AN ABSTRACT OF THE THESIS OF

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Title: THE EFFECT OF GAMES ON COGNITIVE ABILITIES AND ON ATTITUDES TOWARD MATHEMATICS

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The purpose of this investigation was to determine if either of two selected commercial games, when used by seventh-grade mathematics teachers, would significantly improve students' (1) attitudes toward mathematics, (2) quantitative cognitive abilities, and (3) nonverbal cognitive abilities.

Equations, a mathematics game, and Tac-Tickle, a strategy game, were chosen as representatives of commercial games available to classroom teachers. The instruments used to measure cognitive abilities and attitudes were the Quantitative and Nonverbal Batteries of the Cognitive Abilities Test (CAT), Level F and Dutton's Attitude Scale. The major research hypotheses were as follows:

H_1: Student-participation in games will improve attitudes toward mathematics as measured by the Dutton Attitude Scale.

H_2: Student-participation in games will increase quantitative cognitive abilities as measured by the Quantitative CAT.

H_3: Student-participation in games will increase nonverbal cognitive abilities as measured by the Nonverbal CAT.

In addition, subtests of the Quantitative and Nonverbal CAT Batteries were used to measure six minor hypotheses.

A three-way analysis of covariance was employed to test the three major and six minor hypotheses. Pretest scores were used as the covariate. Seven F-values were calculated for each hypothesis to compare variations in adjusted posttest gains attributable to (1) sex, (2) school, (3) treatment, (4) sex-by-school, (5) sex-by-treatment, (6) school-by-treatment, and (7) sex-by-school-by-treatment.

Subjects for the experiment were 182 students from nine seventh-grade mathematics classes in three junior high schools. One experienced mathematics teacher in each of the three schools assisted in the experiment. Each game was randomly assigned as a treatment variable to one of three classes taught by each teacher. Hence, each teacher instructed one control class, one Equations experimental class, and one Tac-Tickle experimental class.

All nine classes were pretested with the Dutton Attitude Scale and the two batteries of the CAT. Students in the experimental classes played games for half the class period approximately every other day for six weeks. Conventional classroom lessons continued intermittently with game-instruction. At the conclusion of the experiment, all classes were posttested with the Dutton Attitude Scale and the two CAT batteries.

Findings

The 21 F-values for the three major hypotheses were not significant at the .05 level. Three F-values were found to be significant for the minor hypotheses. Differences in adjusted mean gain scores on the Equations Building subtest of the Quantitative CAT were significant for school and for school-by-treatment interaction. Also, school variability in adjusted mean gain scores on the Figure Synthesis subtest of the Nonverbal CAT was significant.

As a further analysis not related to the hypotheses, pretest scores on the Dutton Attitude Scale and the two batteries of the CAT were used to identify the top 30 and bottom 30 percent of the students in the control group, in the *Equations* group, and in the *Tac-Tickle* group. F-Tests were used to compare variations in adjusted attitude and cognitive ability mean gain scores between the top three groups. The resulting F-values were not significant. The bottom 30 percent groups were also compared by the same procedure. Again, no significant differences were found. Finally, t-test score gain comparisons were made between the top 30 and bottom 30 percent within each of the three groups. The calculated t-values revealed no significant differences between top and bottom students on any of the three measures.

The salient results of this investigation were as follows:

1. The intermittent use of games by actual classroom teachers was found to be as effective as conventional instruction in terms of increasing students' attitude and cognitive ability scores.
2. Game-participation did not produce significant boy-girl differences in attitude and cognitive ability scores.
3. Treatment comparisons between two types of commercial games revealed no significant differences in attitude and cognitive ability mean score gains.
4. The results of the study indicated that teacher variability was a significant factor in the learning of mathematics-equation comprehension and spatial relations through the use of games.

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THE EFFECT OF GAMES ON COGNITIVE ABILITIES AND ON ATTITUDES TOWARD MATHEMATICS

I. INTRODUCTION

The utilization of games as teaching devices has received considerable attention from educators during the past decade. However, teaching with games is not entirely an educational innovation since man has long recognized the importance of games as learning tools. Yet, until recently their application in the classroom has been extremely limited.

What factors account for the current interest in using games as teaching tools? One factor has been the evolution of games as new teaching materials through curriculum revision, a major issue of the 1950's. Financial assistance from the federal government along with substantial grants from industrial and private organizations provided the catalytic agent for curriculum examination and revision. A considerable amount of this effort was focused upon the development of teaching devices, the assumption being that an improvement in the instruments of learning would, in turn, improve the quality of education (Schwartz, 1969).

A second factor contributing toward this recent enthusiasm has been the influence of contemporary learning theory. One theory stresses the play element of game activities in learning. Here learning is seen as an enjoyable and active experience, totally involving the student, as contrasted to classrooms composed of passive students and teacher-disseminated information. This position has as its base ideas drawn from the writings of Jean Piaget, a Swiss psychologist, and Jerome Bruner, a Harvard professor of psychology. Piaget views learning as an active process. He says:

> Learning is possible only when there is active assimilation. . . All emphasis is placed on the activity of the subject himself, and I think that without this activity there is no possible didactic or pedagogy which significantly transforms the subject (1964, p. 184).

Bruner (1966) states that games "provide a superb means of getting children to participate actively in the process of learning--as players rather than spectators" (p. 95).

These two elements, emphasis upon instructional materials and student-centered learning theory, have resulted in the production and distribution of educational games designed by everyone from classroom teachers to professional publishers. Numerous games are now being commercially produced and marketed to schools as educational materials, touching upon practically every subject in the curriculum.

The design of these teaching games can be categorized under two basic types, nonsimulated and simulated. Glazier (1969) describes nonsimulated games as "the more traditional type," consisting of gameboards, cards, dice, or other "hardware" which apply effectively to quantifiable subject matter such as math and science (p. 4).

Simulated games, on the other hand, involve "role-play situations, more on the order of play without script." These games are "appropriate where qualitative factors are paramount, in social studies, for example" (p. 2). In other words, nonsimulated games usually emphasize manipulation of concrete variables, whereas simulated games generally emphasize human variables.

Although literature dealing with simulated educational games is vastly preponderant to that of the nonsimulated type, there exists a lack of adequate research to verify the educational worth of either type. This fact is made perspicuously evident by Glazier.

> There is surprisingly little good research evidence on the educational value of games. Anyone who has seen a good educational game played can give you volumes of anecdotal, impressionistic data proving the effectiveness of game learning, but organized, systematic studies are virtually nonexistent (p. 2).

Furthermore, this absence of research is even more conspicuous in the area of nonsimulated games developed for teaching mathematics. If educational games are to be considered as worthwhile teaching devices, it must be shown that they contribute some instructional value.

The Problem

The purpose of this study will be to investigate several hypotheses concerning the educational value of two selected games; Equations, a skill game, and Tac-Tickle, a strategy game. These two games were specifically selected for a number of reasons:

First, Equations and Tac-Tickle are representative of non-simulated, commercially prepared mathematics games easily attainable by the classroom mathematics teacher. Both games are produced and marketed as academic games adaptable to classroom use by WFF N'PROOF Publishers (Ruderman, 1965; Allen, 1969).

Second, representative commercial mathematics games were chosen because publisher-advertisement suggests these products can be effective instructional materials. For example, advertisement of the WFF N'PROOF games (including Equations and Tac-Tickle) in professional journals, educational catalogs, and other distributed literature implies that these games can be successfully used by any interested mathematics teacher.

A third argument for selecting these games over more familiar commercial games like chess or checkers is explicable. The latter types of games are not advertised as mathematics games, nor are they new to the learner. Perhaps these famous parlor games possess instructional value; however, any attempt to control treatment variables would be difficult if not impossible. Confounding variables such as previous playing experience, participation in the game outside the experimental setting, and game participation by the control would render the study invalid. Since Equations and Tac-Tickle are not familiar games to the students, nor readily accessible by them, they can be controlled in the experiment.

The fourth reason for the selection of commercially prepared games is based upon statements by many publishers who claim that their products are being used in a number of schools. Although this claim is without question, virtually no research studies exist to verify the results.

Fifth, these particular games were picked in order to make comparisons between two different types of games. Equations is a game of skill relying on a knowledge of mathematical operations. Tac-Tickle, in contrast, does not require a knowledge of mathematical operations. It is a game of pure strategy where winning depends upon reasoning and problem-solving ability similar to tic-tac-toe but far more complex.

Finally, the playing time required for each game is short, allowing several games to be played during a class period. In addition, these two games seem to present an appealing format and a level of difficulty appropriate for seventh-grade students.

The problem, then, is one of examining the games Tac - Tickle and Equations to determine if they have an educational purpose in the mathematics classroom. That is, do they increase quantitative or nonverbal cognitive ability? Does the utilization of these games in the classroom affect attitudes and interests toward mathematics? If participation in games increases cognitive abilities and produces positive attitudes toward mathematics, are these changes retained over a period of time? Is the learning value of mathematics games different for boys than for girls? Is there a difference in the learning value of a pure strategy game and a game in which the outcome depends, to some extent, upon subject matter skills? These questions suggest the following hypotheses for this study in an attempt to measure statistically the significant effects of the two academic games upon certain cognitive abilities and attitudes toward mathematics.

Statement of the Major Hypotheses

The test of each major hypothesis will compare differences in adjusted mean gains attributable to (1) sex, (2) school, (3) treatment, (4) sex-by-school, (5) sex-by-treatment, (6) school-by-treatment, and (7) sex-by-school-by-treatment. The three major hypotheses to be tested are as follows:

H_1: Student-participation in mathematics games will improve attitudes.

H_2: Student-participation in mathematics games will increase quantitative cognitive abilities.

H_3: Student-participation in mathematics games will increase nonverbal cognitive abilities.

If several significant findings result from the experiment, a one-month retention test will be considered.

Need for the Study

As Glazier points out, there is little systematic research to support the educational value of games. If academic games are worthwhile tools for teaching mathematics, then research is needed to verify their educational value. Currently, the available research is too limited for such verification. Consequently, most game-learning has been based upon enthusiasm, intuition, observation, and other forms of empirical evidence.

Carlson (1969) substantiates a need for research to evaluate educational games, and he also identifies some major questions which need answering.

> Do students learn more facts from games than from conventional teaching methods? Do strategy games spur critical thinking? Do they really inculcate constructive values? So far there is little evidence to argue one way or the other, particularly as to whether games teach values (p. 170-171).

Willoughby (1969), in his discussion of games in the _Encyclopedia of Educational Research_, lists only four references relevant to game research in mathematics; Allen _et al._ (1966), Paschal (1966), Davis (1966), and a report by the U. S. Office of Education (1964). In the course of his game literature review, Willoughby noted that "this seems to be a promising field for further research if a sufficient number of appropriate games can be created and tested" (p. 773).

Aiken (1970), in reviewing the research on attitudes toward mathematics from 1960 to 1970, mentions only one study related to the influential effect of the use of games in teaching mathematics. This reference is to Jones (1968), who reported a significant improvement in the attitudes of ninth-grade remedial students taught by modified program lectures and mathematical games.

A need for further investigation into the learning value and attitudinal effect of mathematical games seems obviously apparent from the noticeably small quantity of studies available on the topic. The following statements provide a summary of the needs for this study:

1. Many writers, including Glazier, Carlson, and Willoughby, express a need for additional research in the area of educational games.
2. The number of research studies thus far conducted to investigate the learning value of games in mathematics is exiguous.
3. Very few actual research studies exist concerning the effect of games on attitudes toward mathematics.

Assumptions

In order to conduct this study, these assumptions must be made:

1. Attitudes toward mathematics can be measured by the Dutton Attitude Scale.

2. Learning from educational games can be measured by the Cognitive Abilities Test (CAT).

Definition of Terms

1. Play is a voluntary activity involving one or more persons.
2. A game is a contest between two or more decision-makers, played according to predetermined rules, each striving to attain some particular goal.
3. An educational game refers to any game designed primarily to enhance learning, rather than just to amuse or entertain.
4. An academic game is an educational game which embodies a format based upon one or more academic subjects.
5. In this study, a strategy game is defined as an educational game requiring problem-solving abilities in the form of a careful plan or method by the decision-maker to either achieve a goal or prevent opponents from achieving a goal.
6. A mathematical game is either an academic game or a strategy game, usually consisting of some manipulative materials.
7. 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). In this study, it is a score derived by averaging the weighted values of the statements checked on the Dutton Attitude

Scale indicating how a student feels toward mathematics; higher scores indicating a more favorable attitude.

8. Quantitative cognitive ability refers to thinking ability which relies upon Relations, Number Series, and Equation Building; the subtests of the CAT test battery. In other words, this is a measure of a student's ability to classify quantities as greater, less, or equal; project number sequences; and comprehend mathematical operations, using quantitative concepts.

9. Nonverbal cognitive ability refers to thought processes involving Figure Analogies, Figure Classification, and Figure Synthesis; the three subtests of the battery. Nonverbal cognitive abilities "emphasize discovery of and flexibility in manipulating relationships expressed in figured symbols or patterns" (Thorndike and Hagen, 1971, p. 4). In this study, nonverbal cognitive ability is the score a student obtains on this test battery.

10. Level of significance is the determining probability level for rejection of each null hypothesis to be tested. The rejection level for this study is $\alpha = .05$.

11. For this study, retention is the ability of classes to maintain consistency in score changes one month after the conclusion of the treatment. That is, any significant test score gains by one group over another group will also be significant one month later.

12. Learning refers to the acquisition of mathematically related knowledge or skills as demonstrated by an increase in students' test scores on the Cognitive Abilities Test (CAT).

Limitations

1. The study is limited to three selected mathematics teachers in three different junior high schools and to nine classes of seventh-grade mathematics students.
2. The study is limited in generalizability because of selection procedures and sample size.
3. The study is limited by teacher cooperation according to pre-established procedures.
4. The study is limited to the extent to which subjects (students) seriously participate as players in the mathematical games.
5. The study is limited by the reliability and validity of the measuring instruments.

Design of the Study

The experimental design includes three mathematics teachers, each teaching three comparable sections of seventh-grade mathematics in different junior high schools. Nine randomly selected classes serve as control or experimental groups. The treatment variable for one experimental class in each school is the mathematical game, Equations, while the second experimental variable is the Tac-Tickle game. Students in the experimental classes play these mathematical games 20 to 30 minutes a day, three days a week during their regularly scheduled class period for six weeks.

