effect of the attitude pretest with the games treatment. The mean for the pretested, no-games group (5.93) was higher than the mean for the unpretested, no-games group (4.97). This comparison suggested the pretest without the games increased the attitude posttest score. The mean for the unpretested, games group (5.02) was only slightly higher than the mean for the unpretested, no-games group (4.97). This comparison suggested the games, without the pretest, only slightly increased the attitude posttest score. The mean for the pretested, games group (5.64) was higher than the mean for the unpretested, no-games group (4.97); however, the increase was not as great as the increase observed between the two no-games groups. This observation suggested the increase was more likely a result of a main pretest effect than an interaction effect of the pretest with the games. Statistical analysis, indicated in Table 6, supported the observation of unlikely interaction effects.

#### Analysis Using SAT Data

As indicated in Chapter III, the sample population was stratified by students with SAT scores and students without SAT scores. Table 10 indicates the group sizes of the initial random assignment and the stratified distribution after the withdrawal date (end of third week).

The comparison in Table 10 indicates the enrollment on the first class day contained 143 students, 69 with SAT scores and 74 without SAT

Table 10. Group sizes for initial random assignment and stratified distribution at the end of the third week of classes.

	Initial	Final	Withdrew
<u>Number of students with SAT scores</u>			
Pretested experimental	17	11	6
Pretested control	17	16	1
Unpretested experimental	17	15	2
Unpretested control	<u>18</u>	<u>13</u>	<u>5</u>
Total	69	55	14
<u>Number of students without SAT scores</u>			
Pretested experimental	18	8	10
Pretested control	19	8	11
Unpretested experimental	18	7	11
Unpretested control	<u>19</u>	<u>11</u>	<u>8</u>
Total	74	34	40
<u>Total number of students</u>			
Pretested experimental	35	19	16
Pretested control	36	24	12
Unpretested experimental	35	22	13
Unpretested control	<u>37</u>	<u>24</u>	<u>13</u>
Grand total	143	89	54

scores. After the third week of classes, 89 students remained, 55 with SAT scores and 34 without SAT scores. This withdrawal rate was expected since many schedule adjustments were typically made until the withdrawal date at the end of the third week of classes. However, effects of students withdrawing were considered using SAT scores.

Since SAT scores were available for slightly less than two-thirds of the students in the remaining sample population, the questions of achievement and attitude toward mathematics were reconsidered by analysis of covariance using scores of students with SAT data. For the

comparison of achievement means, the achievement pretest, SAT-M, and SAT-V were used as covariates; for comparison of attitude toward mathematics means, the attitude pretest, SAT-M, and SAT-V were used as covariates. The results of these two tests are presented in Table 11.

Table 11. Analysis of covariance for attitude and achievement differences for pretested SAT strata.

Source of variation	d.f.	F-value for measurement variables	Probability levels
<u>Attitude Analysis</u>			
Covariates			
Attitude pretest	1	18.145*	.001
SAT-M	1	3.202	.095
SAT-V	1	2.423	.142
Games effects	1	.004	.948
Residuals	14		
<u>Achievement Analysis</u>			
Covariates			
Achievement pretest	1	.121	.731
SAT-M	1	9.692*	.005
SAT-V	1	.314	.581
Games effects	1	.057	.831
Residuals	22		

\*Significant,  $p < .01$

The results of the analysis of attitude means described in Table 11 were consistent with the results of the analysis for hypothesis two (see Table 6). These data also indicated the attitude pretest was a significant predictor of posttest scores ( $p=.001$ ) whereas the SAT covariates and the games effects were not significant at the .05 level.

This analysis provided additional support for the conclusion that the games did not significantly improve students' attitudes toward mathematics.

The results of the achievement data analysis using the achievement pretest and the SAT data as covariates (Table 11) agreed with the initial indication in the two-by-two analysis of variance that the games treatment effect was not probable (Table 3). Yet, these test results were not consistent with the implication in the analysis of covariance displayed in Table 4. Statistical interpretation of the achievement results in Table 11 indicated SAT-M was a significant ( $p = .005$ ) covariate. In other words, adjustment of achievement posttest scores with the SAT-M scores significantly explained the initial variation in the posttest scores between the pretested games and no-games subgroups. The test results did not show a strong effect of the games treatment. However, the analysis of covariance, using only the achievement pretest scores as the covariate, suggested the games treatment seemed to account for some of the difference between the groups.

An important difference in the covariance analyses was the composition of the groups used for the comparisons. The analysis, using only the achievement pretest as a covariate, compared the achievement posttest means of the entire pretested, games group ( $n=19$ ) with the entire pretested no-games group ( $n=24$ ). However, the analysis, using the achievement pretest and the SAT scores as covariates, compared the achievement posttest means of the students with SAT scores in each of those groups (games subgroup,  $n=11$ ; no-games subgroup,  $n=16$ ).

To suggest an explanation for the conflicting results, a possible relationship between the SAT scores and the students withdrawing from the class was investigated. The data in Table 10 specified that seven pretested students with SAT scores withdrew from the course. Six of these seven were from the pretested experimental subgroup and only one student was from the pretested control subgroup. As suggested in the analysis using the SAT-M scores as a covariate (Table 11), SAT-M scores were significantly related to achievement. If the six students, who were assigned to the pretested experimental subgroup but who withdrew from the course, tended to have lower SAT-M scores than the average SAT-M for their subgroup, then their withdrawal may have initiated a bias favoring the pretested experimental group. The shift could explain the observed higher achievement posttest mean for the pretested games group (Table 8). It could also explain the differences in the two analyses of covariance for achievement.

This conjecture was tested using the SAT-M scores of the students who withdrew from the course prior to the end of the third week of classes. Only subgroups of the experimental and control groups were used in this analysis since SAT scores were not available for all students. The SAT-M mean scores as a result of students withdrawing are compared in Table 12.

Table 12 indicates the withdrawal intensified initial differences in mean SAT-M scores of the pretested and unpretested subgroups. The effect of students withdrawing from the unpretested subgroups was negligible. Yet, the effect of students withdrawing from the pretested subgroups was not. This observation, in conjunction with the

Table 12. Comparison of SAT-M mean scores depicting the effect of student withdrawal on the randomization of the pretested subgroups.

	Initial subgroup		Students withdrawing		Students remaining	
	n	mean	n	mean	n	mean
Pretested experimental	17	411	6	368	11	435
Pretested control	17	415	1	380	16	418
Unpretested experimental	17	377	2	385	15	376
Unpretested control	18	405	5	404	13	405

observation that SAT-M was a significant predictor, suggested an explanation for the observed differences between the pretested and unpretested groups indicated in Table 8.

As noted, the effect of students withdrawing from the pretested subgroups was not negligible. The mean SAT-M of the six withdrawing students in the pretested experimental subgroup (368) was lower than the mean for the initial subgroup (411). As a result, the mean SAT-M score for the remaining subgroup was raised to 435. The SAT-M score for the one withdrawing student in the initial pretested control subgroup (380) was lower than the mean for the initial subgroup (415). The withdrawal of that one student only slightly raised the mean SAT-M score for the remaining pretested control subgroup (418). Obviously, the withdrawal created a marked difference in the final SAT-M mean scores of the two pretested subgroups which did not exist with the initial randomization. If this trend extended to the entire pretested groups, the comparison of these groups, using only the achievement pretest as a covariate, may have attributed the variance to the games treatment.

Since SAT-M was found to be a significant predictor of achievement, the SAT-M scores were used to predict the effect on the achievement posttest means of students withdrawing from SAT subgroups if no students had withdrawn from these subgroups. For this prediction a regression equation was obtained from the analysis of covariance using SAT-M scores as the covariate. A predicted achievement posttest mean was calculated for each subgroup using the mean SAT-M for students who withdrew from that subgroup. This mean was averaged with the mean for the students who remained in that subgroup to obtain a prediction of the achievement posttest mean if the students had not withdrawn. The results of this prediction analysis are presented in Table 13.

