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THE EFFECT OF MICROCOMPUTER-ASSISTED INSTRUCTION ON MATHEMATICS ACHIEVEMENT AND ATTITUDES TOWARD MATHEMATICS AND MICROCOMPUTERS OF PRESERVICE ELEMENTARY TEACHERS

The Ohio State University

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ON MATHEMATICS ACHIEVEMENT AND ATTITUDES TOWARD
MATHEMATICS AND MICROCOMPUTERS OF PRESERVICE
ELEMENTARY TEACHERS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of the Ohio State University

By

Richard M. Krach, B.S., M.A.

* * * * *

The Ohio State University
1986

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To My Wife, JoAnn
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Last, but certainly not least, gratitude is expressed to Penny Lang, a word processing wizard, who received more than she bargained for when she agreed to type my dissertation.
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CHAPTER I
INTRODUCTION, CONCEPTUAL FRAMEWORK, AND STATEMENT OF THE PROBLEM

The Introduction section of Chapter I presents an in-depth historical overview of the development and use of computer-assisted and microcomputer-assisted instructional materials in mathematics education. Also included in this section is a discussion of the instructional uses of manipulative materials. The Conceptual Framework section provides a discussion of the theoretical relationships which exist between mode of treatment and impact on achievement and attitude. Finally, the objectives of this study are presented in the Statement of the Problem portion of Chapter I.

"Mathematics programs must take full advantage of the power of computers and calculators at all grade levels."

(NCTM, 1980)

Even though the above statement was published (and subsequently endorsed by numerous educational agencies) in 1980, researchers, as early as 1963, were working diligently to determine the power and impact of computers as an instructional delivery system.
Introduction

(Micro)Computer-assisted Instruction. In 1963, Patrick Suppes at the Institute for Mathematical Studies in the Social Sciences at Stanford University designed and instituted one of the first computer-assisted instructional (CAI) programs to increase the basic skill levels of elementary school students in English and mathematics. In addition, his work focused on the development and implementation of a reading and arithmetic CAI program for culturally disadvantaged students (Suppes, Jerman, & Brian, 1968).

At the same time as this project was in operation, the Stanford Drill and Practice System was created. During the 1967-1968 school year, as many as 3,000 elementary and secondary school students, in both urban and rural settings, received daily lessons in basic reading, spelling, and arithmetic via CAI (Suppes & Morningstar, 1972).

Initiated in 1969, Project Solo (currently named Soloworks), a joint venture of the University of Pittsburgh and the National Science Foundation, has produced exemplary CAI materials which are used as a supplement to the traditional topics in the high school mathematics curriculum. A major goal of this project was to determine the effect, on student achievement, of the reorganization of the secondary school mathematics program around computer-based laboratories. The researchers investigated the integration of mathematics via time-sharing CAI throughout the entire high school curriculum (Dwyer, 1975).
Also during the late 1960's, the National Science Foundation, in response to the need for establishing evidence of CAI effectiveness, subsidized two, now famous, large-scale computer-assisted instructional systems: PLATO (Programmed Logic for Automatic Teaching Operators) and TICCIT (Time-Shared, Interactive, Computer-Controlled, Information Television). Both systems were designed to exploit the potential of the computer in college teaching.

The PLATO system is a large educational and computing network located at the University of Illinois. It has the capacity to produce complex CAI programs having sophisticated graphics capabilities, voice output, and other state-of-the-art functions. The PLATO system has been used in such areas as remedial education, economics, guidance and counseling, music, and social studies, as well as in mathematics, statistics and computer science (Bitzer & Skaperdas, 1971).

The TICCIT system was developed at the University of Texas and Brigham Young University with the support of the Mitre Corporation. Undergraduate instruction in English and mathematics is provided via a color-television monitor connected to the student's typewriter-like keyboard and a localized mini-computer (Stetton, 1971).

During the evaluation of the educational effectiveness of these systems, student achievement was studied. However, for the first time during a major CAI research project, student attitude toward the instructional setting was deemed an important variable for consideration.
These pioneering projects, along with those from Penn State and Florida State universities, established the foundation and framework for subsequent studies, which focused their efforts on similar student populations, characteristics, and hypotheses, but usually on a much less ambitious scale. For example, a current study, funded by the National Science Foundation, is in the process of developing a CAI system which incorporates a speech synthesizer to teach arithmetic to second grade students. The system demonstrates the mathematical procedure to the student, furnishes practice exercises, corrects the exercises, and diagnoses error patterns ("What's Going On...,"Arithmetic Teacher 30, March 1983). In an experimental study with freshman precalculus students, Pulat and Wang compared the traditional lecture format for instruction with a CAI approach. The methods were compared in terms of their effectiveness in preparing students for the subsequent calculus sequence (Pulat & Wang, 1982).

Two of the most significant deterrents to quality CAI research during the 1960's and most of the 1970's was the unavailability, due mainly to cost constraints, and at times, the unsuitability of mainframe-computers as an instructional delivery system. However, with the advent of integrated circuits, silicon technology, and the microprocessor, the microcomputer has circumvented these and many of the other short-comings associated with mainframe computers, thereby, prompting the instructional use of microcomputers, not only in the classroom and at home, but also as the focus of microcomputer-assisted instructional (MCAI) research (Bork & Franklin, 1979).
The Minnesota Educational Computing Consortium (MECC) was established in 1973 to assist Minnesota schools and universities in implementing instructional computing (MECC, 1983). It was one of the first state-wide, microcomputer-oriented, research and development organizations to come into existence. The initial function of this consortium was to catalog an extensive comparison of the capabilities, limitations, and costs of all commercially available microcomputers, including their uses in the educational environment. Two significant results of this effort were the installation of several hundred microcomputers throughout the state of Minnesota, with an accompanying growth in the development of MCAI programs and lessons, and the provision that support would be made available for subsequent MCAI research.

One study which benefited from the work accomplished by the MECC was the 1981-82 Micro-Computer Project, funded by the Minnesota State Department of Education (Carrier & Post, 1982). The major goal of this project was the development, implementation, and evaluation of locally-authored MCAI materials for elementary school children (grades K-6). Another study, which used MECC generated materials, dealt with adult basic education students. In this study, the MECC materials were used to teach these students how to use microcomputers and microcomputer-assisted instructional materials for learning basic arithmetic and language arts skills (Gates, 1983).

The MECC has not only made a major contribution to the development and implementation of MCAI materials, but also to the evaluation of the effectiveness of these materials. By providing the incentive
and support for these and subsequent studies, the MECC is considered one of the leaders in the development, evaluation, and distribution of MCAI materials.

Since microcomputers and MCAI are, in research terms, a recent phenomenon, few research and development organizations and projects the size and complexity of the MECC are in existence. However, another major project, on a somewhat larger scale than that of the MECC, was established in 1981: Project BEST (Basic Educational Skills Through Technology). This project, which was funded by the U.S. Department of Education, was developed to provide technical assistance to state and local education agencies. BEST used a range of technologies, including microcomputers and microcomputer-assisted instruction, to deliver information and to illustrate current and potential uses of technology for learning basic skills. The project was most successful in aiding educational agencies in organizing their resources for a coordinated approach to the use of instructional technology.

In addition to these large-scale, nationally-funded projects, there are MCAI projects which are primarily supported by local and private funds, such as MicroSIFT and CONDUIT. MicroSIFT (MicroSIFT Computer Technology Program, 1983) was created to establish effective procedures for the collection, evaluation, and dissemination of MCAI materials and information, provide technical assistance to school systems, and develop new MCAI materials. CONDUIT (CONDUIT, 1983) was established to aid in the search and selection of MCAI materials appropriate for use at the collegiate level.
Currently, the NSF is supporting a major MCAI research, development, and evaluation project at the Ohio State University College of Education: Project TABS (Technology and Basic Skills). Suzanne Damarin and Marlin Languis are developing MCAI curricula in the areas of geometry, probability, statistics, estimation, and computer literacy and investigating their effectiveness on the achievement and attitude of elementary and middle school children. The researchers believe that through the use of microcomputers and MCAI, students will gain a more thorough understanding of mathematics, microcomputers, and microcomputer-assisted instruction (Damarin, 1983).