One possible representation of the three teachers and nine classes involved in the study are diagrammed in Table 1.

Table 1. A table representing one possible outcome of treatment assignment.

Classes	Teachers		
	1	2	3
1		X_2	X_1
2	X_1		X_2
3	X_2	X_1	

X_1 = treatment variable Equations

X_2 = treatment variable Tac-Tickle

The experimental design selected for this study involves pretesting and posttesting the experimental and control groups, with a possible follow-up test one month later to measure retention. This procedure is described by Campbell and Stanley (1963) as the Non-equivalent Control Group Design. In actuality it is a quasi-experimental design because of the intact grouping of students into classes. Figure 1 pictorially represents a model of this design.

O------X_1------O------O

O------X_2------O------O

O-------------O------O

Figure 1. A diagram representing the Nonequivalent Control Group Design. The symbols X_1 and X_2 refer to the treatment variables, i. e., the games <u>Equations</u> and <u>Tac-Tickle</u> respectively. The symbol O represents measurements on both the CAT and the Dutton Attitude Scale.

Data consist of the pretest and posttest scores of the students in the nine classes. The Nonequivalent Control Group Design suggests an analysis of covariance (ANCOVA) as the proper statistical treatment of the data. The ANCOVA statistical technique provides adjustment for initial differences in attitudes and cognitive abilities between the classes, making them equivalent in respect to control measures (Popham, 1967).

Organization of the Remainder of the Study

The remainder of this study is separated into four chapters. Chapter II reviews literature related to educational games and studies involving the use of mathematical games. Chapter II describes in detail the procedure used in the study. An analysis of the data is reported in Chapter IV indicating the results of the tested hypotheses. The final chapter contains a summary, conclusions, and recommendations for further study.

II. RELATED LITERATURE

A review of the literature on games, particularly as games and play relate to learning, lends support to the productive value of games as direct educative agents. Based upon the conviction that games can be educational, this chapter is divided into the following sections: (1) Introduction, (2) Historical Contributions to Educational Games, (3) Play, Games, and Learning, (4) Functions, Advantages, and Limitations of Educational Games, (5) Related Research Studies, and (6) Summary.

Introduction

One can only speculate on the origin of games since their origin dates back to the beginning of civilization. Historical accounts of the origin of games through game references in early literature, anthropological, archaeological, and folklore sources indicated that games have always been a natural part of the culture and heritage of man (Avedon and Sutton-Smith, 1971). Whether games evolved for the direct purpose of teaching survival skills, transmitting cultural heritage to future generations, or for the seemingly unproductive purpose of recreation and social benefits has been argued by many writers.

> All people at all times have depended upon plays and games for a large part of the education of children, especially young children (Dewey, 1915, p. 103).

If games are as old as the culture of man, why has it taken so long for man to capitalize upon their educational potential for teaching subjects like mathematics? This is not to imply that games were a recent innovation to education, for they were incorporated into early school curriculums in the forms of physical activities, contests, and various other types of competition. Plato (Johnson, 1958) recognized the potential of using games for teaching mathematics over 2,000 years ago.

> Amusement and pleasure ought to be combined with instruction in order to make the subject more interesting. There should be games of various kinds such as a game played with different kinds of coins mixed together. There should also be problems connected with boxing and wrestling matches. These things make a pupil useful to himself and more wide awake (p. 69).

Although games have had recognition as teaching potentials for thousands of years, their use in the schools has been limited. It has been only recently that they have made a noticeable impact on the academic subjects in the classroom. Concerning this impact, Carlson (1969) wrote: "Whatever the learning effect of games, . . . there's no question that they are proliferating and spreading far beyond their original confines. Most noticeably in schools" (p. 14).

Historical Contributions to Educational Games

A review of the educational game literature (Boocock and Schild, 1968; Carlson, 1969; Abt, 1971; and others) suggested that the current educational game impact was a result of multiple complex factors which influenced educators' opinions regarding the value of game-learning. These contributions included (1) war games, (2) computer development, (3) mathematical game theory, (4) changing educational philosophy, and (5) new learning theories.

War Games

The history of war games revealed that military leaders have known the educational value of games for centuries. While no record of the first military usage of war games exists, references to war games among tribal groups can be found in ethnological literature verifying the antiquity of the practice. These first war games appeared to be exercises in physical skill and strategy, later moving to simulated board exercises of strategy in the form of chess (Avedon and Sutton-Smith, 1971). According to Murray (1913), the original name for chess was Chaturanga, which meant the army game. Avedon and Sutton-Smith both supported Murray's opinion that this game was invented by an inhabitant of Northwest India specifically for the purpose of teaching war strategy.

Van der Linde, on the other hand, proposed a contrasting theory. He claimed chess was invented to turn men's minds away from war (Barlett, 1969). In any case, this was paradoxical for, regardless of its origin or initial purpose, chess became an important tool in military education until after the Napoleonic Wars. Then war games moved off the chess board and onto maps with realistic, simulated exercises relying upon the judgment of umpires (Carlson, 1969).

During the eighteenth century, Prussian army officers separated war games into two types dependent upon rigid or free styles of play. The new free Kriegspiel eliminated the standardization of rules and procedures allowing a free style of play in which umpires were required to use military experience to determine the winner (Avedon and Sutton-Smith, 1971).

Computer technology and game theory added new dimensions to war games following World War II. War games are now a common practice in military education. Their worldwide acceptance and demonstrated success in teaching military strategy have provided convincing evidence that games have educational value.

Computer Development

The development of electronic computers in the late forties, combined with their present-day sophistication and accessibility, have unquestionably made a significant contribution to the emergence of educational games.

Within the past few years, several studies dealing with computer-based game-instruction have been conducted. However, since computer games are only tangentially related to this study, this literature was not reviewed. It is sufficient to recognize that computer programs are one means of game-instruction which has contributed to the educational game impact.

This contribution can be attributed, in part, to the adaptability of game-play to computer programs and the ability of modern computers to store enormous quantities of information with instantaneous retrieval. With the inclusion of mathematical game theory, the program can be written to include more than one player, yet allow each player to participate on his competitive level. Furthermore, the game skeptic is less critical of games when the player is simultaneously learning to use a computer.

Mathematical Game Theory

According to Richardson (1958), the mathematical theory of games received its impetus in 1944 through Von Neumann and Morgenstern's book, The Theory of Games and Economic Behavior. Previously, it had been possible to analyze pure chance games using the theory of probability, but games involving pure strategy or a mixture of chance and strategy were not adaptable to probability theory. The mathematical language and model of game theory solved this problem by allowing more control over decisions involving many possible outcomes and different pay-off values.

Decisions of n-person games involving two or more players result in either "zero-sum" or "non-zero-sum" pay-offs. In the "zero-sum" pay-off, the sum of the winners and losers is zero. That is, what one or more player wins, other players must lose. In contrast, "non-zero-sum" games allow pay-offs which are not necessarily at the expense of the other players; some or all players could win, or for that matter, some or all could lose. Mathematically complex n-person games ($n > 2$) with "non-zero-sums" have perhaps their best adaptability to competitive aspects of reality in the form of simulated games. Game theory contributed to the educational game impact by providing a model for realistic decision-making in the numerous business, social, and political science games now available to schools.

The combined effects of mathematical game theory, computer development, and the successful history of war games were influential factors in educational game acceptance and growth. However, only a changing educational philosophy allowed the game impact to become a reality.

Changing Educational Philosophy

From the first conception of formalized education as an institution in western civilization until present times, philosophy has guided the purposes, goals, and curricula of education and, consequently, the method of instruction. Early American education was based upon an eclectic of old world philosophies and deep religious convictions reflecting the socio-economic conditions and historical developments of the times.

In this early period, games were considered to be frivolous activities equated with play and amusement. Games were not perceived as worthwhile activities, particularly for older students. These same ideas have persisted through the years, continuing to influence modern education although to a much lesser extent.

The influence of pragmatism and progressive education brought about a change in the philosophy of education. As the educational philosophy changed, so did the learning theory, adding new dimensions to the purpose of play especially in terms of its educational value.

It is unlikely that educational games would have made the impact that exists today had it not been for such men as Dewey, James, Pierce, and others in this century who stressed sensory- and activity-learning. Boocock (Boocock and Schild, 1968) wrote that the defense of games culminated in the general educational philosophy of Dewey and the principles of progressive education.

> It has been said that the education innovations of the 1960's represents a second and more accurate translation of the principles of educational progressivism into classroom practices. . . . The core principles of the technique--e. g., the active and simultaneous participation of all students in an educational game, with the teacher in the role of aid rather than judge; the internal rather than external focus of rewards, and thus motivation in a game; and the linking of the student to the outside world. . . --can all be traced to one or another of Dewey's works (p. 57).

The existing consanguinity between the changing educational philosophy and new learning theories conducive to using educational games should be evident. Without the philosophy supported by Dewey and his contemporaries, the practice of learning through games would not have emerged into the present state of acceptability.

Early Learning Theories

Views on learning set forth by such eminent educators as Comenius, Rousseau, Pestalozzi, and Frobel supported theories based upon activities favorable to play and games as an integral part of the school curriculum. For example, Comenius, a seventeenth century Czechoslovakian educator, believed that children should be taught through activity and independent study. Rousseau, in the eighteenth century, advocated sensory impressions, motivation, and spontaneous expression in activities as essential to cognitive learning. Near the beginning of the nineteenth century, Pestalozzi, a Swiss experimental educator, attempted to make education meaningful through concrete examples and constructive activity for the learner.

Frobel, a nineteenth century German educator, also supported the educational value of activity-learning. Writing on the importance of games in education, Usova (1963), a Russian educator, claimed that it was Frobel who "first characterized games as an educational phenomenon" (p. 29).

Near the beginning of the present century, learning theories continued to stress the importance of play and game-like activities. In mathematics education, these ideas were reflected in the works of Montessori, Cuisenaire, and others who developed multisensory physical representations of arithmetic abstractions. The use of these materials enabled students to learn mathematical concepts through play and game-like activities. It also allowed teachers to spend less time directing students and more time observing them.

Finally, the pragmatic theory and practice of Dewey synthesized these earlier learning theories, lending support to educational games. Dewey believed learning should be founded upon activity. He emphasized, though, that an activity was not an end in itself. In order to be of educational value, an activity must contain directional content related to the needs of the student.

> The children must have activities which have some educative content, that is, which reproduce the conditions of real life. This is true whether they are studying about things that happened hundreds of years ago or whether they are doing problems in arithmetic (Dewey and Dewey, 1915, p. 292).

In referring to the modern psychology of his era, Dewey (1916) stated that the ready-made faculties of older theories had been substituted by a complex group of instinctive and impulsive new tendencies. The new tendencies had a decidedly favorable effect in classrooms. When students had an opportunity to participate in physical activities which involved their natural impulses, school became more enjoyable.

Furthermore, students accepted more responsibility and learning became easier.

Dewey (1916) openly favored the use of play and games. He stated that the role of play and games in the curriculum exceeded mere diversification, claiming that games and other activities provided a definite intellectual and social value. "In short, the grounds for assigning play and active work a definite place in the curriculum are intellectual and social, not matters of temporary expediency and momentary agreeableness" (p. 228-229).

Play, Games, and Learning

Dewey wrote extensively on the subject of play as it related to education. Within this body of literature, reference was frequently made to games. Many contemporary writers followed this same procedure, avoiding the distinction between play and game. In order to establish a frame of reference relating these activities, it is necessary to begin with a distinction between "game" and "play."

Distinction Between Game and Play

The use of the word "game" in conjunction with the word "play" to form such expressions as "play games" or "game-play" frequently results in an association of one concept with the other. This merging of concepts often leads to a confusing and unclear distinction between the definitions of the two terms. Consequently, many people consider the definition of game to be "fun," "amusement," "sport," or "frivolity." This type of reasoning is misleading. There is nothing in the formal definition of game which suggests that it must be a "sport" or that it must be "fun," "amusing," or "frivolous." In fact, some games are quite complicated and extremely serious.

In order to clarify the ambiguity encompassing the distinction between game and play, authorities on the two subjects have developed their own definitions. Three representative definitions of "game" are presented:

1. A game reduced to its formal essence is, according to Abt and Cogger (1969), "an activity among two or more independent decision-makers seeking to achieve their objectives in some limiting context" (p. 36). This identical definition was again stated by Abt (1971) in his book, Serious Games (p. 6).
2. Abt (1968) defined a game as "any contest (play) among adversaries (players) operating under constraints (rules) for an objective (winning, victory or payoff)" (p. 67).
3. Avedon and Sutton-Smith (1971) defined 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 disequilibrial outcome" (p. 7).

Although Glazier (1969) did not formally define game, he did state that a game required certain elements; players, rules, materials, and a win criterion. All of these authorities suggested that a game was a contest between two or more decision-makers, played according to predetermined rules, each striving to attain some particular goal.

An additional factor which distorts the definition of game is the methaphoric use of the word. One constantly encounters phrases like the "political game," the "waiting game," the "war game," the "teaching game," etc. These figures of speech seemingly suggest that any activity can be perceived as a game. A game does involve action and is, therefore, an activity, but the converse need not be true. All games are activities, but all activities are not games. In particular, play is one activity which does not have to be a game. Nor should puzzles be classified as games despite their similarity. Games require competition among players, whereas puzzles are a one-person activity in which only one player competes against himself, nature, or some other external element.

Play is usually described rather than defined. Sutton-Smith (1967) has pointed out that "there is no generally accepted definition of what play really is or what it does" (p. 362). When definitions are given, they do, as in the definitions of game, possess certain commonalities. Three examples are as follows:

1. Huizinga (1955) wrote that play was "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).

2. Bower (1968) agreed that play was a voluntary activity. He claimed that "essentially, play is 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).

3. Avedon and Sutton-Smith (1971) also supported the view that play was a voluntary exercise. These two authorities defined play as that type of behavior depicted by an "exercise of voluntary control systems" (p. 6).

Play can be unrestricted, competition-free, and independent of an outcome but games are restricted by rules, are competitive, and are dependent on an outcome. "Play may merely be the enactment of a dream, but in each game there is a contest" (Opie, 1969, p. 2).

Theories of Play

Near the beginning of this century, a number of theories were formulated which attempted to interpret the function of play. A cursory review of the more notable theories of this era should provide some insight into the attitudes toward play and games as educative agents.