Table 13. Predicted achievement posttest means assuming no student withdrawal from SAT subgroups.

	Students remaining		Students withdrawing		Assuming no students withdrew	
	n	mean achievement (actual)	n	mean achievement (predicted)	n	mean achievement (predicted)
Pretested experimental	11	147.45	6	123.13	17	138.87
Pretested control	16	145.75	1	131.96	17	144.94
Unpretested experimental	15	131.13	2	134.40	17	132.52
Unpretested control	13	130.77	5	130.40	18	130.67

The prediction for the unpretested subgroup data suggested students withdrawing from those subgroups did not strongly influence the posttest achievement mean for either the unpretested control or

experimental subgroups. However, the students withdrawing from the pretested subgroups tended to have lower SAT-M scores than the average SAT-M for their subgroups. As a result, the prediction for the pretested subgroups (see Table 13) showed a marked change in achievement posttest means. According to the prediction, the six students withdrawing from the pretested experimental subgroup raised the achievement posttest mean by almost nine points ( $147.45-138.87=8.58$ ). Since only one student withdrew from the pretested control subgroup, the achievement posttest mean of that subgroup was not as strongly affected; the prediction indicated that student withdrawal raised the achievement posttest mean approximately one point ( $145.75-144.94=0.81$ ).

These predictions clearly emphasized the effect of students withdrawing from the SAT subgroups on the achievement posttest score. These data predicted that the withdrawal created an achievement bias favoring the pretested experimental subgroup. An adjustment of initial differences with SAT-M scores in an analysis of covariance accommodated for this bias (see Table 11). Thus, in essence, these predictions concretely supported the conjecture that student withdrawal, and not treatment, probably initiated the student achievement increase observed in the pretested experimental group in this study.

### Correlation Studies

Throughout the treatment period, the researcher recorded the amount of computer time used each week by the subjects in the games groups in System Resource Units (SRU's). Students in the games groups were instructed to interact with the mathematical computer games at

least one and one-half hours per week for eight weeks. At the end of the term, the median number of SRU's used per week was calculated. If the student did not work with the games more than four weeks, the median score was zero.

Only 12 of the 41 students in the games treatment groups received a median SRU score greater than zero. Correlations were computed for these 12 students between the total SRU's used and the attitude posttest scores and between total SRU's used and achievement posttest scores. The results of the correlation studies are presented in Table 14.

Table 14. Correlation studies relating SRU's to achievement and attitude posttest scores.

	Correlation with total SRU's
Attitude posttest	.47
Achievement posttest	.72

Results of the correlation studies indicated that the total SRU's used was highly correlated (.72) with the achievement posttest scores. No cause-and-effect relationship was intended in this correlation. The correlation only illustrated that the students who scored higher on the achievement posttest used more computer time.

#### Summary of the Results

The results presented in this chapter include not only the analysis of the major and minor hypothesis but also the analysis of the main and interactive effects of pretesting. The analyses of pretest and

posttest data provided empirical information concerning achievement and attitude effects of the use of the mathematical computer games, POE and EQUATIONS, in the entry-level intermediate algebra course at Oregon State University, winter term, 1980.

The Solomon Four-Group Design was used to statistically control for initial group differences and to measure the effects of pretesting. The analysis measuring the effects of achievement pretesting showed the pretest did not influence the students' achievements in the course. Furthermore, the achievement pretest did not significantly interact with the games treatment, producing a treatment other than the one proposed.

Although students were pretested and posttested with the same attitude inventory, statistical analysis did not reflect significant main or interaction effects at the .05 level. The results verified that the attitude pretest did not interact with the games treatment. The p-value of .06, although not significant at the .05 level, suggested taking the pretest may have directly influenced the student responses on the attitude posttest.

The results of the analysis of the achievement posttest scores, after adjustment for initial differences with the achievement pretest, suggested the games treatment did not significantly increase student achievement in this study. However, a probability level of .10 suggested a games treatment trend. Using SAT data obtained for a subset of the sample, further analysis investigated the observed trend for a games treatment effect. The analysis of the achievement posttest scores, after adjustment for initial differences with the achievement pretest and the SAT scores (SAT-M and SAT-V), indicated the games

treatment did not explain the variation between the groups. In fact these data implied SAT-M significantly ( $p=.005$ ) accounted for the variations in achievement.

A tentative explanation for the differences in the two results was proposed from additional descriptive data concerning students withdrawing from the course. These data indicated the withdrawal of students with SAT scores created an increased SAT-M mean score for the pretested experimental subgroup. The observed increase in SAT-M mean for the pretested experimental subgroup may have identified a similar change for the pretested experimental group. Moreover, since SAT-M was significantly related to the achievement in this course for this study, the change may have created a marked difference between the pretested experimental and pretested control groups. This difference may have indirectly created the suggestion of a games treatment trend.

Subscores for the achievement posttest were used for testing specific skill areas; simplifying algebraic expressions, solving problems with a given equation, and solving problems requiring the creation of the algebraic equation. Conclusions from the three individual t-tests were that the mathematical computer games, POE and EQUATIONS, did not significantly increase (at the .05 level) student achievement in the predetermined specific skill areas.

The analysis of the posttest attitude scores, after adjustment for initial group differences with the attitude pretest, revealed no treatment effect. For these data the attitude pretest significantly accounted for the variation between the treatment and control groups. The conclusion from this analysis was that mathematical computer games,

POE and EQUATIONS, did not significantly improve (at the .05 level) student attitudes toward mathematics in this course.

Investigation of computer time used per week by students in the treatment groups illustrated student response to the games as an additional assignment. Although these students were assigned to play the games a minimum of one and one-half hours per week for eight weeks, only 12 of 41 students worked with the computer games more than four weeks. An analysis of SRU data indicated the achievement of these 12 students was highly correlated with the total time spent using the computer to play the games.

## V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This final chapter presents a summary of the study in addition to conclusions and recommendations. The chapter is divided into three main sections. The first section reviews the entire study. The second section presents the conclusions and relates the findings to theory and research. The third section presents recommendations for further study.

### Summary of the Study

#### The Problem

The entry-level intermediate algebra course at the university is typically taught using a large group, lecture format. The emphasis is on learning in a passive, information-processing mode with little opportunity for active examination and exploration of the concepts. Currently, many game advocates believe mathematical games provide students opportunities to actively manipulate the concepts and encourage student involvement, individualization, and motivation. Conceivably, mathematical games provide a means of enhancing learning in the university entry-level algebra course.

Although educational game theory and classroom experiences propose games have value in the learning of mathematics, little systematic research has been conducted to substantiate the claims. The goal of this study was to provide some empirical data concerning the effects on cognitive and affective learning through games at the university level. Specifically, the problem was to determine if two mathematical

computer games, POE and EQUATIONS, included as learning aids in addition to regular instruction in a university entry-level intermediate algebra course significantly increased student achievement in the algebra course and improved student attitude toward mathematics.

The hypotheses for this study, in condensed form, stated the following: Mathematical computer games, POE and EQUATIONS, will significantly increase student achievement in the university entry-level intermediate algebra course, will improve student attitude toward mathematics, and will significantly increase student achievement in predetermined specific skill areas.

#### Design of the Study

For study of cognitive and affective learning effects of the mathematical computer games, POE and EQUATIONS, in the entry level mathematics course at the university level, the large lecture section of Mth 95: Intermediate Algebra I taught winter term, 1980, at Oregon State University was selected. This course involved three lecture and one recitation sessions per week for nine weeks. Throughout the term, mastery-oriented tests and retests were administered in the MSLC at a time selected by the student (within deadlines). The two-hour final examination was administered at one specified time for the entire class during the tenth week of the term.