On a less ambitious scale, Gary Bitter, of the Arizona State University Microcomputer Research Clinic, is directing an experimental study to determine the effectiveness of a microcomputer-assisted instructional model for remediating mathematical deficiencies in undergraduate college students enrolled in the elementary teacher education program at the Arizona State University. Students needing remediation are assigned to one of three treatment groups: one that is totally computer-based, a second that is exposed to a combination of computer-based instruction and independent study, and a third that participates only in independent study. The data produced from this study will be used to answer questions concerning the effective use of microcomputers as an instructional delivery system in the mathematics classroom. In addition, Bitter will study the roles of sound and color in computer-assisted instruction, and which types of programs encourage creativity (Bitter, 1983).
Two additional examples of current MCAI research projects are the Title I Mathematics Computer Assisted Instruction Project and the Utilizing Computers in the Teaching of Secondary Mathematics Project. The Title I project provides inservice training, follow-up assistance, and program materials to mathematics teachers of students in grades 3-6 (Cortez, 1983). The Secondary Mathematics Project provides microcomputer-assisted instructional materials and techniques to improve mathematics skills in different areas of secondary school mathematics (Detalvo, 1983).

Much of the past CAI and present MCAI research is of the developmental genre and, as a rule, does not investigate the educational effectiveness of computer-based material on its audience. However, much evaluative CAI research does exist in the literature, but as Chambers and Sprecher have stated, "well-defined, tightly controlled evaluation studies concerning the impact of CAI are rare" (Chambers & Sprecher, 1980). This observation is also shared by Alfred Bork (Bork, 1983), one of the leading authorities on the educational utility of CAI. In the past, many of the CAI studies were of the two-group variety, relying on the t-test to determine group differences. Many of these research studies used software of dubious quality, failed to establish initial group equivalence, and avoided such important research considerations as the "Hawthorne" or novelty effect, and attitude assessments of their research subjects. Many of these same problems plague much of the current experimental research in the area
of MCAI, i.e., much of the current experimental research in MCAI is not
capitalizing on the design and methodological errors from previous CAI
studies as well as from current and recently completed MCAI research.

Subsequent to perusing numerous dissertations and other experi­
mental studies, five major issues which adversely affect the quality of
many past CAI and current MCAI experimental studies have been identified.
The first of these is the researcher's failure to control for the
"Hawthorne" or novelty effect. According to Grayson, the "Hawthorne"
effect may be the most influential factor which contributes to the
positive results of many CAI studies (Grayson, 1970).

A second major area of concern is the failure, in many experi­
mental CAI studies, to assess student attitudes. However, the heart of
this issue is the question of the validity of the results of the
research. According to Hazen, when only one measurement method is used
to assess the impact of computer-based instruction on its audience, a
major threat to the validity of the results is introduced (Hazen,
1980). In other words, the validity of the experimental outcomes of
the study is greatly increased whenever the results of two or more
independent measurement methods converge.

The third major issue concerns the researcher's restriction of an
attitude assessment to only feelings toward the status of the inter­
vention. Aiken and Braun argue that affective studies, rather than the
statistical analyses of achievement test scores, are a more viable
alternative as a determinant of the effectiveness of CAI materials.
They contend that the results of a statistical analysis of achievement test data are only meaningful as measures of performance. Other methods, such as affective studies, must be employed to obtain meaningful measures of learning (Aiken & Braun, 1980).

The position advanced by Aiken and Braun not only supports Hazen's work, but also provides a rationale for conducting affective assessments: the first to determine the research subjects' feelings toward the study of mathematics, the second to determine their feelings toward the use of microcomputers. In addition, the affective data should be statistically analyzed instead of being merely inspected for "trends."

Another major issue of concern is the failure of researchers to use content-appropriate MCAI software in their experimental studies. To rectify this serious problem, research needs to be conducted using microcomputer-appropriate subject matter, such as elementary probability. Probability and statistics has recently become one of the "BASIC SKILLS AREAS" in mathematics education. The importance of the informed consumer understanding principles of probability and statistics has been acknowledged by such eminent mathematical organizations as the Cambridge Conference on School Mathematics (1964), the National Advisory Committee on Mathematics Education (1975), the National Council of Supervisors of Mathematics (1977), and most recently, the National Council of Teachers of Mathematics (1980).

The determination to use a microcomputer-assisted laboratory in elementary probability has been partially influenced by this collective opinion. Also, the area of elementary probability is well suited for
computer-assisted instruction due to the dynamic nature of a stochastic event, which fits comfortably within the microcomputer's ability to perform rapid computations and its capacity for interactive and graphics functions. For example, many exercises in elementary probability require frequent and tedious computations. The microcomputer can be used to perform the monotonous computations while the student concentrates on concepts and relationships.

Microcomputers can also be programmed to simulate experiments and can quickly perform a large number of trials during the experiments. Therefore, the students can quickly compare theoretical results with the computer-generated results, which can aid in forming a clear understanding of the concept involved in the simulation. According to Haigh, this use of the microcomputer implies that although the solution of probability problems by theoretical methods is important, the use of microcomputers to solve many of these same problems by experimental methods makes it possible to discuss/introduce these problems at an earlier stage in the mathematics curriculum (Haigh, 1985). Such an approach to the learning of probability can both motivate the student and inspire a positive attitude toward probability, microcomputer-assisted instruction, and the study of mathematics.

The final major issue of concern is the failure of most MCAI researchers to consider the importance of examining the effectiveness of microcomputer-assisted instruction on the achievement and attitude of preservice elementary teachers. Most previous and many current MCAI studies used elementary and secondary school students, adult basic
education students, and assorted undergraduates as subjects of research. Very few studies used preservice elementary teachers. It seems obvious that if the effectiveness of microcomputer-assisted instruction is to be thoroughly investigated and the results generalizable, all subpopulations of the universe of students need to be included in research. One of the most critical objectives in the preparation of elementary school teachers is the development of a positive attitude toward mathematics and mathematics instruction. Even though strong evidence does not exist, it is generally assumed that a teacher's attitude toward mathematics will affect the manner in which the subject is taught and how well it is mastered (Vance, 1978; Bowling, 1976). This assumption is supported by a 1973 study by Phillips (Phillips, 1973). In this study, it was determined that students who had teachers with a positive attitude toward mathematics in each of the previous three years had a more favorable attitude toward and higher achievement in arithmetic than students of teachers with neutral or negative attitudes. Phillip's conclusion is supported by a 1984 research report by Suydam (Suydam, 1984). In the report, she states that evidence has been found that a teacher's attitude toward mathematics affects students' attitudes toward mathematics, and that the effect may be cumulative.

In a related study, Kane found that elementary school teachers' attitudes toward mathematics and mathematics instruction were positively related to their achievement in college-level mathematics and mathematics education courses (Kane, 1968). In a 1982 study, Battista and Krockover based their proposed model for the computer education of
prospective elementary school teachers on the premise that if these students develop a positive attitude toward computers and the use of computers in teaching, they would be more likely to use computers in instruction when they become teachers (Battista & Krockover, 1982). This implies that educational institutions that are concerned with the total educational environment of their elementary teacher education students would provide and require mathematics experiences, including an opportunity to interact with microcomputers and MCAI, which cultivate higher achievement in mathematics and, thereby, generate in these students, a more positive attitude toward mathematics and mathematics instruction, which they, in turn, will transmit to their students.

In addition to the previous major considerations, any results generated from the present research could have curricular implications for the restructuring of the content in the required mathematics sequence for elementary education majors at the Ohio State University and, possibly, at other elementary teacher education institutions. Also involved in this decision to use preservice elementary teachers as research subjects is the general lack of experimental studies in MCAI which address this particular group of students. Of the studies which do exist, most are concerned with computer literacy research (e.g., Battista & Krockover, 1982) or remediation studies using MCAI as the primary vehicle for instruction or as instructional support (e.g., Bitter, 1983).
It seems pedagogically expedient to address the aforementioned issues prior to commencing any research study in education. Therefore, these issues will either be controlled or incorporated into the study so that the results produced by the research will be worthy of interpretation.