One of the well known theories of this period was the "surplus energy theory" (Lehman and Witty, 1927, p. 7). This theory was generally associated with the writings of Schiller and Spencer. Spencer (1873) wrote that higher animals, when not fully occupied with their immediate needs, accumulated excessive time and energy in unused "faculties." If that energy was not released, organic need occurred to discharge it in the form of "superfluous and useless exercise of faculties" through the wasteful activity of play (p. 629-630). Sometimes this play activity took the form of a game.

Spencer's view of the nonproductivity of play was in contrast to Groos' (1919) productive view where play was considered to be the practice of natural hereditary instincts and other activities essential to life. Groos' "practice theory," presented from a biological standpoint, considered play as the exercising of various instincts merely for purposes of practice, especially when there was no occasion for the natural exercise of these instincts. In other words, Groos believed that the phenomena of play was dependent upon the psychological need to exercise ordinary instincts and impulses that otherwise remained inactive.

Groos later supplemented his "practice theory" by including the concept of catharsis. The "catharsis theory" explained play as a method of releasing accumulated anti-social energy in socially acceptable activities through physical contact games such as boxing and football (Lehman and Witty, 1927).

Several other theories were suggested during this era by other distinguished authorities. For instance, Hall proposed a "recapitulation theory" which explained play as the rehearsal of the activities of one's ancestors. McDougall, on the other hand, adhered to a "rivalry theory" considering play to be the development of rivalry instincts. As a last example, Patrick suggested a "recreation theory" based upon the principle that play resulted from a desire for a change of work (Lehman and Witty, 1927).

The theories presented up to this point attempted to justify play to a work-oriented society founded upon puritanical convictions. Therefore, these theories had little to do with the educational value of play or with the value of games that resulted from play. Dewey, however, saw little difference between play and work, stating that the economic condition of work often confused the distinction. While he did not state a theory of play, he did write about the function of play in education and life:

> Psychologically, the defining characteristic of play is not amusement nor aimlessness. It is the fact that the aim is thought of as more activity in the same line, without defining continuity of action in reference to results produced. Activities as they grow more complicated gain added meaning by greater attention to specific results achieved. Thus they pass gradually into work (Dewey, 1916, p. 241).

Recent literature indicates a changing attitude toward the functional significance of play and games. This changing attitude can be attributed to success in probability theory and mathematical game theory, interest in creativity, and emphasis upon behavior (Sutton-Smith, 1967).

Contemporary Views Linking Play, Games, and Learning

Through methods of clinical observation and interviews of children, Piaget (1964) has separated the structure of learning into the following four stages of intellectual development: (1) sensory-motor, (2) pre-operational, (3) concrete operational, and (4) formal operational. Within this structure, Piaget (1962) related the importance of play and games to intellectual development from the sensory-motor schemes to the conceptual schemes. He claimed that children begin learning by imitation and then proceed to play. The first stages of play encountered are symbolic games which gradually diminish into constructional rule-based games, and finally transcend into adult play and work. These forms of play and games develop cognitive structure and broaden creativity.

Bruner (1966) also stressed the importance of play and games in cognitive development. He stated that "play serves the function of reducing the pressures of impulse and incentive and making it possible thereby for intrinsic learning to begin. . ." (p. 135). He believed that playing games favorably involved students in "understanding language" and "social organization" (p. 95).

Dienes (1963b), a mathematician turned psychologist, considered play and game activities essential to developing structures in learning mathematics and for making the subject more enjoyable. He separated play into three categories; exploratory-manipulative, representational, and rule-bound play. The latter category, rule-bound play, is essentially playing a game and can be transformed into higher-order cognitive activities (for illustrations, see Dienes, 1963a, p. 21-56).

Dienes' theory for learning mathematics was based upon four principles which incorporated game-like activities. Freemont (1969) summarized Dienes' principles as follows:

1. The dynamic principle: preliminary, structured games provide experiences.
2. The constructivity principle: adventurous thinking is emphasized in these games and precedes analysis.
3. The mathematical variability principle: experiences involve a maximum number of variables for the situation.
4. The perceptual variability principle: provides for differences between individuals in concept formation and help children abstract the mathematical concept by presenting this concept in a broad variety of conceptual forms (Freemont, 1969, p. 50).

Another contemporary psychologist, Sutton-Smith (1967) viewed play and games as serving multiple functions in cognitive development. In reviewing current literature on the role of play in cognitive development, he suggested that play "increases the child's repertoire of responses, an increase which has potential value (though no inevitable utility) for subsequent adaptive responses" (p. 366). Thus the function of play and games as they relate to learning is perhaps one of making it easier for the learner to adapt representational sets to diverse materials, thereby encouraging creativity. Sutton-Smith pointed out that even though the research is meager, "there is evidence to suggest that play, games, and cognitive development are functionally related," although "the relation. . . is a loose one" (p. 369).

Much of the current educational literature indirectly lends support to the importance of play and games in learning. Writers such as Hawkins, Holt, Hull, Kohl, Silberman, and Rodgers, to name a few, emphasize a more student-directed and student-involved environment where teachers utilize a less structured approach and allow more freedom for the learner to depart from memorization in favor of higher level thought processes. Here the teacher's responsibility becomes one of coordinating and guiding the learning activity, providing the appropriate experiences, analyzing the learning difficulties, and giving assistance when needed. According to game advocates, this is the type of educational climate established when games are used for learning.

Functions, Advantages, and Limitations of Educational Games

The function of any educational game is to promote learning. This specific purpose of all educational games remains invarient whether they are simulated or nonsimulated, commercially produced or teacher prepared; or, even more explicitly, whether or not they are denoted by a subject matter title such as "mathematics game." If games are not valuable and useful as instructional materials, they are not educational.

To be sure, educational games are not a panacea intended to replace all other methods of instruction. Their function is, at best, one of supplementing the many existing practices which have been recognized as sound teaching methods, and have withstood the test of time.

The literature review of educational-game research is limited by a small quantity of controlled studies. Critics have pointed out that educational-game research has failed to prove that game-learning was superior to conventional methods of learning (Carlson, 1967). A second problem also exists. The literature alluding to the functions and values of educational games is highly opinionated and empirically supported. Writers, commenting on educational games and game-studies, generally "focus on describing procedures and rules of games," either omitting or giving secondary consideration to their purpose and value (Avedon and Sutton-Smith, 1971, p. 318).

In spite of the lack of research verifying the learning value of educational games, their use has continued to increase in universities and secondary schools (Carlson, 1967). Nor has this lack of research discouraged many game authorities from writing about the advantages and instructional values of educational games.

Before reviewing the literature attesting to the advantages of educational games, the following three precautions should be reconsidered:

1. The few research studies conducted have not established the value of educational games;
2. The majority of these studies involved simulated games; and
3. Most literature on educational games has focused upon describing games *per se*, with emphasis on rules and procedures.

Advantages of Educational Games

Abt (1971), in his book *Serious Games*, devoted an entire chapter to a detailed presentation favoring the improvement of education with games (see Chapter II, p. 15-34). He, like Wagner *et al.* (1957) and others, considered the motivational value of games as a salient advantage. Abt also emphasized the social values of game-learning and the excellent preparation for real-life decision-making provided by simulated games.

Coleman (1967) contended that the social value of games and their proximity to real life situations outside of school were the predominant assets of simulated games. His position on the social value of games has been supported by Mead (1934), Piaget (1948), Simmel (1950), Huizinga (1955), and Phenix (1965), who have all suggested that play and games provided valuable contributions to society.

The belief that educational games could facilitate learning spurred Coleman (1967) and other advocates to develop academic games modeled after athletic activities. This idea was based upon a study of adolescents which showed that students placed considerably more value on athletic success and peer recognition than on scholastic achievement (Coleman, 1961, 1967). Their academic games utilized principles of intramural and interscholastic competition varying from individual efforts to team efforts, and culminated in a National Academic Olympic Games Tournament (Egerton, 1966; Mikula, 1968; Carlson, 1969; and others). The primary goal of the competitive approach to academic games was to give recognition and prestige for intellectual accomplishments similar to that which athletes received, thereby altering the value and reward systems in schools. A second goal was to provide an alternate learning method (Mikula, 1968).

Boocock (1967) contended that educational games provided a different type of intellectual problem, increased the teacher-pupil relationship, and presented an aspect of realism that was lacking in most traditional classrooms. Abt and Cogger (1968) wrote that science games provided students the opportunity to actively learn science concepts by using prior knowledge, altering strategies, making decisions, and evaluating their own results.

Rasmussen (1969) viewed science games as means of learning to make sound and unbiased decisions on social and political issues involving science. Wagner (1961), Abt (1967), and Strum (Zieler, 1969) also cited numerous advantages of educational games. Hyman (1970) reviewed the literature in support of games and then presented specific justifications for their use. A partial list of educational game advantages which were found to be common throughout the literature is as follows:

1. Games provide motivation and increase academic interest.
2. Games provide social value.
3. Games increase attention span and concentration.
4. Games encourage and increase problem-solving ability.
5. Games provide an alternate method of learning subject-matter facts and skills.
6. Games reduce the authoritarian role of the teacher, and produce more desirable teacher-student relationships.
7. Games encourage student interaction and increase peer learning.
8. Games provide an aspect of realism that requires students to make their own decisions and evaluate their own results.

9. Games provide one means of individualizing instruction.

The literature reviewed in this section discussed advantages of educational games in general and particularly, simulated games. Most of the advantages mentioned though, are appropriate to nonsimulated mathematics games as well since their purposes, values, and uses are essentially congenial. The following review is devoted to justifications for using mathematics games.

Justifications for Mathematics Games. According to Abt (1971), the major objectives of mathematics games were problem conceptualization and drill. Other advantages cited by Abt included the increase in active participation, attention focusing quality, reduction of discipline problems, and enrichment.

Greenholz (1964) and Abt (1971) both felt that mathematical games were effective instructional materials for teaching slow learners. Greenholz stressed the active involvement and sensory manipulation of game-learning as a successful technique for adding variety and interest in mathematics.

Dienes (1963a, 1964) advocated the use of mathematical games to create an atmosphere of interest and excitement conducive to learning. Johnson and Rising (1967) and Johnson and Olander (1957) all gave support to that same beneficial quality of mathematics games.

Johnson and Olander (1957) and later Johnson and Rising (1967) discussed the role of mathematics games in the classroom. They stated that games could be used to achieve the following ten purposes:

1. Games can be used to make practice periods pleasant and successful.
2. Games can be used to teach vocabulary.
3. Games can be used to teach mathematical ideas.
4. Effective study habits may be motivated through the use of games.
5. Games are useful in providing for individual differences.
6. The attitude of children toward mathematics can be favorably changed through the use of games.
7. Games can be used to improve reading in mathematics.
8. Games can provide a means of summarizing or reviewing a unit.
9. Games can be related to seasonal events, and hence add to the enjoyment of the classwork.
10. Games may be appropriate 'homework' (Johnson and Rising, 1967, p. 97-98; Johnson and Olander, 1957, p. 292-293).

Allen *et al.* (1961) suggested the use of games of mathematical logic incorporated with programmed learning as a method to facilitate learning. Later Allen (1965) wrote on combining two mathematics games, *Wff'n Proof* and *Equations*, with programmed instruction. He claimed two points of intersection between programmed instruction and game-playing; first, some games are by nature a representation of programmed instruction and second, programmed materials can be incorporated into game learning. He felt that the advantages of this combination were: (1) active student participation, (2) immediate reinforcement of correct responses, (3) provisions for individualized instruction, (4) improved classroom interaction, and (5) self-motivated and enjoyable learning environments.

Two research studies by Allen _et al._ (1966, 1970) are reviewed later in this chapter. These studies indicated that mathematics games of the _Wff'n Proof_ type were useful in teaching specific subject-matter content and increasing problem-solving ability.

Further justifications for using mathematics games were: (1) their social and practice value (Johnson, 1958), (2) their value in guided discovery learning (Allen _et al._, 1971), and (3) their usefulness in process learning and concept development (Avedon and Sutton-Smith, 1971).

Limitations of Educational Games

As would be expected, educational games are not without criticism. According to one educator, simulation games "do little to prepare students for intellectual participation in a free, open, and rich society" and in actuality are creating a "step backward" in revising the social studies curriculum (Kraft, 1967, p. 72). Some writers have expressed negative attitudes toward all games, considering them useless and unnecessary. Spencer (1873) held this view and, more recently, so did Caillois (1961). In referring to this attitude, Boocock (Boocock and Schild, 1968) stated that in her impression, "this is the view of games still held by many educators" (p. 54).

Strum (Zieler, 1969) pointed out that "the negative psychological effects of games have been disregarded in the literature" (p. 2). It is not yet known what the effect of "losing" has on students' morale, motivation, and concentration span. "This may be a particularly critical area for the emotionally disturbed child" (Zieler, 1969, p. 2).

Other reservations regarding the competitive aspect of game learning have also been exhibited. Egerton (1966) warned of such possible dangers as: (1) excessive emphasis on winning rather than learning, (2) development of emotional rather than intellectual competition, and (3) evolution of a few consistent winners and many spectators.

Related Research Studies

Previously, it was pointed out that only a small number of research studies had been conducted to determine the learning value of educational games. Furthermore, it was verified that the majority of these studies dealt with simulated educational games. Consequently, it should be evident that research studies investigating the educational value of mathematics games is minimal.

Kieren (1969), in a review of research on activity learning in mathematics from January, 1964 through December, 1968, reported three studies dealing with the role of games in learning mathematics. His review was limited to a brief discussion of two studies by Anderson (1965) and Humphrey (1965). Anderson compared a random sample of first-grade students who played program games based on logic skills with a random control group. The data consisted of test results designed to measure responses to novel problems involving conjunctive logical statements. The experimental group needed fewer trials to solve the problems and scored significantly better in the number of problems solved than the control group. Humphrey suggested that first-grade students exposed to active games displayed a greater understanding of number concepts than children who learned the same concepts from a workbook.

Zschocher (Aiken, 1970) investigated the effect of group mathematical games on first-grade children in Germany. His game-favoring conclusions revealed a significant difference between childrens' scores on standardized tests in areas of number concepts, spatial orientation, and basic arithmetic.