The Solomon Four-Group Design was selected for the study in order to provide comparison of the treatment group with a control group and to measure the effect of pretesting on the experimental treatment. SAT scores were obtained for some of the students enrolled in Mth 95 on the

first day of classes. The sample was stratified into two groups, students with SAT scores and students without SAT scores. Students from each stratum were randomly assigned to the four Solomon groups, pretested experimental, pretested control, unpretested experimental, and unpretested control.

Students in the experimental groups were trained to use the computer and to play POE and EQUATIONS in two 50-minute training sessions. After playing POE for two weeks, students played EQUATIONS for the remaining six weeks of the term. The specific assignment instructed the students to play the games for a minimum of one and one-half hours per week for eight weeks. Students in the experimental groups interacted with the games concurrently with instructions, assignments, and tests for the algebra class. Students in the control groups experienced the same instruction, assignments and tests for the class with no additional assignments. In essence the treatment tested in this study involved play of the mathematical computer games, POE and EQUATIONS, as an additional assignment rather than an activity integrated into class-time work. The assignment included initial instructional introduction to the computer and the games by a team of instructors. The treatment period was eight weeks, two weeks for POE and six weeks for EQUATIONS.

Data consisted of pretest scores for students in the pretested groups and posttest scores for all students. Equivalent forms of the course achievement examination were used to measure pretest and posttest student achievement. Dutton's Scale for Measuring Attitudes Toward Mathematics was used to measure both the pretest and posttest attitudes toward mathematics. The achievement pretest, the attitude

pretest and the attitude posttest were administered in the MSLC at a time selected by the student (within two-day deadlines). The achievement posttest was administered at a specific time for all students during the tenth week of the term. SAT scores were available for approximately two-thirds of the sample population.

A two-stage analysis was used to test the major hypotheses. The first stage, a two-by-two analysis of variance, analyzed the main and interaction effects of pretesting and the main effect of the games treatment. Negligible interaction effects of the pretest with the games treatment suggested the second analysis, an analysis of covariance comparing the posttest scores of the pretested experimental group with the posttest scores of the pretested control group. For this test the pretest scores provided an adjustment for differences prior to the treatment. SAT scores, obtained for a subset of the sample, provided additional data for a comparison of the posttest scores. Achievement and attitude scores of students with SAT scores were used to compare the pretested experimental subgroup with the pretested control subgroup. This analysis used the pretest, SAT-M, and SAT-V as covariates to adjust for initial differences.

Subsets of questions on the achievement posttest provided measurements for the minor hypotheses. Since the effect of the achievement pretest was negligible, the pretested and unpretested experimental groups were combined and the pretested and unpretested control groups were combined for the analysis of the subtest scores. Students' t-tests compared the mean subtest scores of the experimental and control groups.

### Results of the Data Analysis

As previously indicated, the main and interaction effects of pretesting indicated no significant (at the .05 level) main and interaction effects of the achievement pretest. The pretest did not significantly influence achievement, as measured by the posttest, and did not significantly interact with the games treatment. Similar results were obtained for the main and interaction effects of the attitude pretest. The F-value for the main effect of attitude pretesting was not significant at the .05 level but suggested a strong possibility that experience with the attitude pretest influenced student responses on the attitude posttest.

The test of the achievement hypothesis showed that for these data the mathematical computer games, POE and EQUATIONS, did not significantly (at the .05 level) increase student achievement in this intermediate algebra course. Although the test indicated a games treatment trend ( $p = .10$ ), additional analysis using SAT scores supported the conjecture that student withdrawal created the increased achievement trend rather than the games.

Analysis of the subscores from the achievement posttest indicated the computer games did not significantly increase student achievement in the predetermined, specific skill areas: simplifying algebraic expressions, solving problems with a given equation, and solving problems requiring the creation of the algebraic equation.

The test of the attitude data showed no significant improvement in attitudes toward mathematics resulting from interaction with the

mathematical computer games, POE and EQUATIONS, concurrent with regular instruction in this university entry-level algebra course.

Investigation of computer time used per week by students in the treatment groups illustrated student response to the games as an additional assignment. Although these students were assigned to play the games a minimum of one and one-half hours per week for eight weeks, the computer time data indicated only 12 of 41 students worked with the computer games more than four weeks. The total time spent using the computer to play the games for these 12 students was highly correlated with their achievement.

### Conclusions

The review of the research on games in the mathematics classroom revealed a number of studies involving the student-student version of EQUATIONS at the junior high level. Most of the studies employed EQUATIONS in a specific classroom model, teams-games-tournaments. This model necessarily imposed student involvement with the game in a competitive mode during the treatment periods. The results of the studies with this model showed increased achievement in mathematics and more positive attitudes.

Two studies investigated EQUATIONS incorporated into the classroom structure in a less competitive model. Henry (1974) compared junior high mathematics classes that played EQUATIONS during the class period to comparable classes not playing the game. Analysis indicated no significant improvement in cognitive abilities and attitudes toward mathematics. Allen and Ross (1974) combined play of EQUATIONS with

Instructional Math Play Kits. Classtime was devoted specifically to play of the games and use of the kits. Skills in applying mathematical ideas significantly improved for students using the combination.

These studies, as well as the others reviewed, differed from this study in several respects. This study involved student-computer play of the two games, POE and EQUATIONS, in a computer-augmented learning mode. The students played the games as an additional assignment rather than as part of a class period devoted specifically to play of the games. This additional assignment emphasized learning from the games in a non-competitive format. The random assignment of students (rather than intact classes) allowed the investigation of the effect of this games assignment and not a comparison of the assignment with another learning method. The students involved in the study were university students rather than junior high students. Student achievement was considered in terms of achievement in the intermediate algebra course in which the students were enrolled. The achievement variable was measured by an examination consistent with the objectives of the course.

Results from this research provided needed empirical data regarding game learning at the university level and game learning via computer games. These data revealed the games treatment did not significantly increase achievement in the intermediate algebra course, winter term, at Oregon State University. Furthermore, play of the computer games, POE and EQUATIONS, did not significantly improve attitudes toward mathematics. These results suggested that additional work with

mathematics through these games did not increase achievement in the course or improve attitudes toward mathematics. However, this conclusion was tempered by the additional data concerning the amount of computer time used by students playing the games. Only 12 or 41 students worked with the computer games more than four weeks. Therefore, most of the students did not continue with the assignment giving them the extra mathematical work. These additional data suggested that perhaps the university level student required more supervision, direction, and encouragement to continue the games assignment. In essence these data suggested that the assignment to play POE and EQUATIONS in addition to other assignments when not incorporated directly into the activities of the course was not sufficiently motivating to encourage the university level students in this course to continue with the assignment.

#### Recommendations

Based on the results and conclusions of this study in conjunction with the literature reviewed, several recommendations for further investigation are presented for future mathematical computer game research.

Questions arose in this study as to the effect on the results of the withdrawal of the students in the first three weeks of class. Therefore, replication of this study is recommended in which the normal withdrawal of students is controlled.

As noted in the conclusions, the inclusion of the computer games as an additional assignment did not provide sufficient motivation to

encourage continued student involvement. A study is recommended to investigate the use of the computer games incorporated directly into classroom activities as laboratory experiences with more supervision and direction for the university entry-level intermediate algebra course. Additional consideration should compare a non-competitive mode with a competitive mode such as teams-games-tournaments.

This study considered co-instructional use of the computer games. A study is recommended to study the achievement of students in the intermediate algebra course who interact with the games in a pre-instructional laboratory session for one term previous to enrollment in the intermediate algebra course.

This study revealed a strong correlation of the amount of computer time used in playing the games with the achievement for those students who played the games more than four weeks. Further study is recommended to examine this relationship. This investigation should consider varying ability levels of students.

The specific attitude measurement in this study was attitude toward mathematics. Further study of these computer games is recommended which considers other affective variables, including attitude toward the particular mathematics class and mathematics anxiety variables.