Manipulative Materials. Manipulative materials have been used to assist children and adults in the learning of mathematics since approximately 600 BC (Adkins, 1956). However, the years 1965-1979 found the use and study of manipulative materials at the elementary school level to be greater than at any other previous time, with most research in this area conducted through dissertation studies (Bernard, 1973; Parham, 1983). The National Defense Education Act of the late 1950's and early 1960's provided money to universities and other educational institutions for the development and dissemination of activity-based instructional materials. Money was also made available to elementary and secondary schools for the purchase of these materials. This added revenue for the development of manipulative materials renewed the interest of the 1930's and 1940's in the effect of activity-based instruction on the learning of mathematics. In addition, the theories of Piaget, Bruner, and Dienes were in the process of being actively and judiciously studied and the relationships among these theories, school-age children, and activity-based instruction were being explored (Kieren, 1971).
A large body of research exists which is related to the question of the effect of manipulative materials on mathematics learning. A search of the literature reveals that most of the research in the use of manipulative materials has been done with either elementary school students (K-8) or preservice elementary teachers. With regard to these students, a large majority of past and present research studies dealing with the use of manipulative materials can be categorized in the following manner (the categories are not necessarily mutually exclusive):


2) studies involving the comparison of concrete, pictorial, and/or symbolic type of materials (Gibb, 1956; Ekman, 1967; Fennema, 1972; Denman, 1975; Scott & Neufeld, 1976; Barnett & Eastman, 1979; Smith, Szabo & Trueblood, 1980; Threadgill-Sowder & Julifs, 1980; Bright, Harvey & Wheeler, 1981)

Studies included in the first category are generally characterized by an experimental treatment group, whose students are permitted to use manipulative materials, and a control group, whose students are not exposed to manipulative materials. At the conclusion of the study, the groups are compared on a dependent variable of achievement and/or attitude.
Studies in the second category are based upon theories developed by Piaget, Dienes, and Bruner (Piaget & Inhelder, 1958; Dienes, 1960; Bruner, 1966). These studies are based on the premise that students progress through three stages of intellectual development: from concrete, physical objects to pictures to symbols. In a majority of studies in this category, researchers were investigating the differential impact on achievement of concrete, pictorial, and symbolic treatments. This type of research study has not been explored, in recent times (1980 to present), as extensively as those in the first category. Even when "learning theory" research was investigated, researchers did not choose to utilize the microcomputer and microcomputer-assisted instruction as an abstract or pictorial representation.

The only recent mathematics research which did consider this approach was the 1984 study by White and Berlin (White, 1985). In their study, microcomputer simulations of manipulative activities were used to determine how children differ in their understanding of mathematics concepts when using the microcomputer compared to using concrete manipulative materials. Further research in this area should be undertaken to help answer questions regarding the nature of the differential impact of concrete and microcomputer activities on students of all ages and achievement levels (White, 1985; Suydam, 1985).
Conceptual Framework

Microcomputer-assisted Instruction. The majority of experimental studies dealing with microcomputers has examined the differential effect of microcomputer-assisted instruction versus traditional non-activity-based instruction on the mathematics achievement of students. In addition, a few studies have included an evaluation of attitude scales as a major portion of the study. The relationship between delivery mode and impact on achievement and attitude can be shown diagrammatically:

![Figure 1](image)

Due to the virtual Socratic relationship between student and machine, plus the additional capabilities of the microcomputer as an instructional delivery system, the theoretical assumption that the use of MCAI will result in superior mathematics achievement and a more positive attitude toward mathematics and microcomputers has been advanced. Even though the empirical verification of the theoretical hypothesis has been mixed, microcomputers and MCAI are and will be an
integral part of the current and future mathematics curricula and it seems pedagogically prudent to continue the verification process across all mathematics subject areas, achievement levels, and student populations.

Activity-based Instruction. In the vast majority of activity-based research, experimenters have focused their efforts on determining if the use of manipulative materials enhances the learning of mathematics more than without the aid of these materials. As in microcomputer-assisted instruction research, most activity-based studies used mathematics achievement as the dependent variable, but a few also included an analysis of attitudinal data as well. The relationship between method of delivery and impact on achievement and attitude can be shown as follows:

![Diagram showing the relationship between instruction with manipulative materials, achievement in mathematics, and attitude toward mathematics.]

Figure 2

Based on theories by Brownell, Piaget, Skemp and Dienes, the theoretical assumption that the use of manipulative materials will result in superior mathematics achievement and a more positive attitude toward mathematics has been advanced (Kennedy, 1986). In addition to
the previous assumption, these theories suggest that students whose learning of mathematics is based on the manipulation of concrete materials will be more likely to understand the relationship between concrete and abstract representations of the same mathematical concept. The use of manipulative materials helps students understand both the meaning of mathematical concepts and the application of the concepts to actual situations.

Evidence from research supports this learning theory-based theoretical supposition for all grade-school levels and achievement levels. However, as grade levels increase, the use of manipulative materials decreases and the results of research become more obscure. Therefore, it seems pedagogically expedient to conduct further activity-based research at advanced educational levels to determine if the results will be consistent with those of previous studies.

MCAI vs. Activity-based Instruction. Based on the previous discussions concerning microcomputer-assisted and activity-based instruction, any theoretical justification as to which of the delivery systems is educationally superior to the other would, most certainly, be dependent upon the student population of interest, the achievement levels of the students, and the mathematical topic under consideration.

Previous empirical research provides little insight into this area. A review of the literature reveals a serious lack of experimental studies dealing with the differential impact of microcomputer-assisted
instruction versus traditional activity-based instruction on the mathematics achievement and attitude toward mathematics of preservice elementary teachers. In fact, only one study investigating this topic was found: a 1984 study, dealing with elementary school students in the second and fourth grades, by White and Berlin (White, 1984).

Therefore, the evidence seems to assert that experimental studies investigating this topic are necessary for two reasons:

1) they will provide empirical data to help construct a theoretical basis for utilizing either or both of the methods in an educational setting.

2) these studies will provide empirical data for use in current and future curricular considerations.

A diagram illustrating the proposed relationship between method of delivery and impact on achievement and attitude is as follows:

![Diagram](image_url)

Figure 3
Statement of the Problem

Given the general lack of quality experimental microcomputer-assisted instruction research and the current interest regarding the relationship between activity-based and microcomputer-assisted instruction, the present study will investigate the effects of these two modes of instruction on the achievement and attitude of preservice elementary teachers. Therefore, the problem in the present study is to compare the effects of a microcomputer-assisted laboratory in elementary probability versus an activity-based elementary probability laboratory on the mathematics achievement, attitude toward mathematics, and attitude toward microcomputers of preservice elementary teachers.

Specifically, the main objectives of the present study are to:

1) determine if there exists a difference in mathematics achievement between the experimental treatment and regular groups following the experimental intervention;

2) determine if there exists a difference in attitude toward mathematics between the experimental treatment and regular groups following the experimental intervention;

3) determine if there exists a difference in attitude toward microcomputers between the experimental treatment and regular groups following the experimental intervention.
The following are secondary objectives for the present study:

1) to determine if previous mathematics achievement has an effect on the mathematics achievement of preservice elementary teachers following the experimental intervention;

2) to determine if previous mathematics achievement has an effect on the attitude toward mathematics of preservice elementary teachers following the experimental intervention;

3) to determine if previous mathematics achievement has an effect on the attitude toward microcomputers of preservice elementary teachers following the experimental intervention.