Jones (1968) reported a pilot research project designed to test a series of hypotheses concerning the effects of programmed lectures and mathematical games upon the achievements and attitudes of low mathematics students. The modified program lectures were developed by the project staff and concepts were presented in the form of mathematical games. Two classes of ninth-grade summer-session students ranging from 15 to 17 years of age were the subjects of the study. The classes were pretested and posttested over a nine-week interval with the Cooperative Arithmetic Test and a sentence-completion attitude survey. Grade-placement scores on the

Cooperative Arithmetic Test were used to measure achievement gains. Attitude scores were determined by four judges who rated each of the 25 completion items on the sentence-completion questionnaire as either favorable, unfavorable, or neutral. Both classes increased in average grade-placement scores by one full year, significant beyond the .05 level. In addition, analysis of the attitude data indicated significant positive attitude changes toward the summer-session program.

Bowen (1969) conducted a study with fourth-grade honors classes to compare the learning of mathematical logic principles taught by two different methods. Two classes were selected as experimental groups while a third class served as a control. One experimental group studied logic from the textbook First Course in Mathematical Logic while the other experimental group participated in the mathematical logic game Wff'n Proof. Each group received instruction from Bowen for one hour each day, three days a week, over a period of six weeks. The measuring instruments consisted of four tests constructed by the experimenter. Although course objectives for the experimental groups were identical, different test forms were constructed to measure each experimental group. The two test forms were considered to be comparable and mathematically equivalent. Reliability checks on the tests proved them to be satisfactory measuring instruments. All three groups were pretested and posttested. The control group took both forms of the tests to further establish reliability of the instruments.

The textbook approach yielded mean difference scores superior to the game approach. A paired t-test indicated a difference score of -4.02 between the two experimental groups, resulting in a rejection of the hypothesis that game instruction would produce a significantly higher degree of proficiency than the textbook approach.

Sutton-Smith and Roberts performed a series of studies on the psychological properties of strategy, chance, and physical skill games. Their findings suggested that "involvement in games is systematically related to a variety of personality, cognitive, social, and political variables" (Avedon and Sutton-Smith, 1971, p. 488). Based on their research, Sutton-Smith and Roberts believe that individual competence in games may parallel psychological competence in reality.

One study reported by Sutton-Smith (Avedon and Sutton-Smith, 1971) tended to confirm this belief. The subjects for the study were 25 boys and 25 girls in grades one through six. The children were tested with a Tick Tack Toe Test designed to reveal whether a tic-tac-toe player was competing for a win or a draw. Other useful information obtained included scores from behavior ratings, achievements, and self-report inventories keyed for masculinity or feminity. The results indicated 15 significant correlations between performance on the Tick Tack Toe Test and other variables for girls, but only two for boys.

Separating the students by both sex and their desire to win or draw, revealed that winning girls had 11 of 16 significant correlations, far more than any other group. The tic-tac-toe game did not model the girl's power but simply reflected the way in which she aggressively asserted herself. In the case of the winning boy, only task persistence was found to be of significant correlation. The drawing girl had significant positive correlations with socio-economic and motivational variables but negative significant correlations with physical aggression and concern with mastery of gross motor skills. The drawing boy displayed significant positive correlation with only one variable, that being the motivational variable of need achievement.

Allen et al. (1966) conducted a study to investigate possible changes in I. Q. scores as a result of playing the Wff'n Proof game of mathematical logic. The subjects were 57 junior and senior high school students from the Burbank, California public school system. The experimental group consisted of 35 students enrolled in a 1963 six-week summer session program who played Wff'n Proof for approximately one hour each day during the term. Since each class period was two hours long, the extra hour was used to study rules and concepts of the game and for periodic testing.

The control group consisted of 22 junior high school students enrolled in regular classes during the fall of 1963. The experimental group was pretested and posttested with the California Test of Mental Maturity (CTMM) 1957, S Form, at the beginning and end of the summer session. Later the control group was given the CTMM twice with a six-week interval between the pretest and the posttest.

Because there were no high school students in the control group, the researchers compared only the results of 23 junior high students from the experimental group with the 22 students from the control group. Also, it should be noted that the experimental group had a much higher boy-girl ratio (16 boys to 7 girls) than the control group (10 boys to 12 girls). Other uncontrolled variables in matching the two groups included a ten-point higher average I. Q. score favoring the experimental group and the fact that the two groups were taught by different teachers.

Differences in mean score gains between the two groups were compared by a t-test. No significant difference was indicated for changes in language scores. However, nonlanguage I. Q. scores showed an average gain of +17. 3 for the experimental group as compared to +9. 2 for the control. This difference was significant at a probability level of p = . 02. Further investigations of the data to account for initial differences in nonlanguage I. Q. scores demonstrated that when initial I. Q. was covaried with change the result was even more significant. An analysis of differences between sexes indicated that although the girls in both groups had high gains, the difference was not significant (+14.3 for experimental to +13.6 for control). Boys in the experimental had an average gain of +18.7 as contrasted to an average gain of +3.9 for boys in the control group. Thus, boys accounted for virtually all the difference between the two groups.

Whether the significant difference in nonlanguage I.Q. scores was the result of playing Wff'n Proof, a classroom situation composed of volunteer summer session students untypical of the ordinary classroom, differences in teachers, or variability in administration of the tests was uncertain. The authors did not deny these possibilities. If these factors were influential, then the language scores should have been affected similarly but that was not the case; leading these researchers to believe that the difference was due to learning that occurred from participating in the game.

Allen et al. (1970) conducted another experiment patterned after the earlier study during the next summer session. In this study, the experimental group consisted of 43 junior high and high school students who were enrolled in a course on logic which met for three weeks, five days a week, four hours a day. The course of study consisted entirely of playing Wff'n Proof except for testing time. A pre-algebra course which was concurrently being taught by another teacher in the same summer program was selected as the control group.

As in the first experiment, both groups were pretested and posttested with the CTMM. Again a t-test was employed to analyze the data, yielding results similar to the first study. That is, no significant difference was found for language scores, whereas a significant difference at the .01 level was determined for the non-language scores. The mean changes reported by sexes for non-language was Boys-Experimental +22.4 vs. Boys-Control +7.3 and Girls-Experimental +18.0 vs. Girls-Control +5.1. Unlike the first study, the difference was attributable to both girls and boys.

Results of the two studies by Allen et al. are in contrast to Cherryholmes' (1966) review of research on simulated educational games. Cherryholmes concluded that simulation games produced more student motivation and interest, but there was no consistent or significant differences in learning, retention, critical thinking, or attitude. His conclusions were drawn from six studies utilizing simulated educational games.

Recently, Edwards et al. (1972) completed a study designed to investigate what effects the playing of Equations in competitive student-teams would have on mathematical achievement. Ninety-six seventh-grade students in an urban junior high school served as subjects for the study. These students were all enrolled in two low- and two average-ability general mathematics classes taught by the same instructor. One low- and one average-ability class was chosen for the experimental group, leaving the remaining two classes to be used for the control group. 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 experimenters. The experimental classes played Equations twice a week for nine weeks along with their traditional lecture-drill-quiz method of instruction. Individual game participation was in three-player groups, each player representing his four-member team.

At the end of a class period each player reported his score. This allowed team scores to be calculated and individual game opponents to be determined for the next session (see Allen's (1969) technique for establishing homogenity of players). Throughout the experiment the treatment group received two kinds of reinforcement, i. e., individual feedback on tests and quizzes and feedback from team standings in game performance through newsletters published two days after each tournament. The control group received only the traditional method of instruction with individual feedback on quizzes and tests.

A 2 x 2 x 2 treatment-by-ability-by-time-repeated-measures ANOVA was employed to analyze the data. The results indicated significantly greater gains for the experimental group on both the Stanford Achievement Test and the divergent solutions test. A treatment-by-ability analysis of the divergent solutions test for the low-ability classes revealed significant gains for the low-ability experimental class while the low-ability control class showed virtually no gain. A regression analysis of posttest scores on pretest scores for each class demonstrated considerably more similarity in the learning rates of the two experimental classes over the two control classes.

Summary

Literature related to educational games was reviewed in this chapter. A number of factors were considered which contributed toward a more acceptable view of educational games as worthwhile learning activities. These factors included the successful history of war games, modern computer technology, and game theory development; combined with a changing educational philosophy that generated new learning theories conducive to game learning.

The relationship between play, games, and learning was reviewed. A distinction was made between "play" and "games"; theories of play were reviewed; and contemporary views linking play, games, and learning were considered.

The functions and advantages of educational games were discussed and supported by the writings of Abt, Cogger, Boocock, Schild, Johnson, Wagner, Carlson, Coleman, and others. Specifically, justifications were presented for the use of mathematics games. The limitations of using educational games were also pointed out. Two problems were identified as needing further investigation, the psychological effects of losing and the possibility of an over-emphasis on winning.

The last section reviewed the available research studies on mathematics games. Studies conducted by Jones, Bowen, Sutton-Smith and Roberts, Allen et al., and Edwards et al. were considered in some detail. In particular, the results of the two studies by Allen et al. and a study by Edwards suggested that mathematics games possessed instructional value.

III. THE STUDY

This chapter is divided into the following main sections: (1) Game Selection, (2) Measuring Instruments, (3) The Hypotheses, (4) Pilot Study, (5) Description of the Games, (6) The Experiment, (7) Statistical Analysis of the Data, and (8) Summary.

Game Selection

The problem was to determine if commercially produced mathematics games, when used by authentic classroom teachers, would significantly (1) influence students' attitudes toward mathematics, (2) increase quantitative cognitive abilities, and (3) increase nonverbal cognitive abilities. Two games, Equations and Tac-Tickle, were selected to represent the commercial mathematics games. These two games were chosen for the following reasons:

1. Equations and Tac-Tickle were representative examples of commercially marketed games for school use.
2. They were representative of two different types of games which allowed comparisons to be made between a pure strategy game and a skill game.
3. Publisher-advertisement suggested that these games were effective instructional materials.
4. Most students were not familiar with the games and did not have

access to them outside of the classroom. If a common game like chess had been selected the experiment would have been virtually impossible to control.

5. A pilot study conducted prior to the actual experiment indicated that the games were appropriate in level of difficulty for seventh-grade students.

6. Both games required a short playing time, averaging approximately five minutes for completion.

Measuring Instruments

The Cognitive Abilities Test, Multi-Level Edition and Dutton's Attitude Scale were selected as the measuring instruments for this study.

The Cognitive Abilities Test

Historically, the Cognitive Abilities Test (CAT) is an outgrowth of the Lorge-Thorndike Intelligence Test in which the multi-level format has been retained. The CAT consists of three batteries. These batteries, or subdivisions, are designed to measure verbal, quantitative, and nonverbal cognitive abilities. Only the Quantitative and Nonverbal batteries were used for this study.

The Quantitative Battery consists of the following three subtests: (1) Quantitative Relations, (2) Number Series, and (3) Equations

Building. The Nonverbal Battery measures cognitive abilities which are "not bounded by formal school instruction" (Thorndike and Hagen, 1971, p. 4). This battery is also divided into three subtests as follows: (1) Figure Analogies, (2) Figure Classification, and (3) Figure Synthesis. Both batteries have been developed to eliminate the reading of verbal material. Items of the Nonverbal Battery contain neither words nor numbers.

The CAT was normed with the Iowa Test of Basic Skills (ITBS) for grades three through eight. Correlations between these two tests clearly indicated a high criterion related validity, especially between quantitative and arithmetic scores. Kuder-Richardson reliability estimates, means, and standard deviations have been determined for each test at the recommended grade level. Reliability estimates were greater than .91 for all levels of both batteries. Intercorrelations of subtests and a bi-factor type of factor analysis of these correlations indicated a common factor running through all the subtests. The authors referred to this common factor as "General Relational Thinking" (see Thorndike and Hagen, 1971, p. 101-104).

The CAT was selected for use over other measuring instruments for the following reasons:

1. It is easy to administer and score.
2. It contains a quantitative test designed to appraise mathematical reasoning ability.

3. It contains a nonverbal test constructed to measure reasoning abilities that are not dependent upon reading and quantitative skills.

5. Both of these batteries have been developed to eliminate the reading of verbal material.

5. The quantitative and nonverbal tests contain three subtests depicting classifications, analogies, and synthesis. The Equations Building subtest was especially appropriate because it required the same skills necessary to successfully play the Equations game.

6. Norms are provided, and evidence is established to substantiate the test as a reliable and valid measuring instrument.

Dutton's Attitude Scale

Dutton's Attitude Scale is a 15-item, Likert-type instrument for measuring attitudes toward arithmetic. This attitude scale, a revision of an earlier instrument, has a reported reliability coefficient of 0.90 (Dutton, 1968). Aiken (1970) cited that Dutton's scale has probably been used more than any other instrument for measuring attitudes toward arithmetic. Although the scale was originally constructed to measure attitudes of future elementary teachers, it has been extensively used in junior high schools to measure changing attitudes toward arithmetic and "new mathematics" (Aiken, 1970; Dutton, 1968).

Through personal correspondence with Dutton, permission was granted to delete and use his attitude scale. One change was made in the instrument prior to the pilot study. The word "math" was substituted for the word "arithmetic" because "math" is currently more vogue in junior high schools than "arithmetic." The substitution was an attempt to eliminate ambiguity and, hopefully, to provide a more accurate measure of how each student felt about mathematics. Callahan (1971) made this same substitution in Dutton's scale to measure eighth-grade students' attitudes toward mathematics. Furthermore, the literature indicates that these two words are used synonomously.

The revised attitude scale is presented in Appendix A. Indicated scale-values for each item have been added to show the weighted item-values used to score the test.

Briefly then, Dutton's Attitude Scale was chosen for the following reasons:

1. It is easy to administer and score.
2. It is reported to be a reliable instrument.
3. The scale has been tested with seventh-grade students.
4. It is a commonly used scale for measuring attitudes toward mathematics at the junior high school level.

The Hypotheses

The test of each major and minor hypothesis compared differences in adjusted mean gains attributable to (1) sex, (2) school, (3) treatment, (4) sex x school, (5) sex x treatment, (6) school x treatment, and (7) sex x school x treatment. The three major hypotheses tested were as follows:

H_1: Student-participation in mathematics games will improve attitudes as measured by the Dutton Attitude Scale.

H_2: Student-participation in mathematics games will increase quantitative cognitive abilities as measured by the Quantitative Cognitive Abilities Test.

H_3: Student-participation in mathematics games will increase nonverbal cognitive abilities as measured by the Nonverbal Cognitive Abilities Test.