This study considered the play of the computer games in a university entry-level intermediate algebra course. Further study should investigate learning from these computer games in different mathematics courses at different age, maturity and grade levels.

Gaming enthusiasts have claimed that learning through games is time-consuming. Future study of the computer games, POE and EQUATIONS, should consider play of the games for varying lengths of time more than eight weeks.

Computers are relatively new teaching aids in the classroom. It is strongly recommended that further studies consider the psychological aspects of playing games via computers as well as the psychological aspects of playing games. It is recommended that future study consider individual personalities and maturity levels with respect to the competitive aspects of game playing and to frustrational aspects of using the computer.

Finally, this study considered only the combination of computer versions of POE and EQUATIONS as aids in the university entry-level intermediate algebra course. It is recommended that further studies consider the games separately, other games, and a combination of the student-student version of EQUATIONS with the computerized version of EQUATIONS.

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## APPENDICES

## APPENDIX A

Units in Computer Version of EQUATIONS

## Concepts

## PART 1 WHOLE NUMBERS (+ - X / )

- Unit 1    0 as additive identity.  
           0 as right identity for subtraction.  
           1 as multiplicative identity.  
           Associativity of addition.  
           1 as right identity for division.
- Unit 2    Order of operations.  
           Use of parentheses.  
           Use of parentheses.  
           Order of operations.  
           Zero X number is zero.
- Unit 3    Zero divided by a nonzero number is zero.  
           Multiplication is distributive over addition.  
           Multiplication by 10 adjoins a zero.  
           Multiplication is distributive over subtraction.  
           Interpretation of place value.
- PART 2 INTEGERS ( + - X / )
- Unit 4    If  $B > A$ , then  $A - B$  is negative.  
           Sum of two numbers with the same absolute value and  
           opposite signs is 0.  
           Sum of positive and negative can be positive.  
           Sum of positive and negative can be negative.  
           Sum of two negatives is negative.
- Unit 5    Positive - negative.  
           Negative - positive.  
           Negative X position.  
           Negative / positive.  
           Positive - (negative X positive).
- Unit 6    Positive / negative is negative. Negative X negative is  
           positive.  
           Positive / negative is negative.  
           Negative - negative can be positive.  
           Negative / negative is positive.  
           Negative - negative can be negative.

## PART 3 RATIONAL NUMBERS ( + - X / )

- Unit 7 Definition of rational number.  
Equivalent rationals.  
Whole  $\times$  reciprocal = 1.  
Whole  $\times$  rational can be whole.  
Whole  $\times$  rational is rational.
- Unit 8 Rational  $\times$  rational can be whole.  
Rational  $\times$  rational is rational.  
Whole divided by rational can be whole.  
Whole divided by rational is rational.  
Rational divided by whole is rational.
- Unit 9 Rational / rational is rational.  
Rational / rational can be whole.  
Rational + rational; like denominators.  
Rational + rational; unlike denominators.  
Whole + rational is rational.
- Unit 10 Rational + rational can be whole.  
Rational - rational; like denominators.  
Rational - rational; unlike denominators.  
Whole - rational can be rational.  
Rational - whole can be rational.

## PART 11 WHOLE NUMBERS ( + - X / \* )

- UNIT 101 Definition of exponentiation (\*).  
1 is a right identity for \*.  
\* takes precedence in order of operations.  
1 to any power is 1.  
Quasi-distributive property of \* with respect to + and X.
- Unit 102 0 to any positive power is 0.  
Quasi-distributive property of \* with respect to - and /.  
The zero power of any non-zero number is 1.  
Repeated exponentiation is related to an exponent that is a product.  
\* is right distributive over X.
- Unit 103 Place value form of  $AX(10^*B)$ .  
Products with powers often.  
Quotients with powers of 10.  
Powers with powers of 10.  
Sums and differences with powers of 10.

## PART 12 INTEGERS ( + - X / \* )

- Unit 104 Definition of negative first power.  
 Definition of negative power.  
 Quasi-distributive property of \* with respect to - and /.  
 Even powers of negative numbers are positive.  
 Odd powers of negative numbers are negative.

## PART 13 RATIONALS AND INTEGERS ( + - X / \* )

- Unit 105 Negative first power of a rational.  
 Whole number power of a rational.  
 Negative integral power of a rational.  
 Negative integral power of a rational.  
 Odd powers of -1.

## PART 14 REAL NUMBERS ( + - X / \* @ )

- Unit 106 Definition of root operation (@).  
 1 is left identity for @.  
 Any non-zero root of 1 is 1.  
 Any positive root of 0 is 0.  
 Definition of fractional root.
- Unit 107 Root of reciprocal equals reciprocal of root.  
 Root is left distributive over X.  
 Root is left distributive over /.  
 When exponent and root index are equal, exponentiation  
 . undoes what root does.  
 Root index is reciprocal of exponent.
- Unit 108 Exponent is reciprocal of root index.  
 Exponent is reciprocal of root index.  
 Repeated root related to root with index that is a product.  
 Power that is an improper fraction related to product of  
 root and whole number.  
 Rationalizing a denominator of the form  $\frac{2}{B}$ .
- Unit 109 @ with power of 10.  
 @ with negative integral index.  
 @ of rational with negative integral index.  
 Difference of two squares.  
 Simplification of  $\frac{A}{B/C/D}$ .

## APPENDIX B

Diagnostic Unit and Diagnostic Summary Sheet

DO YOU NEED INSTRUCTIONS FOR THE DIAGNOSTIC UNIT? <Y/N>

? N

WHAT UNIT NUMBER DO YOU WANT? ? 2

AND NOW, THE C SECTION!

ITEM 1  $6 \times 9 + 5 = \underline{\quad}$

? 59

CORRECT

1. SOLUTION =  $6 \times 9 + 5$   
               =  $(6 \times 9) + 5$   
               =  $54 + 5$   
               = 59.

NOTICE THAT MULTIPLICATION IS PERFORMED BEFORE ADDITION UNLESS PARENTHESES INDICATE OTHERWISE.

FOR EXAMPLE,  $3 \times 7 + 4 = (3 \times 7) + 4 = 21 + 4 = 25$ .

THE ORDER IN WHICH THE FOUR BASIC OPERATIONS ARE PERFORMED IS:

- 1) FIRST MULTIPLICATION AND DIVISION
- 2) SECOND ADDITION AND SUBTRACTION
- 3) LEFT BEFORE RIGHT WHEN TWO CONSECUTIVE OPERATIONS HAVE THE SAME PRIORITY.

ITEM 2  $7 \times (4 + 6) = \underline{\quad}$

? 70

CORRECT

2. SOLUTION =  $7 \times (4 + 6)$   
               =  $7 \times 10$   
               = 70.

NOTICE HOW PARENTHESES CAN BE USED TO INDICATE IN WHAT ORDER OPERATIONS ARE TO BE PERFORMED: THOSE OPERATIONS WITHIN A PARENTHESES ARE ALWAYS PERFORMED BEFORE THE OPERATIONS OUTSIDE THE PARENTHESES.

FOR EXAMPLE,  $3 \times (7 + 4) = 3 \times 11 = 33$  AND

$$\begin{aligned} 2 + [(1 + 6) \times 5 + (7 \times (3 + 2))] &= 2 + [7 \times 5 + (7 \times 5)] \\ &= 2 + [35 + 35] \\ &= 2 + 70 \\ &= 72. \end{aligned}$$

ITEM 3  $18 - (12 - 9) = \underline{\quad}$

? 15

CORRECT

3. SOLUTION =  $18 - (12 - 9)$   
               =  $18 - 3$   
               = 15.

NOTICE THAT PARENTHESES ARE NEEDED TO INDICATE THAT THE SECOND SUBTRACTION IS TO BE DONE FIRST. OTHERWISE, THE OPERATIONS WOULD BE DONE IN ORDER FROM LEFT TO RIGHT.