The production and utilization of microcomputers and microcomputer-assisted instruction materials are proliferating at a very rapid pace. According to the National Center for Education Statistics, U.S. Department of Education, the number of microcomputers available for instructional use more than tripled (31,000 units to 96,000 units) between the Fall of 1980 and the Spring of 1982. Concurrently, the number of mainframe computers available for instructional purposes remained virtually constant (Early Release, National Center for Educational Statistics, 1982). In a study funded by the National Science Foundation, it was reported that the problems associated with the availability of pedagogically sound computer-assisted instruction materials and the lack of reliable evidence of CAI effectiveness were the most critical issues promoting the non-use of computers in instruction (Anastasio & Morgan, 1972). These important concerns, along with
the enormous increase in the production and utilization of microcom-
puters and microcomputer-assisted instruction materials plus the
renewed emphasis concerning activity-based instruction research, demand
that quality research be conducted to determine the differential impact
of microcomputer-assisted mathematics laboratories and activity-based
mathematics laboratories on the achievement and attitude of school-age
students, in general, and preservice elementary teachers, in particular.
Any information obtained from these studies will provide the evidence
and incentive for restructuring the current mathematics curricula, at
all educational levels, to either accommodate or modify the use of the
microcomputer as an instructional delivery system. This author wishes
to make a significant contribution toward this goal of providing
quality research. This study will be a step in that direction.
CHAPTER II
REVIEW OF THE LITERATURE

"...NCTM believes that significant improvements in the teaching and learning of mathematics result from the systematic development of research-based knowledge." (NCTM, 1984)

Computer and Microcomputer-assisted Instruction

The National Council of Teachers of Mathematics (NCTM, 1977) in its official position statement concerning the use of computers in the classroom and the National Council of Supervisors of Mathematics (NCSM, 1977) have asserted that every student should be exposed to the capabilities and limitations of computers through current applications. This position has also been advanced by the respondents to the Priorities in School Mathematics Project survey (PRISM, 1981).

In fact, at a recent NCTM conference concerning the impact of computing technology on school mathematics, it was strongly recommended that computers be used to assist all students in the exploration and discovery of mathematical concepts, in the practice of basic skills, in applied problem solving, and in learning by simulation (NCTM, 1985). It
seems almost sacrilegious to dispute this position. But as any conscientious mathematics educator would attest, evidence that integrating computers and computer-assisted instruction (CAI) into the mathematics curriculum actually enhances student achievement in mathematics should be well-documented in the literature before any wholesale adoption of computers and CAI be supported.

Many mathematics educators have acquired and used computers and CAI simply to become part of the computer "bandwagon" without adequately considering the impact of computer technology on the learning of mathematics. In general, the development of most instructional delivery systems, which includes computers and CAI materials, has proceeded without adequate attention to their educational effectiveness (Anastasio & Alderman, 1973). However, for computers and computer-assisted instruction there exists, in the literature, many research studies which address this critical issue of educational effectiveness in mathematics instruction. This collection of research studies can be categorized in the following manner:

1) Educational level
   a. elementary
   b. secondary
   c. post-secondary

2) Type of instructional delivery system
   a. mainframe/minicomputer
   b. microcomputer
Even though a large number of CAI research studies exist, the number of methodologically sound evaluations of the educational effectiveness of CAI are rare and conclusive results are elusive (Eisele, 1979; Chambers & Sprecher, 1980; Bork, 1983). However, a few generalized conclusions can be made regarding the impact of CAI on the learning process:

1) the use of computer-assisted instruction in instructional mathematics programs either improved learning or exhibited no differences when compared with conventional classroom instruction (Suppes & Morningstar, 1969; Vinsonhaler & Bass, 1972; Taylor et al., 1974; Edwards et al., 1975; Golton, 1975; Kearsley, 1977; Daughdrill, 1978; Magidson, 1978; Splittgerber, 1979; Thomas, 1979; Hallworth & Brebner, 1980; Modissett, 1980; Romero, 1980; Burns, 1981; Yueh, 1981; Pulat & Wang, 1982);

2) the use of computer-assisted instructional mathematics programs improved student attitudes toward the use of computers in instruction (Kieren, 1973; Johnson, 1974; King, 1975; Bickerstaff, 1976; Beck, 1979; Thomas, 1979);

3) the effect on mathematics achievement occurred regardless of the type of computer-assisted instruction used, the educational level of the student, or the type of instrument used to make the measurements (Hallworth & Brebner, 1980; Burns, 1981)
4) the use of computer-assisted instruction in instructional mathematics programs reduced the amount of learning time when compared to traditional classroom instruction (Hall, 1974; Edwards et al., 1975; Thomas, 1979; Chambers & Sprecher, 1980; Bright, 1983).

At the elementary school level, most research in CAI has investigated the impact of drill and practice on the students' mathematics achievement and compared the use of these drill and practice programs with conventional classroom instruction (Overton, 1981). At the secondary school level, CAI tutorials, as well as drill and practice programs, have been extensively studied (Kieren, 1973). Much of the experimental CAI research at the post-secondary school level concerned the tutorial mode of primary CAI (Kulik et al., 1980). In a small number of cases, at all three educational levels, students' attitudes toward mathematics and their attitudes toward the computer as an instructional delivery system have also been examined (Cranford, 1976; Saunders & Bell, 1980; Kulik et al., 1980).

After perusing a multitude of CAI research at the elementary and secondary school levels, a general methodological framework for these studies became apparent. Most of the studies concluded that CAI drill and practice and CAI tutorials were more effective than traditional instruction, where effectiveness was measured by either researcher-constructed or standardized achievement tests. In general, the studies used the classical experimental/control group design with random assignment of intact classrooms into groups. At the elementary school
level, the experimental group received traditional classroom instruction supplemented with daily exposure to CAI drill and practice, while the control group received only traditional instruction. At the secondary school level, the experimental group was exposed to a CAI tutorial, while the control group received only conventional classroom instruction. Mathematics achievement was usually determined for each class by computing an average gain score, which was defined to be the difference between pre- and post-test scores on parallel forms of the achievement test. For the analysis of achievement data, most investigators used the two-sample t-test or the univariate analysis of variance. When initial group equivalence was considered, the two-sample t-test was most often used.

The type of instructional delivery system used in the studies was, in general, either not identified or consisted of typewriter-like keyboards linked to a localized mainframe or minicomputer. It seems most reasonable to assume that the systems not identified were not microcomputer-based due to the relative recency of this type of instructional delivery system and the age of the studies.

The general methodological framework for the typical evaluative study at the post-secondary level is quite similar to the previously mentioned format except that, in general, the experimenter used a single intact class of students and randomly assigned them to experimental and control groups. The members of the experimental group received part of their instruction at computer terminals, whereas students in the control group received their instruction via traditional
teaching methods. At the conclusion of the study, the researcher compared the responses of the two groups on a common examination or on a course evaluation form. Unfortunately, it has proved more difficult to demonstrate the educational advantage of CAI tutorials at post-secondary levels of education, even though the literature seems to support its existence (Jamison et al., 1974; Kulik et al., 1980). Studies which deviate from the aforementioned methodological framework generally do so in terms of investigating additional variables, such as student attitudes, student characteristics such as sex and achievement level, and the amount of instructional time.

The administration of attitudinal measures has not, in general, been a major part of the traditional experimental design at most levels of educational research and even when attitudinal indices were reported, many studies used instruments with unknown or unreported estimates of reliability (King, 1975; Thomas, 1979). The few studies which have assessed student attitudes prior to CAI intervention, as well as after, revealed the following general observations:

1) the use of computer-assisted instruction in mathematics improved student attitudes toward the use of computers in the learning process (Magidson, 1978; Splittgerber, 1979; Hallworth & Brebner, 1980; Bracey, 1982);

2) the use of computer-assisted instruction improved student attitudes toward the learning of mathematics (Saunders & Bell, 1980; Overton, 1981);
3) the use of computer-assisted instruction effected no change in
student attitudes toward computers or the learning of mathematics (Mitzel et al., 1971; Isaac, 1972; Cranford, 1976).

Of all the CAI studies perused which examined student attitudes, in no instance did exposure to CAI, regardless of mode, promote a negative change in student attitude toward either the instructional use of the computer or the learning of mathematics. The only consistent problem concerning attitudinal studies was the experimenter's failure to indicate the manner in which the attitude data were analyzed. In many cases, it appeared that the data were only inspected for trends and not statistically analyzed. In cases where data were statistically analyzed, the univariate analysis of variance was most often used.