Six minor hypotheses were also tested. Measures for each of these hypotheses were subtests of the Cognitive Abilities Tests. The minor hypotheses were as follows:

$H_{2.1}$: Student-participation in mathematics games will increase ability to classify quantities as greater, less than, or equal as measured by the Quantitative Relations subtest.

$H_{2.2}$: Student-participation in mathematics games will increase ability to project number sequences as measured by the Number Series subtest.

$H_{2.3}$: Student-participation in mathematics games will increase ability to comprehend mathematical operations as measured by the Equations Building subtest.

$H_{3.1}$: Student-participation in mathematics games will increase ability to recognize figure similarities as measured by the Figure Analogies subtest.

$H_{3.2}$: Student-participation in mathematics games will increase ability to recognize common attributes as measured by the Figure Classification subtest.

$H_{3.3}$: Student-participation in mathematics games will increase understanding in spatial relations as measured by the Figure Synthesis subtest.

Pilot Study

A pilot study was conducted in May, 1972 at Western View Junior High School in Corvallis, Oregon. The purpose of this pilot study was to determine the appropriateness of the games, the measuring instruments, and the suggested hypotheses.

One teacher and two college students assisted in the study. Two boys and two girls were randomly selected from three seventh-grade mathematics classes, totaling 12 experimental subjects. The two boys and two girls from each class were assigned to play one of three mathematics games, Equations, Tac-Tickle, or Mem, daily for two weeks. These students left their regularly scheduled mathematics classes and played the games for the full 45-minute class period. Each student was required to complete and submit all class assignments given during their absence.

The Mem game (Hopfenberg, 1968a, b) was tested as an alternate strategy game. However, Mem proved to be more difficult to teach than Tac-Tickle, the other strategy game. It also required a much longer playing time. Observed behavior and students' comments indicated that the concepts of Mem were too subtle and complex to be enjoyable. A succinct summary of differences between pre- and posttest scores on the attitude scale and the cognitive abilities tests are presented in Table 2.

Table 2. Mem difference scores.

	Attitude	Quantitative	Nonverbal
Girl 1	-2.4	+8	+3
Girl 2	-2.1	-3	-1
Boy 1	-1.5	-1	-2
Boy 2	+1.0	+4	+3

Table 2 illustrates the possible negative affects of Mem upon attitudes toward mathematics at the seventh-grade level. Three of the four students decreased in attitude scores, reinforcing the opinion that this game was too difficult.

Tac-Tickle was found to be more suitable than Mem for purposes of this study. Directions were simple and rules were quickly learned. Each game required a short playing time, approximately three to five minutes. Students indicated, both verbally and by their behavior, that they enjoyed the game. Enthusiasm remained high during most of each participation time. At the conclusion of two weeks, students continued to demonstrate an interest in the game by their involvement and favorable remarks. Attitude score differences appeared to support this observation. Albeit, the sample size was so small that statistical comparisons were ignored in favor of empirical analysis.

Differences between pretest and posttest scores for the Tac-Tickle subjects are presented in Table 3 as follows:

Table 3. Tac-Tickle difference scores.

	Attitude	Quantitative	Nonverbal
Girl 1	+ .6	a	+6
Girl 2	+ .9	+1	+6
Boy 1	+ .5	+2	+4
Boy 2	+1.0	-4	+5

[a]Did not complete the pretest.

Table 3 is of particular interest since it reveals an increase in score differences for all students in attitudes and nonverbal scores, suggesting that perhaps this game did, in fact, affect these two areas.

All four students who participated in the Equations game displayed an eagerness to learn the game. By the end of the first session they had an adequate comprehension of the rules and were able to competitively participate. During the first week, only game one was played. Each game lasted from four to five minutes. The next week the second game was introduced, and several questions were raised by the students about mathematical operations such as division by zero. Interest fluctuated during the two weeks of play, but at the conclusion, students expressed a desire to continue play rather than return to their regular mathematics classes.

Table 4 shows the differences between pretest and posttest scores for the Equations group.

Table 4. Equations difference scores.

	Attitude	Quantitative	Nonverbal
Girl 1	+2.7	+16	+1
Girl 2	+1.1	- 2	+2
Boy 1	+5.5	- 4	-1
Boy 2	+3.0	- 4	0

The scores given in the above table, like those shown in Table 3, indicate an improvement in attitude for all students. They do not, however, show the increase in nonverbal cognitive abilities scores which were attained by the Tac-Tickle players.

Based upon the pilot study, the following observations and conclusions were made:

1. Boys preferred competition with boys, and girls preferred competition with girls.
2. Boys were more enthusiastic and more competitive than girls.
3. The last Equations session consisted of an all-period tournament between the four students. A boy who was failing his regular mathematics class won the tournament.
4. Although Mem was shown to be too difficult and time consuming for seventh-grade students, Tac-Tickle and Equations proved to be appropriate games for the experiment.
5. Students' attitude scores on the Dutton Scale were judged to be reliable measures by their teachers and the assistants.
6. The Cognitive Abilities Test was easy to administer and score.
7. The CAT appeared to be a reliable measure except for a few sections of Level E form (the form recommended for grade seven) which were found to be too easy. This negative skewedness created a "topping effect," and reduced the chances for gains between pretest and posttest measurements.

In an effort to determine if fall term seventh-grade students would score above the expected norms provided in the examiner's manual (Thorndike and Hagen, 1971), the same form (Level E) was administered to a group of sixth-grade students at Roosevelt

Elementary School which is a feeder school for Western View Junior High School. These test results were again higher than the norms provided by the publisher. Based upon these findings, a decision was made to use a more advanced test (Level F) in the fall experiment. The more complicated Level F form eliminated a few of the easier beginning exercises and included an equal number of harder exercises at the conclusion of each subtest. Most of the same test items were common to both forms. All other testing variables such as time, length, etc., remained invariant. The Level F test is recommended for use in grade eight or grade seven in above average classes and schools (Thorndike and Hagen, 1971, p. 5).

Description of the Games

Both of the selected games, Equations and Tac-Tickle, were designed to encourage favorable attitudes toward mathematics and "symbol-handling activities in general, as well as to teach something about mathematical logic and provide practice in abstract thinking" (Allen, 1969, p. 1).

Tac-Tickle

Tac-Tickle is a two-person, positional game of pure strategy invented by Ruderman (1965). Like other, more familiar positional games such as chess, checkers, and tic-tac-toe, successful play is dependent upon problem-solving ability. A diagram of the game board is illustrated in Figure 2.

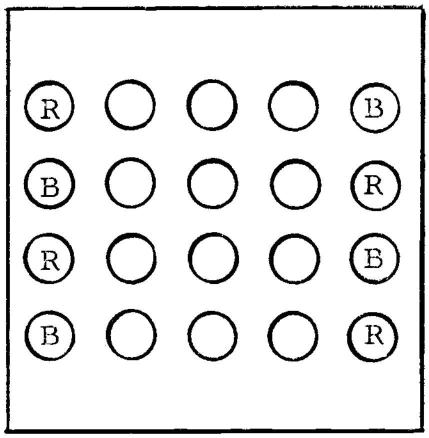

Figure 2. Diagram of the Tac-Tickle playing mat (Ruderman, 1965).

The above diagram represents the Tac-Tickle board ready for beginning play. The playing mat is a small 20-hole square made of Styrofoam. Playing pieces consist of four red and four blue cubes which are indicated by R and B in the diagram.

Players select a color and take turns moving their pieces. A move consists of shifting one piece to a vertically or horizontally adjacent and vacant hole. Diagonal moves are not allowed in the basic Tac-Tickle game, but they are permitted in some of the variations. The object of the game is for a player to get three pieces of his color next to each other in a vertical, horizontal, or diagonal line.

Several variations of Tac-Tickle are explained in the game instructions. Two examples are the commutative and the symmetric variations. The commutative variation allows the exchanging of positions for any two adjacent pieces as an alternate move. The symmetric version allows either vertical, horizontal, or point symmetrical moves to vacant spaces as an option to the basic move.

In addition to the many variations and combinations of Tac-Tickle, a cardboard playing mat is provided for Chinese Tac-Tickle, a game which allows jumping similar to Chinese checkers. An illustration of this board, ready for play, is diagrammed in Figure 3.

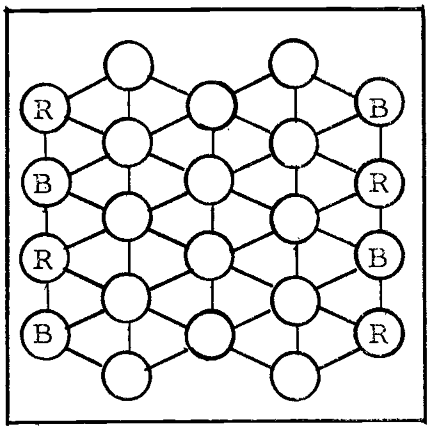

Figure 3. Diagram of the Chinese Tac-Tickle game-board (Ruderman, 1965).

Figure 3 illustrates the Chinese Tac-Tickle game board with playing cubes in the starting positions. R and B again denote red and blue. Game pieces, or cubes, must be moved in pattern with the game board lines. The objective of the game is the same as the basic

Tac-Tickle game. A win occurs when one player has aligned three of his game pieces along one of the indicated patterns, with no intervening spaces.

Equations

Equations is a five-game kit developed by Allen (1969) to provide occasion for learning the elementary mathematical operations of addition, subtraction, multiplication, division, exponentiation, and root.

The number of players required to play Equations ranges from two to as many as can conceivably encircle the playing area and see the cubes, although "three-player games are recommended for classroom use" (Allen, 1969, p. 3).

Game pieces included in the kit consist of 32 dice-like cubes, one playing mat, and a timer. Twelve of the 32 cubes are red, eight are blue, six are green, and six are black. Table 5 gives a breakdown of symbols on the color-coded cubes.

Table 5. Equations playing cubes.

Cube color	No. of cubes	Symbols on each cube
red	12	0, 1, 2, 3, +, -
blue	8	0, 1, 2, 3, x, ÷
green	6	4, 5, 6, -, x, *
black	6	7, 8, 9, +, ÷, $\sqrt{\ }$

Each cube contains six symbols, one symbol appearing on each face. Symbols include both numerals and operational signs. The indicated operations are addition (+), subtraction (-), multiplication (x), division (÷), power (*), and root ($\sqrt{\ }$).

Games can be played at many levels of difficulty dependent upon the color and number of cubes used. Recommended game levels by Allen (1969, p. 4) are reproduced in Table 6.

Table 6. Equations game levels.

Game level	Approximate age level	No. of cubes to use: red	blue	green	black
1	6	12			
2	6	8	8		
3	6	6	6	6	
4	11 and up	5	5	5	5

In addition to the game levels shown in the above table, a fifth level, Adventurous Equations, can be played. In Adventurous Equations each player is required to introduce one new rule at the beginning of a game (see Allen, 1969, p. 33). All five game-levels involve the same style of play, but each increases in complexity.

Figure 4 provides a diagram of the Equations playing mat (Allen, 1969, p. 6).

Resources		
Forbidden	Permitted	Required
____________ Solution	=	____________ Goal

Figure 4. Equations playing mat diagram.

The sections of the playing mat shown above are essential to all versions of Equations. To begin a game, the first player shakes the allotted cubes to determine the resources. After establishing the resources, this same player sets a goal on the playing mat or claims "no goal." At this point, any of the remaining opponents may challenge if they believe the set goal is not attainable from the resources or the goal can be achieved in the next move. In the event that no challenges are made, the second player must move a cube from the resources to either the forbidden, permitted, or required area of the playing mat. Following the move the opponents are provided another opportunity to challenge. Any challenge at this stage asserts that one of the following three mistakes have been made:

1. The goal is no longer attainable from the resources, permitted, or required sections of the playing mat.
2. It is possible for the next player to achieve the goal in one move.

3. Previous mistakes have been made.

When it is no longer possible for a player to keep the next player from achieving the set goal in one move, this fact is stated, and the game ends in a draw. Perfectly played games will always end in a draw. To win, a player must correctly challenge an opponent's mistake, or be incorrectly challenged by another opponent. When a challenge is made, the third player must join either the challenger or the mover. Obviously, intentional mistakes are a strategic move since they can later be challenged by the player who originally and intentionally made the mistake.

The Experiment

A written request was submitted to the Superintendent of Corvallis School District 509J in August, 1972 seeking permission to conduct the study during the subsequent fall term. Following the request, the researcher was invited to meet with the Assistant Superintendent of Instruction and three junior high administrators, whereupon permission was granted to proceed with the study in the three Corvallis junior high schools.

Population

One hundred eighty-two students in nine sections of seventh-grade mathematics classes served as subjects for the experiment.

Seventh-grade students were specifically selected as subjects for the following three reasons:

1. All students at the seventh-grade level are required to take basic mathematics, while eighth and ninth-grade students are presented optional choices of mathematics classes.
2. This is the beginning level of departmentalized instruction where one teacher instructs several classes of the same subject-matter.
3. Research by Dutton (1968), Dutton and Blum (1968), Reys and Delon (1968), and Callahan (1971) indicated that attitudes toward mathematics are acquired throughout school, but the most influential period seems to be the junior high school years, particularly grade seven.

Experimental Design

The experiment is a "Nonequivalent Control Group Design" as described by Campbell and Stanley (1963, p. 217). One seventh-grade mathematics teacher from each of the three junior high schools was chosen to assist in the experiment. This selection required each teacher to be currently teaching three comparable sections of seventh-grade mathematics in his school. The two games, Equations and Tac-Tickle, were randomly assigned as treatment variables in two classes taught by each teacher. A representation of the teachers, schools, and random assignment of the two game-variables by class period is shown in Table 7 below.

Table 7. Random assignment of games by class period by school.

Class period	Teacher 1, Cheldelin	Teacher 2, Highland	Teacher 3, Western View
1	-	Control	-
2	Control	-	Equations
3	-	Equations	Tac-Tickle
4	-	-	-
5	-	-	-
6	-	-	-
7	Equations	-	-
8	Tac-Tickle	Tac-Tickle	Control

As Table 7 reveals, the time-of-day variable was not controlled. This was unavoidable since random assignments had to be made within the existing class schedules.

All nine classes were pretested and posttested with the Cognitive Abilities Test and Dutton's Attitude Scale. Experimental time-length was approximately six weeks. Games were originally scheduled to be played in the experimental classes three times per week for 20 to 30 minutes of the class period. As a result of uncontrollable circumstances such as school assemblies, teacher inservices, holidays, and other classroom proceedings which took precedence, this schedule could not always be met. However, all experimental classes did play games for the allotted class time at least twice each week. The total number of participation days in each school is shown in Table 8.