FOR EXAMPLE,  $12 - (9 - 3) = 12 - 6 = 6$  BUT  $12 - 9 - 3 = (12 - 9) - 3 = 3 - 3 = 0$ .

ITEM 4 23-15-3=\_\_\_

? 5

CORRECT

$$\begin{aligned} 4. \quad \text{SOLUTION} &= 23-15-3 \\ &= (23-15)-3 \\ &= 8-3 \\ &= 5. \end{aligned}$$

NOTICE THAT PARENTHESES ARE NOT NEEDED BECAUSE THE LEFTMOST OF TWO IDENTICAL OPERATIONS IS TO BE DONE FIRST. IT WOULD NOT BE WRONG TO USE PARENTHESES, BUT IT WOULD BE REDUNDANT.

FOR EXAMPLE,  $23-12-5 = 11-5 = 6$ , AND  $48/3/2 = 16/2 = 8$ .

ITEM 5 4X7+0X17=\_\_\_

? 28

CORRECT

$$\begin{aligned} 5. \quad \text{SOLUTION} &= 4X7+0X17 \\ &= (4X7)+(0X17) \\ &= 28+0 \\ &= 28. \end{aligned}$$

NOTICE THAT THE PRODUCT OF 0 AND ANY NUMBER IS 0.

FOR EXAMPLE,  $0X8 = 0$  AND  $236X0 = 0$ .

FOR ANY NUMBER A,  $AX0 = 0XA = 0$ .

AND NOW, FOR SOMETHING COMPLETELY DIFFERENT, THE R SECTION.  
(RETURN)

? C

IT CONSISTS OF QUESTIONS IN WHICH YOU ARE GIVEN A SET OF DIGITS AND OPERATIONS (RESOURCES) WITH WHICH TO CONSTRUCT A NUMBER EQUAL TO A SPECIFIED GOAL. YOU MUST USE ALL OF THE RESOURCES GIVEN, AND YOU CANNOT USE RESOURCES THAT ARE NOT AVAILABLE (BUT YOU CAN USE AS MANY PARENTHESES AS YOU LIKE).

EXAMPLE: GOAL = 9  
RESOURCES: + X 0 3 3

$3X3+0$  IS CORRECT.

$3X3$  IS WRONG, BECAUSE IT DOESN'T USE THE + OR THE 0.  
 $3X3+0/1$  IS WRONG BECAUSE / AND 1 ARE NOT IN THE RESOURCES.  
 $3X0+3$  IS WRONG BECAUSE IT IS NOT EQUAL TO THE GOAL.

YOUR ANSWERS TO THE R SECTION DETERMINE WHICH KITS WILL BE SUGGESTED FOR YOU TO PLAY.

ITEM 1 GOAL =12  
RESOURCES:+ X X 0 3 4 7  
?  $3X4+7X0$

CORRECT

$$\begin{aligned} 1. \quad \text{GOAL} &= 12 \\ &= 12+0 \\ &= 4X3+0 \\ &= 4X3+0X7. \end{aligned}$$

RECALL THAT THE PRODUCT OF 0 AND ANY NUMBER IS 0.

HENCE,  $0X12 = 0$  AND  $35X0 = 0$ .

FOR ANY NUMBER A,  $0XA = AX0 = 0$ .

ITEM 2 GOAL =3  
 RESOURCES:- - 2 3 8  
 ? 8-2-3  
 CORRECT

2. GOAL = 3  
 = 5-2  
 = (8-3)-2  
 = 8-3-2.

RECALL THAT PARENTHESES ARE NOT NEEDED WHEN THE LEFTMOST OF TWO IDENTICAL CONSECUTIVE OPERATIONS IS TO BE DONE FIRST.

HENCE,  $31-25-6 = (31-25)-6 = 6-6 = 0$ , AND  $49/7/7 = (49/7)/7 = 7/7=1$ .

ITEM 3 GOAL =25  
 RESOURCES:+ X 3 4 7  
 ? 7X3+4  
 CORRECT

3. GOAL = 25  
 = 21+4  
 = (7X3)+4  
 = 7X3+4.

RECALL THAT MULTIPLICATION IS DONE BEFORE ADDITION OR SUBTRACTION UNLESS PARENTHESES INDICATE OTHERWISE.

HENCE,  $5+8X12 = 5+(8X12) = 5+96 = 101$ , AND  $51-3X9 = 51-(3X9) = 51-27=24$ .

ITEM 4 GOAL =44  
 RESOURCES:+ X 3 4 8  
 ? (8+3)X4  
 CORRECT

4. GOAL = 44  
 = 11X4  
 = (8+3)X4.

RECALL THAT PARENTHESES CAN BE USED TO INDICATE IN WHAT ORDER OPERATIONS ARE TO BE PERFORMED.

HENCE,  $5X(9+2) = 5X11 = 55$  AND  $(4+8)X(11-3) = 12X8 = 96$ .

ITEM 5 GOAL =6  
 RESOURCES:- - 1 4 9  
 ? 9-(4-1)  
 CORRECT

5. GOAL = 6  
 = 9-3  
 = 9-(4-1).

RECALL THAT PARENTHESES ARE NEEDED TO INDICATE THAT THE RIGHTMOST OF TWO CONSECUTIVE SUBTRACTIONS OR DIVISIONS IS TO BE DONE FIRST.

HENCE,  $24-(9-1) = 24-8 = 16$ , BUT  $24-9-1 = (24-9)-1 = 15-1 = 14$ , AND  $108/(12/3) = 108/4 = 27$ , BUT  $108/12/3 = (108/12)/3 = 9/3 = 3$ .

PLEASE PLAY THE FOLLOWING KITS:22,24,25,27,29,31,34,36,37  
 WHAT KIT NUMBER DO YOU WANT TO PLAY? <Q/#>



## APPENDIX C

Sample EQUATIONS Match

WHAT KIT NUMBER DO YOU WANT TO PLAY? <Q/#>

? 22

THIS KIT BEGINS AFTER MOVES IN ADDITION TO SETTING THE GOAL HAVE BEEN MADE.

RESOURCES:	+	+	+	4	6	7	9	
FORBIDDEN								PERMITTED
(X)X								5
								REQUIRED
								----
SOLUTION								GOAL=45

YOUR TURN? <O/I/H/Q/S>

? C,P

YOU WIN. YOU CAUGHT MATE BLUFFING. NO SOLUTION IS POSSIBLE, BECAUSE MATE MADE A P-FLUB. YOUR SCORE IS 10 POINTS.

NOTICE THAT 45 IS NOT A SOLUTION BECAUSE EQUATIONS RULES DO NOT ALLOW A TWO DIGIT NUMERAL IN A SOLUTION.

IN THIS GAME, THE BIGGEST NUMBER THAT CAN BE BUILT WITH THE AVAILABLE RESOURCES IS STILL SMALLER THAN THE GOAL.

DO YOU WANT TO MAKE A SUGGESTION OR COMMENT? <Y/N>

? N

GO ON TO WHICHEVER IS APPROPRIATE:

1. I HAVE MORE UNCIRCLED KITS ON MY DIAGNOSTIC SUMMARY SHEET AND SHOULD GO ON TO THE NEXT ONE.
2. I HAVE NO MORE UNCIRCLED KITS ON MY DIAGNOSTIC SUMMARY SHEET SO, I SHOULD GO TO THE CHECK-UP FOR THE NEXT UNIT.

<1/2>

? 1

WHAT KIT NUMBER DO YOU WANT TO PLAY? <Q/#>

? 36

THIS KIT BEGINS AFTER MOVES IN ADDITION TO SETTING THE GOAL HAVE BEEN MADE.