As in CAI achievement studies, the research has not produced total agreement concerning the effect of CAI on student attitudes. However, the evidence appears to support the conclusion that student attitudes toward mathematics, as well as their mathematics achievement, are enhanced by exposure to computer-assisted instruction (Beck, 1979).

When student characteristics are investigated by CAI researchers, the ones most consistently studied are the subjects' sex and achievement level. With respect to CAI drill and practice programs in mathematics at the elementary and secondary school levels, the literature appears to support their use at all achievement levels, but boys profit more from their use than girls (Taylor et al., 1974; Edwards et al., 1975; Burns & Bozeman, 1981; Overton, 1981; Forman, 1982). However, girls may possess a more positive attitude toward CAI than
boys (Bickerstaff, 1976). With respect to CAI tutorials in mathematics at the elementary and secondary school levels, the research supports their use with low achievement and disadvantaged students and both sexes profit equally from their use (Edwards et al., 1975; Burns & Bozeman, 1981; Forman, 1982).

CAI researchers in mathematics at the post-secondary school level apparently did not utilize student characteristics, such as sex and achievement level, in their studies since it was impossible to locate experimental CAI studies which incorporated student characteristics as independent variables.

In 1975, Edwards et al., summarized nine studies at the elementary and/or secondary school level, in which the amount of instructional time was used as a dependent variable. In each case, the CAI group completed the instructional unit in less time than the control group and at an equal or greater level of achievement. This result is supported at the post-secondary level by Kulik (Kulik et al., 1980). In their meta-analytic study, Kulik found that in all the studies in which the investigator performed statistical tests, the differences in amount of instructional time between CAI and conventional classes were statistically significant. Therefore, it appears that there exists little doubt that students, at all educational levels, can be taught with CAI in less time than with traditional methods of instruction. This result can have serious curricular implications.
Among the many experimental CAI studies at the post-secondary level, few examined the impact of CAI on the mathematics achievement and/or attitude of preservice elementary teachers. Of the few studies which did investigate this group of subjects, all reported nonsignificant differences between the CAI group and the control group in mathematics achievement (Riedesel & Suydam, 1967; Ward & Ballew, 1972; Yueh, 1981; Battista & Krockover, 1982). However, none of these studies examined student-attitude toward the CAI intervention or toward the learning of mathematics. In addition, of the 59 studies included in the meta-analysis of findings on the effectiveness of computer-based college teaching, none of the CAI studies involving mathematics used preservice elementary teacher as subjects (Kulik et al., 1980).

From only a small number of studies, it is unclear as to the impact of CAI intervention on the mathematics achievement and attitude of preservice elementary teachers. However, with an increase in the number and quality of experimental CAI studies using these subjects, a more detailed and accurate estimate of how well preservice elementary teachers learn mathematics by using CAI can be made.

At the beginning of this chapter, it was stated that there exist in the literature numerous experimental studies, at all educational levels, which examine the impact of CAI intervention on the learning of mathematics. In all the cited studies, the mainframe or minicomputer was used as the instructional delivery system. An exhaustive search of the literature produced very few experimental microcomputer-assisted instruction (MCAI) studies dealing with mathematics instruction. This
is due, in part, to the relative newness of this type of Instructional technology, the enormous time-lag between the completion of research and the publication of results, and the lack of researchers investigating the impact of MCAI on the process of learning. This last point may be attributed to the researchers' judgement that MCAI research is merely an extension of CAI research and that the results of MCAI studies will be consistent with those of CAI studies. This attitude has led to the mere adaptation to microcomputers of previous CAI programs without regard for the unique qualities, such as high resolution graphics, multisensory capabilities, and interactive dialogue, inherent to most microcomputers. Fortunately, there are research groups, such as the MECC (MECC, 1983) and the TABS-Math project at the Ohio State University (Damarin, 1984), which are working diligently to remedy this situation by producing curricular materials whose only use will be with microcomputers. In addition, there are MCAI researchers, such as Gary Bitter, who are pioneering experimental microcomputer-assisted instruction research in the learning of mathematics.

Most of the experimental work with microcomputers as an instructional aid in mathematics has been accomplished with elementary and secondary school students. In most cases, the results of these studies have not been spectacular. In almost every case of statistically significant differences, students using MCAI performed better than the control group (Morris, 1983; Steele, Battista & Krockover, 1983; Carrier, Post, and Heck, 1985). However, about the same number of
experimental MCAI studies reported nonsignificant differences with similar students (Battista & Krockover, 1982; Clark, 1983; Fuson & Brinko, 1985).

With respect to post-secondary education and microcomputer-assisted instruction, only a few studies dealing with preservice elementary teachers and the learning of mathematics were located. When using these particular subjects, the researchers either investigated the effect of MCAI on remedial mathematics students (Yueh, 1981; Bitter, 1983) or tried to determine if computer literacy could be learned more effectively with the aid of microcomputers (Battista & Krockover, 1982). In general, MCAI experimenters did not investigate the impact of introducing and reinforcing new mathematical concepts via microcomputer-assisted instruction.

Even with the mixed results of research, microcomputers seem to be an extremely effective pedagogical tool and when used properly, present a viable alternative for the improvement of the quality of the learning of mathematics. Microcomputers offer a dynamic electronic chalkboard for the demonstration and cultivation of mathematical ideas and concepts. However, it seems obvious that more information concerning the impact of MCAI on the learning of mathematics is needed (Pikaart et al., 1981; Spuck, 1981; Hatfield, 1984). This, of course, means further experimentation. In the present study, further experimentation, to gain additional knowledge of the impact of microcomputer-assisted instruction on the learning of mathematics, will be conducted on preservice elementary teachers.
Manipulative Materials/Activity-based Instruction

Manipulative materials have been used as an aid in the learning of mathematics for approximately 2500 years. Consequently, the effects of the use of physical devices on the mathematics achievement of children and adults are well-documented in the literature.

A search of the literature reveals that most research studies dealing with manipulative materials were completed with either elementary school students or preservice elementary teachers. Very few activity-based instruction studies dealt with other groups of students.

One study which did was a 1981 dissertation by Drapac. Twenty-eight college students enrolled in a remedial elementary algebra course used math tiles to facilitate learning integer arithmetic and factoring polynomials. After three and one-half weeks, the students who used the math tiles showed a significantly higher achievement level and a more positive attitude toward mathematics than a control group of 42 students who did not have access to the manipulative materials (Drapac, 1981).

Another study investigated the effect of using manipulative aids in teaching a unit on ratio and proportion to college freshman. No significant differences in mathematics achievement between the experimental treatment and the control groups were reported (Harris, 1979).
With regard to elementary school students, a concrete or manipulative approach to mathematics instruction is generally superior to a more abstract, non-manipulative approach (Friedman, 1978). This conclusion is supported by studies from Prigge and Robinson. When Prigge investigated the effects of the use of manipulative aids on the learning of geometric concepts by third-graders, he found that significant differences favored the treatment in which students used activities with geometric solids over paper-and-pencil treatments (Prigge, 1978). Robinson used Cuisenaire Rods with third and fourth grade students and found that the use of the rods was effective for introducing new mathematical concepts (Robinson, 1978).