Table 8. Total time of game participation.

School	No. days students participated in games	Time lapse between pretests and posttests (weeks)
Cheldelin	17	7 [a]
Highland	15	6
Western View	13	5-1/2

[a]Included Thanksgiving holidays

A minimum of seven hours of classroom instruction time was devoted to game participation. In addition to showing the number of days that students participated in games, Table 8 also gives the time lapse between pretesting and posttesting dates.

In review, the experiment was a Nonequivalent Control Group Design in which pretest scores were used as a covariable to adjust for initial differences between intact groups (classes). The mathematics game Equations was introduced into three experimental classes as one treatment variable. Tac-Tickle was the treatment variable in three different classes. Each teacher taught one Equations experimental class, one Tac-Tickle experimental class, and one control class in which no games were played. Students played the games for 20 to 30 minutes, approximately every other day for a period of six weeks.

Teacher Selection

The experimental design limited the selection to one teacher from each junior high school who was instructing at least three comparable sections of basic seventh-grade mathematics. Three experienced classroom teachers were selected to participate in the experiment, based upon the following rationale:

1. Any authentic measure of the effectiveness of mathematical games in typical classroom situations had to include actual classroom teachers, because they are the people who will ultimately determine the fate of game-learning.
2. The utilization of teachers in their own classrooms created a natural environment and eliminated biases inflicted by the presence of a third party. It also allowed teachers to continue their regular classroom lessons when games were not being played.
3. The involvement of more than one teacher was needed to minimize the effect of confounding variables arising from individual teacher attitudes and methods of instruction.

Final recommendations for the selection of the teachers were made by the junior high school administrators. The researcher then contacted the three teachers individually about their willingness to cooperate in the study.

Two of the recommended teachers were familiar with the games as a result of a college course for secondary mathematics teachers which they had completed the previous summer. Neither teacher, however, had used the games in his classroom. These two readily agreed to take part in the experiment. The third teacher was reluctant to become involved, insisting on further evidence for a need to play games in his classes. After a complete explanation of the study and playing all versions of the two games several times, he agreed to participate.

Procedures

Each teacher was individually instructed in the administration of the measuring instruments and rules of the games. The teachers were also instructed in the procedure of the experiment. The procedure which all teachers adhered to was as follows:

1. In all classes the attitude scale was administered first, followed by the Quantitative Battery of the CAT, and concluded with the Nonverbal Battery.
2. The game-playing schedule which was half the class period every other day, was followed as closely as possible.
3. Tac-Tickle was used as a two-person game.

4. Equations was used as a three-person game.

5. Winners were matched with winners; losers were matched with losers in order to stimulate interest and competition.

6. The control classes were not allowed to play any type of mathematics game during the experiment time. The only game used in the Equations classes was Equations, and the only game played in the Tac-Tickle classes was Tac-Tickle.

7. Games were only played during the regular class period. Teachers did not allow students to remove the games from the classroom at any time during the experiment.

8. The same mathematical topics were taught to all three classes within each school. All schools taught basic mathematical operations and problem-solving with whole numbers.

Teachers were periodically visited by the researcher throughout the experiment. The two teachers who had initially indicated an interest in using games frequently made enthusiastic comments regarding their own attitudes. The teacher who was at first reluctant stated that he tried to remain neutral toward the games. Each teacher spent many extra hours in preparation. The cooperation of all three teachers was commendable.

Data Collection

As previously stated, all nine classes used in the study were pretested and posttested with the Dutton Attitude Scale and two batteries of the Cognitive Abilities Test. These tests were administered by the classroom teachers during the regularly scheduled class periods. Teachers explained to all nine classes that the test results were to be used in a research study. Teachers also assured the students that test scores were confidential, tests would not be scored by the teacher, and scores would not be used for grading purposes. At the conclusion of each testing session, the testing materials were placed in a box to be picked up later by the researcher.

Two to three classroom periods were used for test administration at the beginning and again at the end of the experiment. While the attitude scale was not a timed test, about ten minutes were needed for distribution, directions, responses, and collection. Each battery of the CAT required a 32-minute testing period in addition to time for giving directions, distributing, and collecting the materials.

Students transferring into or out of the classes during the experiment were excluded from the study since both pre- and post-measures for these subjects were not available. In a few cases, when a student was absent and unable to complete all of the tests, the missed tests were made-up on the student's return to class. The final analysis included only the 182 students who completed all of the pretests and posttests. In other words, when data for one of the tests were not available, none of the scores for this subject were used in the analysis.

All of the tests were hand-scored by the researcher. Weighted values of the checked responses on the attitude scale were averaged and the results were rounded to the nearest tenth. Standard MRC answer sheets were used with the CAT, and they were scored with MRC scoring masks. These scores and differences between the pretests and posttests were then recorded for later analysis.

Statistical Analysis of the Data

At the conclusion of the experiment, all raw data were transferred to computer punch cards and statistical calculations were performed by the CDC 3300 computer at Oregon State University. Expertise consultive assistance was provided by Dr. Norbert Hartmann of the OSU Statistics Department in processing the data and interpreting the results.

The Nonequivalent Control Group Design used in the experiment suggested an analysis of covariance (ANCOVA) as the proper statistical procedure for analyzing the data. This technique combines the features of analysis of variance and regression to provide adjustments for antecedent differences between groups (Snedecor and Cochran, 1967). Thus, initial differences between classes were accommodated, making them equivalent in respect to control measures. Other confounding variables due to administering the same tests on two occasions, maturation, etc., would presumably have equal effects on both experimental and control groups.

Prior to submitting the data to an ANCOVA test, a preliminary analysis by t-test comparisons was made. These comparisons revealed significant differences in pretest means between some classes, verifying the necessity of covariate analysis, with pretest scores as the covariate.

The BMD05V-General Linear Hypothesis Program at the OSU Computer Center was used to determine the F-tests of adjusted means for an unbalanced, three-way classification and one covariate (Yates, 1968). Control variables were (1) sex, (2) school, and (3) treatment. Again, the criterion variable was pretest scores.

A mathematical model representing the estimated difference between pretest and posttest scores per observation (Ey_{ijkl}) is:

$$Ey_{ijkl} = \mu + a_i + b_j + c_k + d_{ij} + e_{ik} + f_{jk} + j_{ijk} + \beta X_{ijkl}$$

where

$i = 1, 2$

$j = 1, 2, 3$

$k = 1, 2, 3$

$l = 1, 2, 3, \ldots, 182$

μ = population mean

a_i = sex effect

b_j = school effect

c_k = treatment effect

d_{ij} = sex-by-school interaction

e_{ik} = sex-by-treatment interaction

f_{jk} = school-by-treatment interaction

j_{ijk} = sex-by-school-by-treatment interaction

X_{ijkl} = covariate adjustment

Hence, each observation, Y_{ijkl}, is

$$Y_{ijkl} = Ey_{ijkl} + \epsilon_{ijkl}$$

where ϵ_{ijkl} is error term or residual.

This 2 x 3 x 3 block design with unequal cell replications can be visualized in Figure 5.

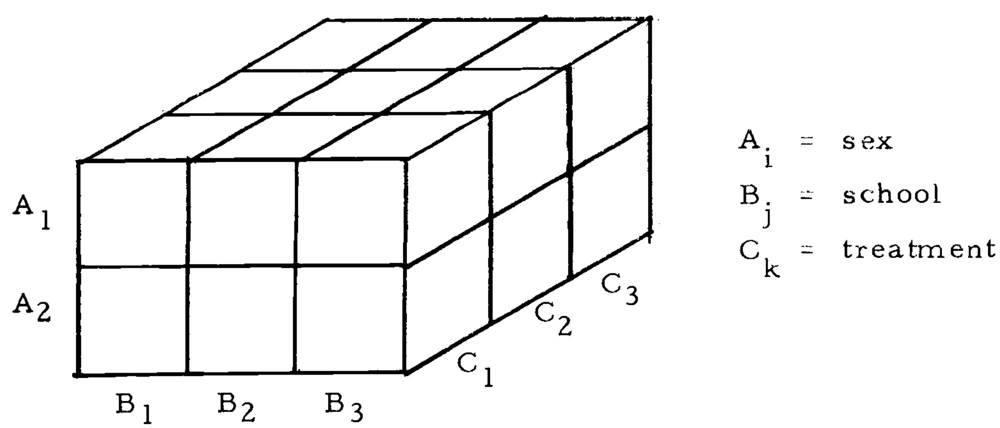

Figure 5. Block diagram of a sex-by-school-by-treatment (2 x 3 x 3) classification of treatment.

The blocks in the above diagram represent the 18 sex-by-school-by-treatment groups. Analysis of covariance was used to measure variations between the adjusted mean gains for these groups. For example, to compare differences between sexes, the adjusted mean for males (top layer) was compared to the adjusted mean for females (bottom layer) by an F-test.

Summary

This chapter presented the procedures used in conducting both the pilot study and the experiment. Justifications were given for the choice of Equations and Tac-Tickle as representative commercial mathematics games. The Cognitive Abilities Test and the Dutton Attitude Scale were discussed and reasons were given for their selection. The major and minor hypotheses were stated in detail. Then, the pilot study and its subsequent verifications were explained. Descriptions of the mathematics games were given. An explanation of the final experiment was presented, which reviewed the population, design, teacher selection, procedures, and data collection. Finally, the method of statistical analysis was identified.

IV. RESULTS OF THE STUDY

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

Method of Statistical Analysis

The data were analyzed by the BMD05V General Linear Hypothesis Program at Oregon State University. This program performs the calculations required for an unbalanced three-way analysis of covariance with one covariate. Computer output includes:

1. Means and standard deviations of the dependent variable and means of the covariate.
2. Sums of squares explained by the hypotheses.
3. Estimates of regression coefficients.
4. Residual sums of squares.
5. F-tests and degrees of freedom (Yates, 1968).

Nine variables were calculated to test the three major hypotheses and the six minor hypotheses. All variables utilized the same model to investigate effects attributable to sex, school, treatment, and their subsequent interactions. The nine variables matched with the appropriate hypothesis are listed in Table 9.

Table 9. Data variables for the hypotheses.

Variable no.		Hypothesis
1	Attitudes toward mathematics	1
2	Quantitative cognitive abilities	2
3	Quantitative relations	2. 1
4	Number series	2. 2
5	Equations building	2. 3
6	Nonverbal cognitive abilities	3
7	Figure analogies	3. 1
8	Figure classification	3. 2
9	Figure synthesis	3. 3

Data variables for Table 9 were derived from Dutton's Attitude Scale and the Quantitative and Nonverbal Batteries of the CAT.

Table 10 accounts for the sex-by-school-by-treatment groups and the number of observations in each group or cell. The information shown in Table 10 (see p. 81) was consistent throughout all calculations. Unadjusted pretest and posttest score results for each sex-by-school-by-treatment group are reported in Appendix B. These scores reveal the initial disparity in pretest means for the 18 groups on each of the nine data variables. For example, attitude pretest scores (variable 1) ranged from a low of 4. 72 to a high of 6. 92. In addition, the mean score spread was in excess of 11 for both quantitative measures (variable 5) and nonverbal measures (variable 9).

Hypotheses Test Results

All hypotheses were presented in Chapters I and III as research

Table 10. Sex-by-school-by-treatment description.

Group number	Sex-by-school-by-treatment group	Number of observations	Description of group
1	$S_1 \times S_1 \times T_1$	7	Males in Cheldelin Control class
2	$S_2 \times S_1 \times T_1$	8	Females in Cheldelin Control class
3	$S_1 \times S_1 \times T_2$	11	Males in Cheldelin Equations class
4	$S_2 \times S_1 \times T_2$	12	Females in Cheldelin Equations class
5	$S_1 \times S_1 \times T_3$	16	Males in Cheldelin Tac-Tickle class
6	$S_2 \times S_1 \times T_3$	9	Females in Cheldelin Tac-Tickle class
7	$S_1 \times S_2 \times T_1$	8	Males in Highland Control class
8	$S_2 \times S_2 \times T_1$	12	Females in Highland Control class
9	$S_1 \times S_2 \times T_2$	13	Males in Highland Equations class
10	$S_2 \times S_2 \times T_2$	2	Females in Highland Equations class
11	$S_1 \times S_2 \times T_3$	16	Males in Highland Tac-Tickle class
12	$S_2 \times S_2 \times T_3$	6	Females in Highland Tac-Tickle class
13	$S_1 \times S_3 \times T_1$	11	Males in Western View Control class
14	$S_2 \times S_3 \times T_1$	12	Females in Western View Control class
15	$S_1 \times S_3 \times T_2$	10	Males in Western View Equations class
16	$S_2 \times S_3 \times T_2$	6	Females in Western View Equations class
17	$S_1 \times S_3 \times T_3$	9	Males in Western View Tac-Tickle class
18	$S_2 \times S_3 \times T_3$	14	Females in Western View Tac-Tickle class

hypotheses. These hypotheses, stated in null form for purposes of statistical testing, assert that there are no significant differences in the students' scores on the measurement variables listed in Table 9 attributable to sex, school, treatment, sex-by-school, sex-by-treatment, school-by-treatment, or sex-by-school-by-treatment. To avoid unnecessary repetition, these hypotheses are condensed into one null form statement as follows; Classroom mathematical game-participation will not improve students' attitudes, quantitative, or nonverbal cognitive abilities as measured by variation in adjusted mean gains for group comparisons attributable to (1) sex, (2) school, (3) treatment, and their group interactions.

The three major hypotheses, H_1, H_2, and H_3, were tested by measuring variation in attitude scores toward mathematics, quantitative cognitive ability scores, and nonverbal cognitive ability scores respectively. The analysis of covariance results for these hypotheses are shown in Table 11.

Table 11 indicates that the covariate was significant beyond the .01 level, whereas F-values for the remaining categories were not found to be significant at the .05 probability level. Therefore, the null hypotheses were not rejected, concluding that mathematical games did not significantly increase students' scores on these data variables.

Table 11. Analysis of covariance for major hypotheses.