RESOURCES:	+	-	X	0	2	7	9	
FORBIDDEN								PERMITTED
								8 (4)4
								REQUIRED
								//
SOLUTION								GOAL=1

YOUR TURN? <O/I/H/Q/S>

? C,A

ON AN A-FLUB CHALLENGE, YOU HAVE THE BURDEN OF PROVING TWO THINGS:

1. THAT THERE IS A SOLUTION WITH AT MOST ONE MORE OF THE

REMAINING RESOURCES, AND

2. THAT THERE IS AN OK ALTERNATIVE MOVE.

TYPE HERE SUCH A SOLUTION THAT YOU THINK IS POSSIBLE. IF YOU DO NOT SEE A SOLUTION, THEN TYPE 'N' (FOR 'NONE').

? 3/4/2

YOUR EXPRESSION IS CORRECT; IT IS A SOLUTION THAT IS POSSIBLE WITH THE RESOURCES AVAILABLE. TYPE HERE THE OK ALTERNATIVE MOVE THAT YOU THINK WAS POSSIBLE. IF YOU DO NOT SEE AN OK ALTERNATIVE MOVE, THEN TYPE 'N' (FOR 'NONE').

? F,+

YOU WIN. YOU CAUGHT MATE BLUFFING ON A DELIBERATE A-FLUB. YOUR SOLUTION AND ALTERNATIVE MOVE ARE CORRECT. YOUR SCORE IS 10 POINTS.

RECALL THAT PARENTHESES ARE NOT NEEDED WHEN THE LEFTMOST OF TWO IDENTICAL CONSECUTIVE OPERATIONS IS TO BE DONE FIRST.

HENCE,  $31-25-6 = (31-25)-6 = 6-6 = 0$ . AND  $49/7/7 = (49/7)/7 = 7/7=1$ .

## APPENDIX D

Sample POE MatchesVersion 1: FP-POE

DO YOU NEED INSTRUCTIONS ON HOW TO PLAY USING THE COMPUTER  
VERSION OF POE? TYPE EITHER "Y" OR "N" (FOR YES OR NO) AND  
PRESS THE RETURN KEY. YOU SHOULD ALSO REMEMBER THAT YOU CAN  
GET HELP SIMPLY BY TYPING "H" (FOR HELP) WHEN IT IS YOUR TURN.

? N

BY THE WAY, WHAT IS YOUR NAME? (PLEASE TYPE IT IN).

? MAGGIE

WOULD YOU LIKE TO SET THE GOAL, MAGGIE? IF SO, TYPE EITHER Y,  
OR N (FOR YES OR NO) AND PRESS RETURN.

? Y

YOU SET THE GOAL, MAGGIE, BY TYPING EITHER O (FOR ODD) OR  
E (FOR EVEN).

? E

MY MOVE IS TO: P,2.

!1	!2	!3
!	! P	!
!4	!5	!6
!	!	!
!7	!8	!9
!	!	!

THE GOAL IS EVEN.

YOUR TURN, MAGGIE!

? P,5

MY MOVE IS TO: P,3.

!1	!2	!3
!	! P	! P
!4	!5	!6
!	! P	!
!7	!8	!9
!	!	!

THE GOAL IS EVEN.

YOUR TURN, MAGGIE!

? C,A

ON AN A-FLUB CHALLENGE, MAGGIE, YOU HAVE TO PROVE THAT  
A SOLUTION EXISTS WITH AT MOST ONE MORE MOVE, AND THAT  
IT WAS POSSIBLE FOR THE COMPUTER TO MAKE AN OKAY ALTERNATIVE  
MOVE INSTEAD OF P,3.

TYPE YOUR ENTIRE SOLUTION, MAGGIE. FOR EXAMPLE,  
123,126,269. REMEMBER TO PUT A COMMA (,) BETWEEN EACH  
CONNECTION IN YOUR SOLUTION. IF YOU DO NOT SEE A SOLUTION  
THEN TYPE N (FOR NONE).

? 258,358

YOU ARE RIGHT, MAGGIE. BY PERMITTING SQUARE 8 A SOLUTION TO  
THE GOAL OF AN EVEN NUMBER OF CONNECTIONS CAN BE OBTAINED.  
I ALSO SEE THAT AN OKAY ALTERNATIVE MOVE WAS POSSIBLE. YOU WIN.  
I AGREE WITH YOUR CHALLENGE THAT I MADE AN A-FLUB.

Version 2: FPR-POE

THE POE GAME  
 COMPUTERIZED BY  
 LAYMAN E. ALLEN AND MITCHELL J. RYCUS  
 HAVE YOU PLAYED POE ON THIS COMPUTER BEFORE? TYPE EITHER "Y" OR "N"  
 (FOR YES OR NO) AND PRESS RETURN.

? Y  
 TYPE "1" TO INDICATE YOU WANT TO PLAY FP-POE, OR TYPE "2" TO INDICATE  
 YOU WANT TO PLAY FPR-POE, AND PRESS RETURN.

? 2  
 DO YOU NEED INSTRUCTIONS ON HOW TO PLAY USING THE COMPUTER  
 VERSION OF POE? TYPE EITHER "Y" OR "N" (FOR YES OR NO) AND  
 PRESS THE RETURN KEY. YOU SHOULD ALSO REMEMBER THAT YOU CAN  
 GET HELP SIMPLY BY TYPING "H" (FOR HELP) WHEN IT IS YOUR TURN.

? N  
 BY THE WAY, WHAT IS YOUR NAME? (PLEASE TYPE IT IN).

? OLD PLAYER  
 WOULD YOU LIKE TO SET THE GOAL, OLD PLAYER? IF SO, TYPE EITHER Y,  
 OR N (FOR YES OR NO) AND PRESS RETURN.

? N

! ! ! !  
 ! ! ! ! THE GOAL IS ODD.  
 ! ! ! !

YOUR TURN, OLD PLAYER!

? R,1

MY MOVE IS TO: R,5.

!R! ! !  
 ! !R! ! THE GOAL IS ODD.  
 ! ! ! !

YOUR TURN, OLD PLAYER!

? P,9

MY MOVE IS TO: P,3.

!R! !P!  
 ! !R! ! THE GOAL IS ODD.  
 ! ! !P!

YOUR TURN, OLD PLAYER!

? F,3

THIS BOX HAS ALREADY BEEN USED. PLEASE MAKE ANOTHER CHOICE.

YOUR TURN, OLD PLAYER!

? F,2

I CHALLENGE YOU, OLD PLAYER, ON A CA-FLUB (C,CA).  
 AFTER MY LAST MOVE P,3 THE SOLUTION 359,259,123,  
 WAS POSSIBLE BY PERMITTING SQUARE NUMBER 2.  
 YOU SHOULD HAVE CHALLENGED ME ON AN A-FLUB (C,A).

## APPENDIX E

Dutton's Attitude Scale

## Part I.

Read the statements below. Choose statements which show your feelings toward mathematics. Let your experiences with this subject in school determine the marking of items.

Place a check (✓) before those items which tell how you feel about math. Select only the items which express your true feelings -- probably not more than five items.

1. (3.2)<sup>a</sup> I avoid math because I am not very good with figures.
2. (8.1) Math is very interesting.
3. (2.0) I am afraid of doing word problems.
4. (2.5) I have always been afraid of mathematics.
5. (8.7) Working with numbers is fun.
6. (1.0) I would rather do anything else than do math.
7. (7.7) I like math because it is practical.
8. (1.5) I have never liked math.
9. (3.7) I don't feel sure of myself in mathematics.
10. (7.0) Sometimes I enjoy the challenge presented by a math problem.
11. (5.2) I am completely indifferent to math.
12. (9.5) I think about math problems outside of school and like to work them out.
13. (10.5) Math thrills me and I like it better than any other subject.
14. (5.6) I like mathematics but I like other subjects just as well.
15. (9.8) I never get tired of working with numbers.

## Part II.

1. List two things you like about mathematics.
  - a.
  - b.
2. List two things you dislike about mathematics.
  - a.
  - b.

---

<sup>a</sup>Weighted item values used to score the test have been added in parentheses.