In support of these studies are a meta-analytic study by Parham and research reports by Suydam and Driscoll. Parham, in a 1983 meta-analytic study of the use of manipulative materials and student achievement in elementary school mathematics, concluded that physical devices do have a positive impact on student achievement in mathematics (Parham, 1983). In a 1984 research report on manipulative materials, Suydam reported that lessons which use manipulative aids have a higher probability of producing greater mathematics achievement than do lessons in which such materials are not utilized (Suydam, 1984). Driscoll, in a 1984 overview of research on manipulative materials in mathematics instruction, concluded that concrete materials are useful not only in the primary grades but also beyond the elementary school level (Driscoll, 1984). In fact, Moser contends that manipulative materials should be used by children of all ages (Moser, 1986)!
However, there exists evidence in the literature, in the form of overviews and experimental studies, which does not support the conclusions of Driscoll and Moser. In a 1978 overview of activity-based instruction research, Friedman concluded that after the first grade, where the use of manipulative materials has been effective, an instructional strategy which gives preeminence to the use of manipulative materials is unwarranted (Friedman, 1978). In support of this contention, Threadgill-Sowder and Julifs found that with increasing grade levels, the number of studies favoring the use of manipulative materials for learning mathematics decreases, with results so varied as to be inconclusive at the junior high school level and beyond (Threadgill-Sowder & Julifs, 1980). For example, in two studies with seventh-grade students, Bright, Harvey, and Wheeler (1981) found no significant differences in mathematics achievement among groups of students who used manipulative materials, pictorial representation of the manipulative materials, or neither physical nor pictorial aids, while Allen found a significant difference in mathematics achievement between groups of students using Cuisenaire Rods and groups not using the rods. Based on his research, Allen concluded that the use of Cuisenaire Rods improved the basic mathematics skills of seventh-grade students (Allen, 1978). In addition, Altizer, in her 1977 dissertation study with eighth-grade students, reported that retention scores favored one group using manipulative materials over a non-manipulative group, while no significant difference was found on the immediate posttest (Altizer, 1977).
At the high school level, Stockdale found little evidence to support or refute the efficacy of instruction using manipulative materials when compared to instruction without manipulatives on student performance on multiplication and factorization of second-degree polynomials (Stockdale, 1980). The same conclusion was reported by Corwin in a 1978 study which investigated the effect of learning geometry with or without the use of manipulative aids (Corwin, 1978).

Similar results were reported for preservice elementary teachers. Barnett and Eastman conducted an investigation with 78 preservice elementary teachers to obtain information regarding the effectiveness of the use of manipulative aids in the enactive and iconic modes of instruction. In 1978, a significant difference was found favoring the enactive group on a mathematics concept test (Barnett & Eastman, 1978). However, when the original researchers replicated the study a year later, they found no significant difference between the enactive and iconic groups on the same mathematics concept test (Barnett & Eastman, 1979).

In three dissertation studies completed in 1977, both Olson and Niver reported finding no significant differences in mathematics achievement between groups of preservice elementary teachers who were permitted the use of manipulative materials and groups who were not (Olson, 1977; Niver, 1977), while Kleinhaus found a significant difference in mathematics achievement, but a nonsignificant difference on the attitude instrument (Kleinhaus, 1977). Niver also investigated the
affective domain of his subjects and, unlike Kleinhaus, found a significant difference between the groups on an attitude toward the study of volume scale.

When the use of manipulative materials is compared to non-use, the general conclusion from the literature indicates mixed results, especially with studies involving preservice elementary teachers. The only educational level where the use of manipulative aids appears to be effective is with elementary school students and even with this group exceptions occur (e.g., Paolini, 1979; Ziegenbalg, 1981; Canny, 1984).

Microcomputer-assisted Instruction vs. Activity-based Instruction

Due to the proliferation of microcomputer and microcomputer-assisted instruction, researchers, in both activity-based instruction and educational technology, are combining their expertise and are now in the process of comparing the instructional effectiveness of manipulative materials with the effectiveness of microcomputer-assisted instruction. White and Berlin, in their 1984 study, compared the use of concrete manipulative materials with a microcomputer simulation of the same materials with children at the second and fourth grade levels (White, 1984). They found that concrete and microcomputer activities have different effects on children depending on their socio-cultural background and their sex.
As can be ascertained from the literature, further research is needed to delineate the nature of the differential impact of concrete manipulative materials and microcomputer activities on the cognitive and affective domains of students. The present study will be a step in that direction.

The remainder of the present study is divided into four chapters. Chapter III will provide a detailed description of the study, including the methodology. Statistical results will be presented in Chapter IV. Chapter V will be devoted to the interpretation and discussion of the results. The final chapter will present a summary of the results of the study and recommendations for further research.
"Empirical, controlled research dealing with the
cognitive effects of microcomputer use is indeed
scarce." (Collis, 1983)

The present experimental microcomputer-assisted instruction study
has three major null hypotheses:

1) preservice elementary teachers using a microcomputer-assisted
introduction probability laboratory will not score significantly different on a probability posttest than those receiv­
ing a conventional introductory probability laboratory.

2) preservice elementary teachers using a microcomputer-assisted
introductory probability laboratory will not manifest a
significantly different attitude toward mathematics than
those receiving a conventional introductory probability
laboratory.

3) preservice elementary teachers using a microcomputer-assisted
introductory probability laboratory will not manifest a
significantly different attitude toward microcomputers than
those receiving a conventional introductory probability laboratory.

This study also investigates three secondary null hypotheses:

1) preservice elementary teachers demonstrating above average mathematical achievement will not score significantly different on a probability posttest than those demonstrating average mathematical achievement.

2) preservice elementary teachers demonstrating above average mathematical achievement will not manifest a significantly different attitude toward mathematics than those demonstrating average mathematical achievement.

3) preservice elementary teachers demonstrating above average mathematical achievement will not manifest a significantly different attitude toward microcomputers than those demonstrating average mathematical achievement.

Prior to any serious investigation of the validity of the aforementioned null hypotheses, a number of critical definitions and descriptions must be provided. Therefore, the primary focus of this chapter is to provide these definitions and descriptions. In addition, the methodology employed in the present study will also be described. In particular, this chapter will:

1) define the variables of interest;

2) describe the data collection instruments;

3) describe the subjects of the study; and

4) present the research design, including appropriate data analysis procedures.
Definitions of Dependent Variables
and Description of Data-gathering Instruments

This study, unlike many previous CAI and/or MCAI research studies, examined both the affective, as well as the cognitive, responses of preservice elementary teachers on instruments specifically designed to measure their attitudes and mathematics achievement: the dependent variables of the present study. More specifically, the dependent variables that were measured were attitude toward mathematics, attitude toward microcomputers, and achievement in mathematics.

Paper and pencil pretests and posttests were administered for each of these dependent variables. Three weeks of instruction (one week for elementary probability), plus two microcomputer laboratory sessions, occurred between administrations of achievement and attitude pre- and posttests. The students were given two class periods to respond to the items on the pre/post instruments (approximately ninety minutes total). All answers were recorded on the General Purpose-NCS-Answer Sheet.

In total, seven instruments were used to gather student data and test for achievement and attitude. These were

1) the Student Information Sheet,
2) the Probability Pretest,
3) the Attitude toward Mathematics scale (pre),
4) the Attitude toward Microcomputers scale (pre),
5) the Probability Posttest,
6) the Attitude toward Mathematics scale (post), and
7) the Attitude toward Microcomputers scale (post).
This section of the chapter will furnish pertinent information regarding each of these instruments.

**Student Information Sheet.** To gather pertinent information regarding the subjects of the present study, a fourteen-question student information instrument was constructed by the researcher. The data generated by this instrument were used to provide a detailed description of the subjects of the present study, i.e., preservice elementary teachers. This instrument was administered to the subjects during the second week of classes, Spring Quarter 1985 (See Appendix A).

**Probability Pretest.** A twelve-question, multiple-choice format, researcher-constructed probability pretest was administered to the subjects of the study at the same time as the Student Information Sheet (see Appendix B). Due to the pretest's initial estimate of reliability (KR 20 = 0.093), four questions were deleted from the pretest for one or more of the following reasons:

1) low index of discrimination (D < 0.30) - #85, #90, #93.

2) unsuitable level of difficulty (Rel. Diff < 0.25 or Rel. Diff. > 0.75) - #85, #88, #93.

3) negative point biserial correlation coefficient - #93.