Source of variation	d. f.	F-values H_1	H_2	H_3
Covariate	1	51.8*	24.3*	11.2*
Sex	1	0.033	0.270	0.036
School	2	0.589	0.853	0.914
Treatment	2	2.31	0.636	0.934
Sex x School	2	1.76	2.06	0.202
Sex x Treatment	2	0.440	0.177	0.299
School x Treatment	4	0.317	2.03	1.26
Sex x School x Treatment	4	0.298	0.662	0.021
Error	163			

*Level of significance = .05

The minor hypotheses were tested by measuring variability in subtest scores on the Quantitative and Nonverbal Batteries of the CAT. The statistical tests for $H_{2.1}$, $H_{2.2}$, and $H_{2.3}$ measured group mean differences occurring on the Quantitative Relations, Number Series, and Equations Building Tests respectively, subtests of the Quantitative Battery. Statistical tests for $H_{3.1}$, $H_{3.2}$, and $H_{3.3}$ measured group mean differences occurring on the Figure Analogies, Figure Classifications, and Figure Synthesis Tests which are subtests of the Nonverbal Battery (see Table 9). Statistical results of the minor hypotheses are reported in Table 12.

Table 12 reveals that all covariates were significant beyond the .01 level. The F-value for $H_{2.3}$ was found to be significant for school variability and school-by-treatment interaction variability on the

Table 12. Analysis of covariance for minor hypotheses.

Source of variation	d. f.	F-values					
		$H_{2.1}$	$H_{2.2}$	$H_{2.3}$	$H_{3.1}$	$H_{3.2}$	$H_{3.3}$
Covariate	1	32.9	39.1	65.6	58.5	19.8	52.7
Sex	1	0.006	1.78	0.217	0.111	0.332	0.302
School	2	1.73	2.02	3.57*	1.62	0.064	3.71*
Treatment	2	0.114	1.15	1.47	0.110	0.510	0.883
Sex x school	2	0.037	1.49	1.27	1.64	2.21	0.442
Sex x treatment	2	0.234	0.419	0.237	2.00	0.538	0.409
School x treatment	4	0.677	0.733	3.33*	0.214	0.806	1.22
Sex x school x treatment	4	0.312	0.583	1.21	0.590	0.489	0.395
Error	163						

*Level of significance = .05.

Figure Synthesis Test. These results suggested that teacher variability was a significant factor in the learning of mathematics-equation comprehension and spatial relations through the use of games. A further elucidation of this possibility is discussed in the next section.

At this stage a decision was made to eliminate the retention hypothesis. Two factors were inherent in this decision. First, the subjects at Western View Junior High School were lost from the study as a result of a nine-week scheduling program. Second, as stated in Chapter I, the retention investigation was subject to significant hypotheses findings. Since essentially no significant differences existed between the groups and about one-third of the students were rescheduled out of the experiment, the retention investigation was not undertaken.

Discussion of the Hypotheses

The significance of the covariates, or pretest scores, for all hypotheses indicated that mean gains should be adjusted to compensate for initial group differences. Thus, prior to comparing group mean gains, an estimated adjusted mean gain was calculated for each group. The procedure employed was as follows:

$$\hat{\mu}_i = \overline{Y}_{i\cdot} - \beta(\overline{X}_{i\cdot} - \overline{X}_{\cdot\cdot})$$

where $\hat{\mu}_i$ = adjusted mean gain, $\overline{Y}_{i\cdot}$ = difference between pretest and posttest means, β = covariate coefficient, $\overline{X}_{i.}$ = group mean, and $\overline{X}_{..}$ = grand mean. These estimated adjusted mean gains are reported for each data variable in the appropriate hypothesis discussion below.

Hypothesis One

The analysis of covariance for this hypothesis (see Table 11) revealed no significant variation in attitudes toward mathematics as a result of using games. An examination of the adjusted means in Table 13 confirms the lack of a significant change in attitudes toward mathematics for any of the 18 groups.

Table 13. Adjusted mean gains for attitudes toward mathematics.

School	Treatment groups					
	Control		Equations		Tac-Tickle	
	boys	girls	boys	girls	boys	girls
1	-.26	.73	-.19	-.35	-.10	.49
2	.53	.43	-.24	-.61	.12	-.12
3	.53	.29	.27	-.03	.50	.01

Average gains for the 18 groups represented in Table 13 ranged from a high of 0.73 for girls in the control group at school 1 to a low of -0.61 for girls in the Equations group in school 2. Best average gains were made by the control groups. Lowest gains were made by the Equations groups where five of the six groups showed a decline in attitudes toward mathematics.

Hypothesis Two

As was shown in Table 11, quantitative cognitive abilities were not significantly increased as a result of using mathematical games. The adjusted mean gains for the Quantitative Battery of the CAT shown in Table 14 further illustrate the insignificant variability among the average gains for each of the groups.

Table 14. Adjusted mean gains for quantitative cognitive abilities.

School	Treatment groups					
	Control		Equations		Tac-Tickle	
	boys	girls	boys	girls	boys	girls
1	2.83	-0.56	3.96	3.74	4.39	2.79
2	4.75	3.04	0.53	-4.87	1.50	2.84
3	1.14	2.88	0.61	3.30	0.89	1.94

Table 14 reveals that the average adjusted mean gains ranged from a high of 4.75 for control boys at school 2 to a low of -4.87 for boys at school 2 in the Equations group. It is of interest to notice that the greatest variation in average gains occurred in school 2. This particular teacher expressed a dislike for the Equations game. He stated that he did not make an effort to actively involve himself when games were played. In contrast, the teacher in school number 1 was enthusiastic about both of the games and his game classes showed higher gains than his control class.

The minor hypotheses $H_{2.1}$, $H_{2.2}$, and $H_{2.3}$ were based upon subtests of the Quantitative Cognitive Abilities Test. The relatively small F-values given in Table 12 suggested that mathematical games had little effect on test scores for Quantitative Relations or Number Series. However, the F-values for $H_{2.3}$ were found to be significant for school variability and school-by-treatment interaction on the Equations Building Test. A presentation of the adjusted mean gains for these three minor hypotheses is shown in Table 15.

Table 15. Adjusted mean gains for quantitative cognitive abilities subtests.

School	Treatment groups					
	Control		Equations		Tac-Tickle	
	boys	girls	boys	girls	boys	girls
Quantitative Relations Subtest						
1	0.22	0.40	1.73	1.71	1.65	1.25
2	2.08	1.46	0.96	0.23	1.37	2.16
3	-0.14	0.91	0.89	-0.11	-0.13	0.28
Number Series Subtest						
1	1.24	-0.72	1.62	0.74	0.38	-0.88
2	1.34	0.58	1.51	-0.76	-0.20	0.74
3	2.05	1.87	0.44	1.55	0.99	1.03
Equations Building Subtest						
1	1.18	0.04	1.04	1.66	1.67	2.05
2	1.61	1.95	-0.59	-3.22	-0.54	0.37
3	-0.56	1.16	-0.16	1.21	0.21	0.43

From Table 15 it can be seen that the highest average group gain for Quantitative Relations was made by girls in the Tac-Tickle class at school number 2. This outcome is worth emphasizing because even though the teacher in school number 2 was completely unenthused about Equations, he frequently expressed favorable comments toward the Tac-Tickle game. In the case of the Number Series Test, control groups showed better overall gains than the experimental groups. The Equations Building Test showed, by far, the greatest variability in group gains, ranging from a low of -3. 22 for girls in the Equations class at school 2 to an average student increase of 2. 05 for girls in the Tac-Tickle class at school 1. In general, students in school number 1 displayed the highest overall score gains in Equation Building.

Hypothesis Three

The F-values for hypothesis three, which were reported in Table 11, were all small and far below significance. Hence, in this study, it must be concluded that playing Equations and Tac-Tickle games did not significantly affect students' Nonverbal CAT scores. Table 16 presents the adjusted mean gains made by each of the 18 groups on the criterion instrument.

Table 16. Adjusted mean gains for nonverbal cognitive abilities.

School	Treatment groups					
	Control		Equations		Tac-Tickle	
	boys	girls	boys	girls	boys	girls
1	2. 33	1. 54	3. 30	3. 36	2. 72	2. 54
2	1. 64	3. 50	-1. 40	0. 77	4. 41	3. 77
3	1. 21	2. 72	5. 63	4. 55	4. 21	3. 17

Table 16 indicates that 17 of the 18 groups displayed an increase in nonverbal cognitive ability scores. The one decrease was for boys in the *Equations* class in school number 2. With the exception of students in the *Equations* class in school number 2, game classes tended to increase more than control classes on the Nonverbal CAT. Best nonverbal score gains were produced by *Equations* classes in schools 1 and 3.

Data variables for hypotheses $H_{3.1}$, $H_{3.2}$, and $H_{3.3}$ were subtests of the Nonverbal CAT, Figure Analogies, Figure Classification, and Figure Synthesis respectively. F-values for the analysis of covariance (see Table 12) revealed that only school variability for Figure Synthesis Test scores was significant. The adjusted mean gains for these results are given in Table 17.

Table 17. Adjusted mean gains for nonverbal cognitive abilities subtests.

School	Treatment groups					
	Control		Equations		Tac-Tickle	
	boys	girls	boys	girls	boys	girls
Figure Analogies Subtest						
1	0.60	3.45	2.67	1.88	1.20	2.64
2	2.02	1.68	1.45	0.77	2.01	1.83
3	0.60	1.82	1.71	0.47	1.88	0.86
Figure Classification Subtest						
1	0.87	0.71	0.93	1.64	1.61	0.05
2	0.11	2.71	-0.55	0.69	1.23	2.57
3	0.32	0.33	1.92	0.57	1.42	0.96
Figure Synthesis Subtest						
1	0.64	-0.59	0.66	0.72	-0.35	-0.12
2	0.07	0.03	-1.53	0.20	0.15	0.32
3	-0.23	0.66	2.14	2.91	1.20	0.82

Table 17 shows that all groups gained on the Figure Analogies Test. In addition, all but one of the groups increased on the Figure Classification Test. Tac-Tickle classes obtained greater score gains than the other two treatment groups with boys making larger total gains than girls. On the Figure Synthesis Test, however, group gains were not as large and showed greater variability. These scores ranged from a loss of -1.53 for the Equations group in school number 2 to a gain of 2.91 for the Equations group in school number 3. The Equations treatment group made higher gains than the other two groups, largely because of the results of school number 3. In fact, school number 3 produced higher total gains than either of the other two schools.

Findings Not Directly Related to the Hypotheses

As a final comparison, two methods of statistical analysis were employed. First, a t-test was used to compare the adjusted gains in attitudes and cognitive abilities for high-scoring pretest students against those of low-scoring pretest students. Second, a one way analysis of variance was used to compare the gain differences between the high control and the high Equations and Tac-Tickle groups. This same technique was also used to compare gain differences between low control and low experimental groups. The procedure involved adjusting individual student gains, using pretest scores as a covariate. Next, the top and bottom 30 percent of the students from the control and two experimental groups were identified from pretest scores. Thus, each high and low group created consisted of 17 students from the control classes, 16 students from the Equations classes, and 21 students from the Tac-Tickle classes.

Values for the t-test comparisons of the adjusted mean gains between the high and low groups with respect to attitudes and cognitive abilities are listed below in Table 18. Positive t-values indicate greater gains for the high group.

Table 18. t-Test values comparing adjusted mean gains of high and low groups.

Group	t-Values for measurement variables		
	Attitude	Quantitative	Nonverbal
Control	1.829	-0.101	-0.847
Equations	-1.154	0.552	-0.961
Tac-Tickle	-0.371	-0.319	0.903
t-Value required for .05 level of significance	2.042	2.042	2.021

As shown by the t-values listed in Table 18, there was no significant difference in adjusted mean gains between high and low scoring students on any of the three criterion instruments.

F-values for the one-way analysis of variance test which compared the variation between the high control, Equations, and

Tac-Tickle groups are listed in Table 19. The table also includes F-values for the variation in the low groups. That is, high scoring students in the control, Equations, and Tac-Tickle classes were compared to determine if a significant difference existed between their adjusted mean scores. Low scoring students were compared in the same manner. F-values for both groups on all three criterion measures are reported together in the table.

Table 19. Analysis of variance between adjusted gains for high control, Equations, and Tac-Tickle groups and between adjusted gains for low control, Equations, and Tac-Tickle groups.

Source of variation	d. f.	F-values for measurement variables		
		Attitude	Quantitative	Nonverbal
Between top 30% Control, Equations, & Tac-Tickle groups	2	2.433	0.035	0.897
Error	51			
Between bottom 30% Control, Equations, & Tac-Tickle groups	2	0.093	0.475	1.062
Error	51			

The required F-value of 3.17 for significance at the .05 level is larger than any value listed in Table 19. Thus, when adjusted mean gains for the top 30 percent of the control, Equations, and Tac-Tickle groups were compared on each of the three measurements, no significant difference was found. Nor were scores of the bottom 30 percent of the three groups significantly different in attitude, quantitative, or nonverbal abilities.

Summary

Chapter IV was separated into four major sections. The first section included the method of statistical analysis used to interpret the data. Section two presented the analysis of covariance test results for the three major and the six minor hypotheses. The third section discussed the results of the hypotheses. None of the F-values for the three major hypotheses was found to be significant at the .05 level. Three significant F-values were found for the minor hypotheses. Analyses of data not directly related to the hypotheses were explained and reported in the fourth section.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter is divided into four major sections. The first section presents a summary of the study, including a review of the need and purpose, the pilot study, the experimental design, procedures, and statistical analysis. The second section is devoted to the conclusions of the hypotheses test results and findings not directly related to the hypotheses. Section three relates this study to other similar research studies done with mathematical games and the fourth section is devoted to recommendations for further study.

Summary

Need and Purpose of the Study

Educational games are currently vogue in classroom instruction. This fact is obvious from the abundant quantity of game-literature appearing in educational books and journals. The numerous commercial games now marketed and advertised for classroom use are further support of game-teaching popularity.

The need for studies validating the effectiveness of games as appropriate instructional materials is apparent from the lack of adequate available research. Game advocates and many educators do believe that classroom game-participation is a worthwhile learning activity. The problem remains, however, that this belief is founded more upon intuition than research evidence. This study was one attempt to provide additional insight into the educational value of mathematics games.

Specifically, the purpose of the study was to determine if two commercially produced mathematics games, when used by seventh-grade mathematics teachers, would significantly improve students' (1) attitudes toward mathematics, (2) quantitative cognitive abilities, and (3) nonverbal cognitive abilities.