## APPENDIX F

Assignment SheetsUnpretested ExperimentalASSIGNMENT SHEET

\*\*\*\*\* PLEASE LEAVE IN FILE \*\*\*\*\*

DIRECTIONS: Please read carefully taking note of due dates. Return this sheet to be kept in your file. You may ask for it as you need.

COMPLETE THE FOLLOWING IN ORDER

<u>ASSIGNMENT</u>	<u>WHEN TO COMPLETE</u>
<p>1. PLAY MATH COMPUTER GAMES: During the term you are to interact with two mathematical computer games. In order to simplify the instructions for this assignment, you are to attend a 50 minute meeting. At this meeting you will be given</p> <ol style="list-style-type: none"> <li>1. instructions in the use of the computer;</li> <li>2. instructions in playing the math games;</li> <li>3. computer time and numbers;</li> <li>4. answers to questions on this assignment.</li> </ol> <p>Report to Kidder 282 for the session you choose.</p>	<p>Sign up for Introductory Session by Friday, January 11.</p> <p>Possible sessions:  Monday, Jan. 14 at 1700  Tuesday, Jan. 15 at 1700  Wednesday, Jan. 16 at 1900</p> <p>Complete the attached form to notify us of the session which you will attend.</p>
<p>2. YELLOW DATA CHECK: Request the data check on the <u>yellow</u> paper from your file and take in the testing area. Return completed form to testing desk.</p>	<p>Tuesday, March 4  OR  Wednesday, March 5</p>

Pretested ExperimentalASSIGNMENT SHEET

\*\*\*\*\* PLEASE LEAVE IN FILE \*\*\*\*\*

DIRECTIONS: Please read carefully taking note of due dates. Return this sheet to be kept in your file. You may ask for it as you need.

COMPLETE THE FOLLOWING IN ORDER

<u>ASSIGNMENT</u>	<u>WHEN TO COMPLETE</u>
1. BLUE DATA CHECK: Request the data check on the <u>blue</u> paper from your file and take in the testing area. Return completed form to testing desk.	Wednesday, January 9 OR Thursday, January 10
2. WHITE DATA CHECK: Request the data check on the <u>white</u> paper from your file and take in the testing area. Return completed form to testing desk.	Thursday, January 10 OR Friday, January 11
3. PLAY MATH COMPUTER GAMES: During the term you are to interact with two mathematical computer games. In order to simplify the instructions for this assignment, you are to attend a 50 minute meeting. At this meeting you will be given 1. instructions in the use of the computer; 2. instructions in playing the math games; 3. computer time and numbers; 4. answers to questions on this assignment. Report to Kidder 282 for the session you choose.	Sign up for Introductory Session by Friday, January 11.  Possible sessions: Monday, Jan. 14 at 1700 Tuesday, Jan. 15 at 1700 Wednesday, Jan. 16 at 1900 Complete the attached form to notify us of the session which you will attend.
4. YELLOW DATA CHECK: Request the data check on the <u>yellow</u> paper from your file and take in the testing area. Return completed form to testing desk.	Tuesday, March 4 OR Wednesday, March 5

Pretested ControlASSIGNMENT SHEET

\*\*\*\*\* PLEASE LEAVE IN FILE \*\*\*\*\*

DIRECTIONS: Please read carefully taking note of due dates. Return this sheet to be kept in your file. You may ask for it as you need.

COMPLETE THE FOLLOWING IN ORDER

<u>ASSIGNMENT</u>	<u>WHEN TO COMPLETE</u>
1. BLUE DATA CHECK: Request the data check on the <u>blue</u> paper from your file and take in the testing area. Return completed form to testing desk.	Wednesday, January 9 OR Thursday, January 10
2. WHITE DATA CHECK: Request the data check on the <u>white</u> paper from your file and take in the testing area. Return completed form to testing desk.	Thursday, January 10 OR Friday, January 11
3. YELLOW DATA CHECK: Request the data check on the <u>yellow</u> paper from your file and take in the testing area. Return completed form to testing desk.	Tuesday, March 4 OR Wednesday, March 5

Unpretested ControlASSIGNMENT SHEET

\*\*\*\*\* PLEASE LEAVE IN FILE \*\*\*\*\*

DIRECTION: Please read carefully taking note of due dates. Return this sheet to be kept in your file. You may ask for it as you need.

<u>ASSIGNMENT</u>	<u>WHEN TO COMPLETE</u>
1. YELLOW DATA CHECK: Request the data check on the yellow paper from your file and take in the testing area. Return completed form to testing desk.	Tuesday, March 4 OR Wednesday, March 5

## APPENDIX G

Handouts for First Training Session

## COMPUTER MATH GAMES ASSIGNMENT

One of your assignments for this term is to play two math games a minimum of 1½ hours per week on the computer.

The first game you will play is called POE. It is designed to teach the rules to the second game, EQUATIONS. You need not play POE with the intention of winning at first. In fact the rules begin to make sense when you lose a few times and must figure out why. There are two versions of POE -- FP POE AND FPR POE. You should begin with FP POE; then progress to FPR POE when you understand the FP version. When you find that you beat the computer at most of the games in FPR POE, you are ready to play EQUATIONS. You should begin playing EQUATIONS in about two weeks.

EQUATIONS is a game designed to provide a stimulating and entertaining opportunity for learning to work with equations. The computerized version contains 19 units, each unit contains several kits. The units progress in mathematical difficulty. Thus, as you learn more through the coursework of MTH 95, you should be able to play the more difficult units. You will be given more information on playing EQUATIONS at the HELP SESSIONS held during the week of January 28.

You are to attend one of the HELP SESSIONS scheduled in Kidder 282. Sign up for one of the sessions on the bottom of this sheet. Hand the completed bottom half of this sheet to the Graduate Assistant before leaving this help sessions.

-----  
TEAR HERE

## CHECK ONE

I plan to attend the session in Kidder 282 held on

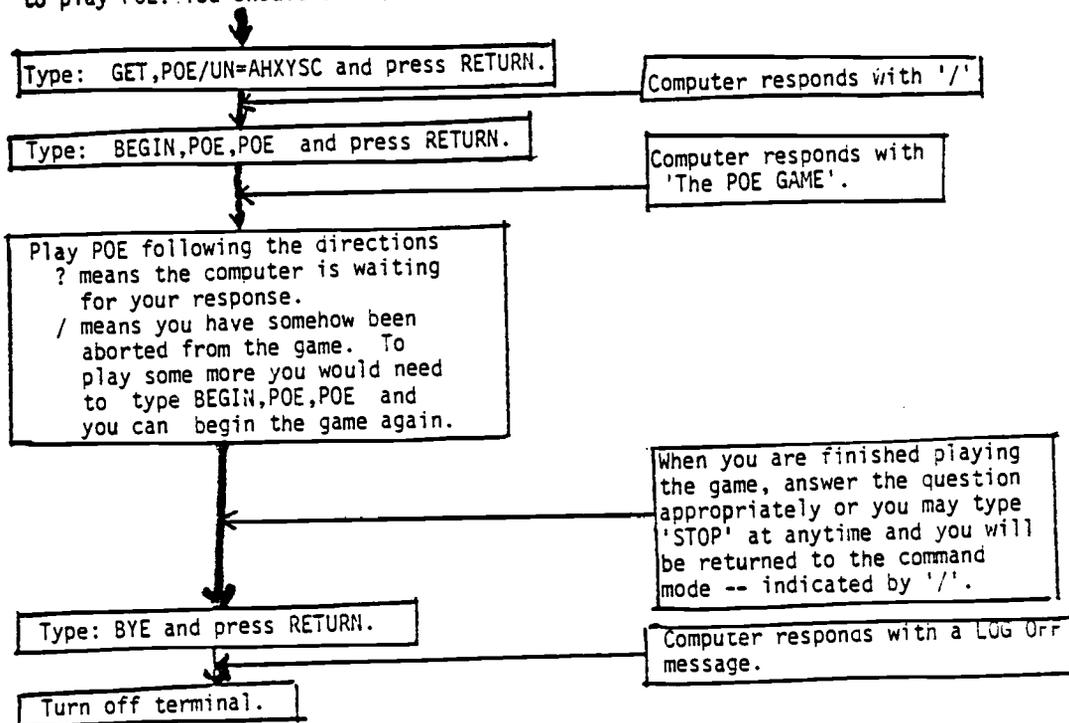
- \_\_\_\_\_ Monday, Jan. 28, 1700  
 \_\_\_\_\_ Tuesday, Jan. 29, 1700  
 \_\_\_\_\_ Wednesday, Jan. 30, 1900