The KR 20 for this new eight-item pretest was 0.276. Because of this low reliability estimate, it was assumed that this pretest was measuring random error. However, the students' scores for this pretest were used, with caution and reservation, for further analysis.
Attitude toward Mathematics Scale (Pre and Post). The students' attitudes toward mathematics were measured by the Attitude toward Mathematics Scale by Suydam and Trueblood (Mitzel, et al., 1971; Suydam, 1984). This one-dimensional, Likert-type scale consisted of 26 statements which expressed a feeling or attitude toward mathematics. Each statement was scored on a 1-to-5 basis and the higher the score the more positive the attitude toward mathematics. A total raw score was derived for each student by summing the scores on the 26 items. In previous administrations of this instrument to teachers, coefficient alpha, a measure of internal consistency reliability, averaged 0.94. This scale, in its present form was used for both pretest and posttest data collection purposes (see Appendix C). Both the pretest and the posttest administrations yielded reliability estimates of 0.96. As a pretest, this instrument was administered during the second week of Spring Quarter, 1985, and as a posttest, during the fifth week of the same quarter.

Attitude toward Microcomputers Scale (Pre and Post). Student attitude toward the microcomputer as an instructional delivery system was measured by the Attitude toward Microcomputers scale (see Appendix D). It is a researcher-constructed, Likert-type scale. Each of the thirteen statements were scored on a 1-to-5 basis such that the higher the score the more positive the attitude toward microcomputers. A total raw score was derived for each student by summing the scores on the thirteen items. Coefficient alpha for both the pre and post administration of these instruments was 0.90. As with the Attitude toward Mathematics scale, this instrument was given to the subjects in
both the Experimental and Regular groups during the second week of Spring Quarter as a pretest, and the fifth week of the same quarter as a posttest.

**Probability Posttest.**\(^3\) The initial probability posttest was the same test as the original probability pretest. However, the posttest's initial reliability estimate was \(KR20 = 0.443\). In an attempt to increase this low estimate of reliability, three questions were deleted from the analysis of posttest scores for the following reasons:

1) low index of discrimination \((D < 0.30)\) - #178, #182, and
2) unsuitable level of difficulty \((Rel. Diff. < 0.25\) or \(Rel. Diff. > 0.75\)) - #172.

The \(KR20\) for this new nine-item posttest was 0.514. Each of the nine questions was graded right or wrong and a composite raw score was obtained for each student by summing the total number of correct responses. This posttest was given as the weekly quiz during the fifth week of Spring Quarter, 1985 (see Appendix E).

**Definition of Independent Variables**

The independent variables in the present study are mode of treatment, level of mathematical achievement, and time of testing.

**Mode of Treatment.** Mode of treatment consisted of two levels:

1) Experimental - students in this group were provided with a microcomputer-assisted probability laboratory (see Appendix F) with additional microcomputer experience in the form of an
Introduction to LOGO laboratory (see Appendix G). The LOGO laboratory was administered one week prior to the microcomputer-assisted probability laboratory.

2) Regular - students in this group were given the conventional worksheet/manipulative probability laboratory (see Appendix H). During the week before the probability laboratory, this group of students was also exposed to the Introduction to LOGO microcomputer laboratory. Both treatment groups were exposed to the LOGO microcomputer laboratory so that the students' responses to the Attitude toward Microcomputers scales could be statistically compared within and across groups.

The microcomputer-assisted probability laboratory was designed to be similar in content to the conventional worksheet/manipulative probability laboratory. Format differences occurred due to the different capabilities of the two instructional media. One major difference was in the delivery of feedback. Students using the microcomputer-assisted probability laboratory received immediate, personal feedback. The students using the conventional probability laboratory in the normal small group situation (usually groups of 3 to 5 students) had to wait for feedback until the instructor was available, plus the feedback was usually group-directed not individually-directed.

The other major difference between the two laboratories was the degree of control over laboratory activities. In the microcomputer format, the computer "threw" the dice and "counted" the outcomes. In the conventional format, the students had to perform these tasks.
Mathematical Achievement. For the present study, mathematical achievement, which was defined as the student's final grade in Math 105\textsuperscript{4}, consisted of two categories:

1) Average Achievement - students were assigned this status if they received a B-, C+, C, or C- in Math 105, and

2) Above Average Achievement - students were assigned this status if they obtained an A, A-, B+, or B in Math 105.

The rationale for creating these two categories was motivated by two considerations:

1) curricular implications, and

2) aptitude \times treatment interaction.

Mathematics content courses in elementary teacher education programs should be examined and restructured to accommodate microcomputers as an integral part of all such courses, if verified by experimental research. Therefore, if the Experimental group outperforms or performs as well as the Regular group on the Probability Posttest, empirical evidence would then exist for the inclusion of the microcomputer-assisted probability laboratory in the official Department of Mathematics Math 106 syllabus.

Another consideration is aptitude \times treatment interaction. Work by Cronbach and Snow (1977) has suggested that nonsignificant differences between treatment effects is often a hint to possible interaction of the treatments with an aptitude measure. For instance, students with average mathematical achievement might have more need for concrete materials and would therefore find a manipulative approach for the learning of mathematics more beneficial than an abstract approach, such as microcomputer-assisted instruction. On the other hand, students
with above average mathematical achievement would probably be less affected by instructional methods and be able to process information from either approach.

Time. For this study, time was considered a within-subjects, repeated-measures, independent variable with two levels:

1) Time 1 - all pretest measures for achievement and attitude were included in this level, and

2) Time 2 - all posttest measures for achievement and attitude were included in this level.

The time variable was used to incorporate all pretest and posttest measures of achievement and attitude in the design and analysis of the experiment.

Description of the Subjects and Course

The subjects of the present study were the students enrolled in Math 106, Spring Quarter 1985, who completed all work up to and including the section on probability. Table 1 shows that most of the students enrolled were Sophomore or Junior females between the ages of 18 and 21. The table also indicates that the subjects of the study were unfamiliar with the use of microcomputers in an educational setting. With regard to the study of probability; no student had a full course in probability at the high school level and only three had an entire probability course at the college level. Additional information regarding the subjects' academic backgrounds is provided in Table 1.
# TABLE 1

**STUDENT INFORMATION SHEET**

**MATH 106**

**SPRING QUARTER 1985**

<table>
<thead>
<tr>
<th>SEX</th>
<th>MALES</th>
<th>FEMALES</th>
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<td></td>
<td>8 (8%)</td>
<td>94 (92%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AGE</th>
<th>18-19</th>
<th>20-21</th>
<th>22-23</th>
<th>24-25</th>
<th>26 and over</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>36 (35%)</td>
<td>45 (44%)</td>
<td>7 (7%)</td>
<td>3 (3%)</td>
<td>11 (11%)</td>
</tr>
</tbody>
</table>
Table 1 (continued)

<table>
<thead>
<tr>
<th>COLLEGE</th>
<th>UVC</th>
<th>EDUCATION</th>
<th>ARTS &amp; SCIENCES</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>72 (71%)</td>
<td>22 (22%)</td>
<td>2 (2%)</td>
<td>6 (6%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>YEAR IN COLLEGE</th>
<th>FRESHMAN</th>
<th>SOPHOMORE</th>
<th>JUNIOR</th>
<th>SENIOR</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14 (14%)</td>
<td>59 (58%)</td>
<td>21 (21%)</td>
<td>3 (3%)</td>
<td>5 (5%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TRANSFER STUDENT</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>19 (19%)</td>
<td>83 (81%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>YEARS OF HIGH SCHOOL MATHEMATICS</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 or more</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 (8%)</td>
<td>16 (16%)</td>
<td>34 (33%)</td>
<td>41 (41%)</td>
<td>3 (3%)</td>
</tr>
</tbody>
</table>
Table 1 (continued)

**AVERAGE GRADE IN HIGH SCHOOL MATHEMATICS**

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17 (17%)</td>
<td>51 (50%)</td>
<td>30 (29%)</td>
<td>4 (4%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

**COLLEGE MATHEMATICS COURSES TAKEN AT OSU**

<table>
<thead>
<tr>
<th></th>
<th>MATH 105 only</th>
<th>MATH 102 AND 105</th>
<th>OTHER MATH</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 105 only</td>
<td>28 (28%)</td>
<td>30 (29%)</td>
<td>44 (43%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**GRADE IN MATH 105**

<table>
<thead>
<tr>
<th></th>
<th>A, A-</th>
<th>B+, B</th>
<th>B-, C+</th>
<th>C, C-</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25 (25%)</td>
<td>37 (36%)</td>
<td>19 (19%)</td>
<td>21 (21%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