Pilot Study

A pilot study was conducted during the 1972 spring quarter at Western View Junior High School in Corvallis, Oregon. The purpose of that investigation was to determine whether the selected games and measuring instruments were appropriate variables for the suggested hypotheses. As a result of the pilot study, Equations, a game of mathematical skill, and Tac-Tickle, a game of pure strategy, were found to be suitable games for seventh-grade students. Dutton's Attitude Scale and the Houghton Mifflin Cognitive Abilities Test proved to be satisfactory measuring instruments for the ensuing experiment. After two weeks of game-participation, the differences between pre- and posttest scores suggested that mathematical games might have influenced attitudes and nonverbal cognitive abilities.

Experimental Design

The experiment required a Nonequivalent Control Group Design utilizing nine classes of seventh-grade mathematics students in three junior high schools. One experienced mathematics teacher in each of the three schools was recommended by the school administrator to assist in the experiment. All of these teachers were currently teaching three sections of seventh-grade mathematics.

Each game was then randomly assigned as a treatment variable to one of the three classes, leaving the third class to serve as a control group. In other words, each of the three teachers instructed one control class, one Equations experimental class, and one Tac-Tickle experimental class in three different junior high schools.

Procedures

Each teacher was provided with complete explanations of the research project and individually instructed in test-administration and game-procedures. When teachers had been thoroughly tutored in rules and strategies of the games, several games were played with the researcher. This enabled the teachers to gain confidence in their knowledge of the games, and it clarified any ambiguities that might have existed.

Since the experiment was designed to measure the effectiveness of game instruction by actual classroom teachers, each teacher was required to administer his own tests and to instruct the game sessions. This eliminated third party biases and created a more natural classroom environment. Experimental subjects participated in games for approximately half of the instructional period every other day, allowing in part, the routine classroom lessons to continue. When the students became proficient in the games, winners were matched with winners, losers with losers in an effort to stimulate interest.

All of the students involved in the study were pretested and posttested with the Dutton Attitude Scale and the Cognitive Abilities Test over a six-week interval. Pretests were administered to all nine classes prior to the study. Students were assured that individual test results were confidential, would not be scored by the teacher, and would not be used for grading purposes. Upon completion, tests were immediately turned over to the researcher who hand-scored them and entered the results as pretest experimental data. The same procedure was followed at the conclusion of the experiment when the results were entered as posttest data for later analysis.

Students who had not completed both the pre- and posttests were eliminated from the study, leaving a total of 182 students serving as subjects in the experiment. Test scores were then transferred to IBM punch cards as raw data for statistical analysis.

Statistical Analysis

The Nonequivalent Control Group Design suggested an analysis of covariance as the proper statistical technique for analyzing the data. The BMD05V-General Linear Hypothesis Program at the Oregon State University Computer Center was used to calculate F-values for differences in adjusted mean scores on an unbalanced, three-way classification with pretest scores as the covariate. Control variables for the experiment were (1) sex, (2) school, and (3) treatment. Variation in adjusted posttest gains were compared between these three groups as well as group interactions. That is, seven F-values were calculated for adjusted mean gains on each data variable for differences between (1) sex, (2) schools, (3) treatment, (4) sex-by-school, (5) sex-by-treatment, (6) schools-by-treatment, and (7) sex-by-school-by-treatment.

As an additional investigation not directly related to the hypotheses, differences in mean gains were compared between high and low students. The method of analysis included several steps. First, all pretest scores on each data variable were adjusted with the grand mean. Second, the top 30 percent and the bottom 30 percent of students in the control and the two experimental groups were identified from adjusted pretest scores. Third, the previously calculated adjusted gains for these high and low students were then compared with respect to differences in attitudes and cognitive abilities. An F-test was used to compare adjusted gain differences for attitudes and cognitive abilities between high groups and also between low groups. A t-test comparison between high and low adjusted attitude scores and cognitive abilities scores was made within each of the three groups.

Conclusions

Results of the Hypotheses

F-tests of the three major hypotheses measured group-adjusted mean gain differences for attitudes toward mathematics (H_1), quantitative cognitive abilities (H_2), and nonverbal cognitive abilities (H_3). F-tests for the six minor hypotheses measured group-adjusted mean gain variation for Quantitative Relations ($H_{2.1}$), Number Series ($H_{2.2}$), Equations Building ($H_{2.3}$), Figure Analogies ($H_{3.1}$), Figure Classification ($H_{3.2}$), and Figure Synthesis ($H_{3.3}$). Measurement variables for these minor hypotheses were subtests of the Quantitative and Nonverbal CAT Batteries.

The null hypotheses formulated to test all nine hypotheses differed only with respect to the measurement variables. To avoid unnecessary repetition, these hypotheses are condensed into one null-form statement as follows: Classroom mathematical game-participation will not improve students' attitudes, quantitative, or nonverbal cognitive abilities as measured by variation in adjusted mean gains for group comparisons attributable to (1) sex, (2) school, (3) treatment, and their group interactions.

Results of the Major Hypotheses. The 21 F-values for the three major hypotheses were not significant at the .05 level. It was concluded that mathematical game-participation did not significantly affect attitude scores or overall quantitative and nonverbal ability scores. A comparison of adjusted mean gains revealed that control groups improved more in attitude scores than did the treatment groups.

Adjusted mean gain comparisons for nonverbal cognitive abilities showed higher gains made by the game groups with the exception of one Equations class. The teacher for that class had, in fact, expressed a dislike for the Equations game.

Results of the Minor Hypotheses. No significant F-values were found for Quantitative Relations, Number Series, Figure Analogies, or Figure Classifications. F-values were significant for school and school-by-treatment interaction on the Equations Building subtest of the Quantitative CAT. The School F-value was also found to be significant on the Figure Synthesis subtest of the Nonverbal CAT. These results indicated that teacher variability was a significant factor in the learning of mathematics-equation comprehension and spatial relations through the use of games.

Findings Not Directly Related to the Hypotheses

F-values were calculated to compare adjusted mean gains between the top 30 percent of the students in the control and the two experimental classes as identified by adjusted pretest scores. No significant score differences were found in measures of students' attitudes toward mathematics, quantitative cognitive abilities, or nonverbal cognitive abilities. Attitude mean scores showed the greatest variation.

F-values were also calculated to compare adjusted mean gains between the bottom 30 percent of the students in the control and experimental groups. Again, no significant differences in mean score gains were found for attitudes, quantitative, or nonverbal cognitive abilities. The attitude variation for the low groups was quite small. The greatest score variation occurred on the nonverbal measure.

Finally, t-values were calculated to compare differences between high and low students within each of the three groups. These calculations revealed no significant difference in attitude, quantitative, or cognitive abilities between high and low students. In general, the low students in game-classes showed greater gains in Quantitative Test measures but did not gain as much as low students on the Nonverbal Test. These results were reversed for students who participated in the Tac-Tickle game; i.e., low students had better gains on the Quantitative Test, and high students showed better gains on the Nonverbal Test.

Discussion

Four studies involving mathematical game-learning at the junior high school level were reviewed. These studies differed in many respects from this current study. Two studies by Allen *et al.* (1966, 1970) showed that students significantly increased in nonverbal I. Q. scores as a result of playing *Wiff'n Proof*, a game of mathematical logic. Jones (1968) found that programmed lectures presented to low-achievers in the form of mathematical games significantly increased attitudes and achievement. Edwards *et al.* (1972) concluded from their research that competitive participation in *Equations* significantly increased achievement and divergent problem-solving ability.

It is necessary to emphasize the differences between this study and the previous studies. In most respects, this research is more appropriate to typical classroom situations. For example, Allen's two studies were conducted on summer session students who played *Wiff'n Proof* for two hours every day for six weeks in one study and four hours every day for three weeks in the second study. Both studies measured increases in I. Q. scores on the California Test of Mental

Maturity. Jones' research was conducted with summer session under-achievers in a private school. The programmed lectures were presented every day for nine weeks. Edwards' research most resembled this investigator's study. It differed in that two of his four classes were under-achievers; Equations was the only game used; and only one teacher was involved in the experiment.

Briefly then, the obvious differences between these studies and the present one were (1) the use of different measuring instruments, (2) the use of different measuring criteria, (3) game variabilities, (4) subject variabilities (low-achievers vs. homogeneous grouping), (5) duration of studies, and (6) teacher variabilities.

Although this study did not produce the significant findings of the above studies, it should be considered as a worthwhile contribution to game-learning research. The salient features of this study which should be of interest to mathematics teachers are as follows:

1. The intermittent use of games by actual classroom teachers was found to be as effective as conventional instruction in terms of increasing students' attitude and cognitive ability scores.
2. Game-participation did not produce significant boy-girl differences in attitude and cognitive ability scores.
3. Treatment comparisons between two types of commercial games

revealed no significant differences in attitude and cognitive ability mean score gains.

4. The results of the study indicated that teacher variability was a significant factor in the learning of mathematics-equation comprehension and spatial relations through the use of games.

Recommendations for Further Study

As a direct result of this study and through a review of educational game research, the following recommendations are presented for consideration in future mathematical game research:

1. Teacher variability is an important aspect in determining students' attitudes and abilities in learning mathematics. Since only three teachers were used in this study, it is recommended that a similar mathematical game study be conducted involving a greater population of teachers.
2. It is further recommended that a study be undertaken which will measure the effects attributable to individual teacher attitudes toward mathematics games.
3. In addition to involving a greater number of teachers in a similar study, a larger variety of commercial games should be considered for purposes of comparing results of diverse types.
4. Game-playing times should be staggered in an attempt to determine if an optimum game-involvement time exists.

5. As an alternative to measuring attitudes toward mathematics or any other subject matter through the use of educational games, students' attitudes toward the teacher using such games should be measured. According to game-learning literature, the authoritarian role of teachers can be diminished and better teacher-pupil relationship can be developed through the use of game-instruction. This researcher recommends a study to investigate whether students' attitudes toward their instructors change as a direct result of game-instruction.
6. Significant differences in student cognitive abilities may not occur as a result of game-participation, especially over a short experimental-time period. Therefore, it is recommended that further research in this area be directed at measuring specific achievement differences rather than cognitive abilities.
7. One of the most frequently cited advantages of playing educational games in the literature is that they will increase student motivation and interest. Studies have not been conducted to directly measure this quality. It is recommended that a study be undertaken for that purpose.
8. Another claim of game-learning in educational literature is that it can change student behavior by reducing discipline problems and increasing student involvement and attention span. This claim also needs to be investigated.

9. Many educational games are highly competitive. Presently, it is not known what negative psychological affects, if any, may arise as a result of this type of competition. The emotional affects of game competition should be investigated with respect to individual personalities.

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APPENDICES

APPENDIX A

DUTTON'S ATTITUDE SCALE

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 statements 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)[a] 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.

[a]Weighted item values used to score the test have been added in parentheses.

APPENDIX B

UNADJUSTED GROUP MEANS FOR ALL DATA VARIABLES

Group	Variable 1		Variable 2		Variable 3		Variable 4		Variable 5	
	pre	post	pre	post	pre	post	pre	post	pre	post
1	5.61	5.55	12.14	12.43	13.29	15.00	8.71	10.00	34.14	37.43
2	6.31	6.96	12.38	12.76	15.62	14.62	9.75	9.37	37.75	36.75
3	6.08	5.91	12.09	13.91	15.27	16.72	9.18	10.09	36.55	40.37
4	6.48	5.98	12.42	14.09	15.25	15.83	10.25	11.25	37.92	41.17
5	5.67	5.75	10.25	12.75	14.00	14.63	7.75	10.00	32.00	37.38
6	6.89	7.07	11.56	13.12	14.78	13.89	7.89	10.45	34.22	37.44
7	6.26	7.74	13.12	14.87	17.00	17.63	8.88	10.50	39.00	43.00
8	5.77	6.34	15.25	15.50	16.58	16.58	10.33	11.58	42.17	43.67
9	6.22	5.94	13.15	13.77	15.15	16.53	7.92	7.84	36.23	36.69
10	6.10	5.50	16.50	15.00	15.50	14.50	10.50	6.50	42.50	36.00
11	5.89	6.10	10.62	12.68	13.75	13.88	6.81	7.31	31.19	33.88
12	4.72	5.15	13.50	15.17	15.50	16.00	9.67	9.67	38.67	40.84
13	6.58	6.92	12.18	12.09	14.91	16.91	9.45	8.63	36.55	37.55
14	6.94	6.90	11.08	12.50	13.83	16.00	10.25	10.75	35.17	39.25
15	6.18	6.42	13.50	13.90	15.50	15.70	9.40	9.00	38.40	38.40
16	6.25	6.17	13.67	13.00	12.33	14.66	8.67	10.00	33.83	37.66
17	6.64	6.93	12.00	12.00	15.78	16.45	9.56	9.45	37.33	37.89
18	5.41	5.69	12.29	12.58	13.07	14.64	34.00	36.43	34.00	36.43

Group	Variable 6		Variable 7		Variable 8		Variable 9	
	pre	post	pre	post	pre	post	pre	post
1	17.29	18.00	17.29	18.43	25.14	15.85	59.71	62.28
2	16.50	20.38	17.75	18.63	24.75	24.38	59.00	60.88
3	16.73	19.73	18.55	19.46	26.36	26.63	61.64	64.91
4	20.42	21.17	20.17	21.42	25.25	26.00	65.83	68.58
5	17.44	18.69	17.88	19.63	24.56	24.50	59.88	62.82
6	17.22	20.00	18.22	18.33	25.89	25.56	61.33	63.89
7	18.25	20.00	19.50	19.38	26.50	26.12	64.25	65.50
8	20.33	20.91	18.67	21.34	26.08	25.83	65.08	68.08
9	17.54	19.00	19.46	18.69	26.38	24.46	63.38	62.07
10	17.00	18.00	21.50	21.50	28.50	27.50	67.00	67.00
11	15.38	18.25	16.19	17.94	24.25	24.81	55.81	61.00
12	18.83	20.16	19.50	21.83	27.50	27.00	65.83	69.00
13	16.55	17.55	17.09	17.73	24.73	24.73	58.36	60.00
14	17.75	19.50	19.58	19.66	25.08	25.83	62.42	65.00
15	17.60	19.30	19.90	21.50	24.90	27.20	62.42	67.90
16	17.50	18.00	17.33	18.16	23.33	27.00	58.17	63.17
17	17.00	19.11	20.33	21.33	26.44	27.22	63.78	67.67
18	17.21	18.21	17.36	18.57	24.29	25.50	59.57	63.00