\_\_\_\_\_  
Signature

## TO PLAY POE ON THE COMPUTER

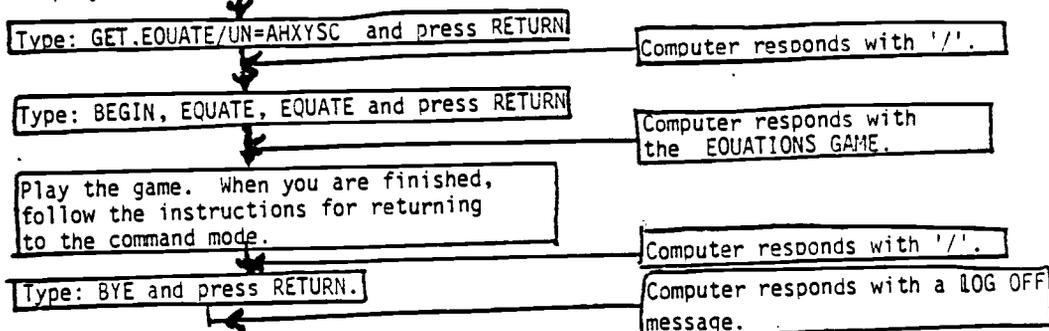
REMEMBER: If you make a mistake in typing, press ESC or ALT MODE and retype that line.

Once you are logged on to the computer you may follow these instructions to play POE. You should see '/' on the left of the screen.



## TO PLAY EQUATIONS ON THE COMPUTER

Once you are logged on to the computer you may follow these instructions to play EQUATIONS. You should see '/' on the left of the screen.



## FP-POE

MAT:

	Top			
	1	2	3	
Left	4	5	6	Right
	7	8	9	
	Bottom			

GOAL: Even or Odd number of connections.

CONNECTIONS: 3 touching squares which are filled with a "P" that run either from top to bottom or from left to right.

When it is your turn, you may:

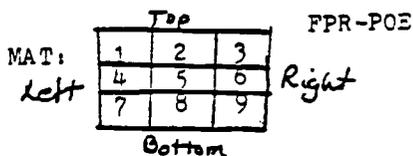
1. Fill an empty square
  - P, (Square number)
  - or F, (Square number)
2. Challenge
  - P-Flub: Last move made 'goal' impossible Q,P
  - A-Flub: Last move 'allowed' a solution in one more move C,A
  - CP-Flub: Last player failed to challenge a prior P-Flub C,CP
  - CA-Flub: Last player failed to challenge a prior A-Flub C,CA
- or 3. Declare Force Out \* F,GUT

PERMITTED CONNECTIONS have 3 P-squares

When TOTALING the number of connections a permitted connection may be counted but does not have to be counted.

Therefore, Diagonal Permitted Connections may be counted even or odd

\*FORCE OUT: A player should declare force out whenever the prior player has allowed a solution by filling in one more empty square and that writer was forced to do so. This will occur, if at all, when there is just one empty square left.



GOAL: Even or Odd number of connections  
 CONNECTIONS: 3 touching squares which are filled with a "P" or "R" the run either from top to bottom or from left to right.

When it is your turn, you may:

1. Fill an empty square P, \_  
F, \_  
R, \_
2. Challenge C, P
  - P-Flub: Last move made 'goal' impossible
  - A-Flub: Last move 'allowed' a solution in one more move C, A
  - CF-Flub: Last player failed to challenge a prior P-Flub C, CF
  - CA-Flub: Last player failed to challenge a prior A-Flub C, CA
- or, 3. Declare Force Out F, OUT

PERMITTED CONNECTIONS: 3 P-Squares  
2 R-Squares and 1 P-Square  
or 3 R-Squares

REQUIRED CONNECTIONS: EXACTLY 1 R-Square and 2 P-Squares

COUNTING CONNECTIONS:

In counting connections;

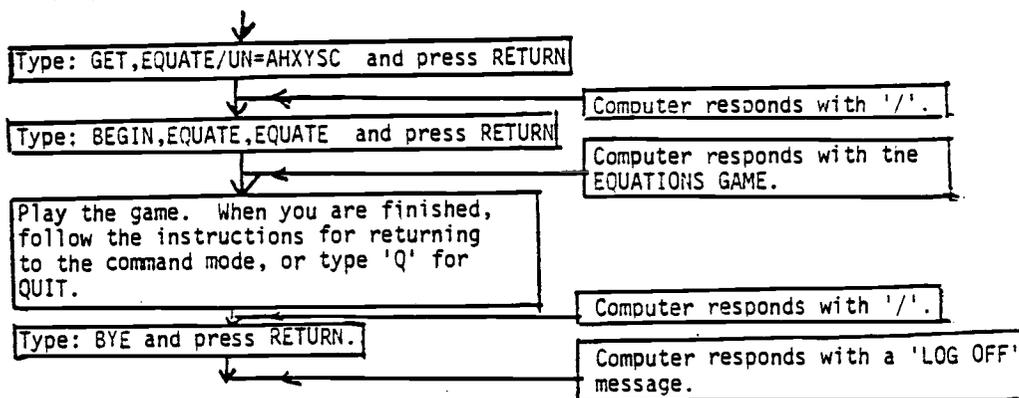
1. Each permitted connection may or may not be counted.
2. Each required connection must be counted.
3. In order for a set of connections to be a solution to the GOAL each R-square in the network must appear in at least one Required connection.

## APPENDIX H

Handouts for Second Training Session

## TO PLAY EQUATIONS ON THE COMPUTER

Once you are logged on to the computer you may follow these instructions to play EQUATIONS. You should see '/' on the left of the screen.



## \*\*\*\*\*IMPORTANT NOTES\*\*\*\*\*

1. Some times when you are playing EQUATIONS, you will get a message which indicates \*TIME LIMIT\*. Do not press RETURN. Just type: T,20 and press RETURN. You will be returned to the game.
2. <PRESS RETURN> means type C and press RETURN.
3. <O/I/H/Q/S> means type O to find your options.  
type I for discussion of an idea.  
type H for help.  
type Q to quit.  
type S to give a suggestion.  
Generally, you should use only O, H, or Q.
4. <Q/#> means type Q if you want to quit or type the KIT NUMBER you want to play.

## EQUATIONS

GOAL: One side of the equation determined by the computer.

RESOURCES: Operations and numbers allowed for the game.

When it is your turn, you may:

- |  |                      |
|--|----------------------|
| 1. <u>Forbid</u> a resource to be used in the solution     | F, <u>(Resource)</u> |
| <u>Permit</u> a resource to be used in the solution        | P, <u>(Resource)</u> |
| <u>Require</u> a resource to be used in the solution       | R, <u>(Resource)</u> |
| 2. <u>Challenge</u>  |                      |
| P-Flub: Last move made 'goal' impossible                   | C,P                  |
| A-Flub: Last move 'allowed' a solution in<br>one more move | C,A                  |
| CP-Flub: Last player failed to challenge a<br>prior P-Flub | C,CP                 |
| CA-Flub: Last player failed to challenge a<br>prior A-Flub | C,CA                 |
| OR 3. <u>Declare Force Out</u>                             | F,OUT                |