**NUMBER OF TIMES TAKEN MATH 106**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3 or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of</td>
<td>100 (98%)</td>
<td>2 (2%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>times taken</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 1 (continued)

HIGH SCHOOL EXPOSURE TO MICROCOMPUTERS

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 (17%)</td>
<td>85 (83%)</td>
</tr>
</tbody>
</table>

COLLEGE EXPOSURE TO MICROCOMPUTERS

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 (20%)</td>
<td>81 (79%)</td>
</tr>
</tbody>
</table>

EXPERIENCE PROGRAMMING MICROCOMPUTERS

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 (19%)</td>
<td>83 (81%)</td>
</tr>
</tbody>
</table>

STUDIED PROBABILITY IN HIGH SCHOOL

<table>
<thead>
<tr>
<th>NOT AT ALL</th>
<th>PART OF HIGH SCHOOL COURSE</th>
<th>ENTIRE COURSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 (47%)</td>
<td>54 (53%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>
Table 1 (continued)

<table>
<thead>
<tr>
<th>STUDIED PROBABILITY IN COLLEGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOT AT ALL</td>
</tr>
<tr>
<td>46 (45%)</td>
</tr>
</tbody>
</table>
According to Edward J. Schlechty, Manager of the Scheduling, Registration and Records Office at the Ohio State University, the class-scheduling computer randomly assigns students to individual sections of Math 106 (Schlechty, 1984). As a result, it was assumed that the two treatment groups were initially nonsignificantly different. In addition, the eight intact Math 106 recitation sections were randomly assigned to treatment groups: four in the Experimental group and four in the Control group. To be relatively certain that the two treatment groups were initially nonsignificantly different, a probability pretest was administered to all one-hundred two Math 106 students involved in the study and the resultant data were sorted by treatment groups and then compared using the two-sample t-test.

The prerequisite course for Math 106 is Math 105, Mathematics for Elementary Teachers I. A student must successfully complete the requirements for Math 105 to be eligible for enrollment in Math 106. Math 106, which is a continuation of Math 105, is a five quarter-hour course whose topics include rational and real number arithmetic, elementary probability, and informal geometry. Successful completion of Math 106 and Math 105 satisfies the mathematics requirement of the certification program for elementary teacher education in the State of Ohio. The text for both Math 105 and Math 106 is Mathematics for Elementary School Teachers, 2nd Edition by James E. Schultz plus Supplements A through E (Math 105) and Supplement F (Math 106) by Joseph Ferrar and Joan Leitzel.
The lecture-recitation format was the mode of instruction for Math 106. Students attended large-group lectures on Monday, Wednesday, and Friday and small-group recitation sections on Tuesday and Thursday. Recitation sections, in general, fulfilled two major functions:

1) provided time for answering student questions regarding the current topic(s); and

2) provided pertinent laboratory activities, often involving manipulative materials, which introduced or reinforced the current material discussed in lecture.

Five instructors were involved in the present study: one faculty-member lecturer and four graduate-student instructors. The graduate-student instructors were M.S. students in mathematics who were interested in the mathematics preparation of elementary school teachers. They were employed by the Department of Mathematics and worked under the supervision of an experienced professor (the lecturer). Each graduate-student instructor was responsible for two recitation sections per week.

Experimental Design

Design. The research design that was used to test for main and interaction effects in the comparison of mode of treatment, level of achievement, and time of testing on the students' achievement in mathematics, attitude toward mathematics, and attitude toward microcomputers was the Multivariate Two Between-One Within-Subjects Design.
This design was defined by between-subjects variables mode of instruction (which consisted of two levels, Experimental and Regular) and achievement level (which consisted of two levels, Above Average and Average), which crossed, and within-subjects factor time of testing (which consisted of two levels, Time 1 (pre) and Time 2 (post)). The design was multivariate in nature because for each level of the time variate, one achievement test and two attitude scales were administered to each student in the study. For a more lucid description of the structure of this design, see the data matrix presented in Table 2.

It can be deduced from Table 2 that this 2x2x2, unbalanced, factorial design had 47 students in the Experimental group, of whom 28 were in the Above Average Achievement Level and 19 were in the Average Achievement Level, and 54 students in the Regular group, of whom 34 were in the Above Average Achievement Level and 20 were in the Average Achievement Level. These 101 students were selected for the study because each of them completed all sections of the instruments employed in the study.5

The Model. The model for the Two Between-One Within Subjects Design for each dependent variable in the present study is

\[ x_{ijkm} = \eta + \alpha_j + \beta_{ik} + (\alpha \beta)_{ij} + \pi_{ijkm} + \gamma_m + (\alpha \gamma)_{jm} + (\beta \gamma)_{km} + \xi_{ijkm} \]

where
Table 2

DATA MATRIX
FOR MULTIVARIATE TWO BETWEEN-ONE WITHIN-SUBJECTS DESIGN
FOR THE PRESENT STUDY

<table>
<thead>
<tr>
<th></th>
<th>S1</th>
<th>PPRA MAPR MIPR</th>
<th>PPOM MAPO MIPO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S28</td>
<td>PPRA MAPR MIPR</td>
<td>PPOM MAPO MIPO</td>
<td></td>
</tr>
</tbody>
</table>

EXPERIMENTAL

<table>
<thead>
<tr>
<th></th>
<th>S1</th>
<th>PPRA MAPR MIPR</th>
<th>PPOM MAPO MIPO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S19</td>
<td>PPRA MAPR MIPR</td>
<td>PPOM MAPO MIPO</td>
<td></td>
</tr>
</tbody>
</table>
Table 2 (continued)

<table>
<thead>
<tr>
<th></th>
<th>$S_1$</th>
<th>PPRE</th>
<th>MAPR</th>
<th>MIPR</th>
<th>PPO</th>
<th>MAPO</th>
<th>MIPO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Above</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$S_{34}$</td>
<td>PPRE</td>
<td>MAPR</td>
<td>MIPR</td>
<td>PPO</td>
<td>MAPO</td>
<td>MIPO</td>
</tr>
</tbody>
</table>

CONTROL

<table>
<thead>
<tr>
<th></th>
<th>$S_1$</th>
<th>PPRE</th>
<th>MAPR</th>
<th>MIPR</th>
<th>PPO</th>
<th>MAPO</th>
<th>MIPO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$S_{20}$</td>
<td>PPRE</td>
<td>MAPR</td>
<td>MIPR</td>
<td>PPO</td>
<td>MAPO</td>
<td>MIPO</td>
</tr>
</tbody>
</table>

$^\dagger$ PPRE - Probability Pretest, MAPR - Attitude toward Mathematics scale (pre), MIPR - Attitude toward Microcomputers scale (pre).

$^{\dagger\dagger}$ PPO - Probability Posttest, MAPO - Attitude toward Mathematics scale (post), MIPO - Attitude toward Microcomputers scale (post).
1) $X_{ijkm}$ is the dependent variable score (probability test, attitude toward mathematics or attitude toward microcomputers) for the $i$th student in group $j$, achievement level $k$, and at time $m$,

2) $\mu$ is the overall population mean for each dependent variable and is a constant for all observations under consideration,

3) $\alpha_j$ is the effect for the $j$th group,

4) $\beta_k$ is the effect for the $k$th level of achievement,

5) $(\alpha\beta)_{jk}$ is the effect for interaction between the $j$th group and $k$th level of achievement,

6) $\tau_{ijk}$ is the error term for the $i$th student within combinations of group $j$ and level of achievement $k$,

7) $\gamma_m$ is the effect for the $m$th level of the time of testing variable,

8) $(\alpha\gamma)_{jm}$ is the effect for interaction between the $j$th group and the $m$th level of testing time,

9) $(\beta\gamma)_{km}$ is the effect for interaction between the $k$th level of achievement and the $m$th level of testing time,

10) $(\alpha\beta\gamma)_{jkm}$ is the effect of interaction among the $j$th group, the $k$th level of achievement, and the $m$th level of testing time,

11) $(\alpha\gamma)_{imjk}$ is the effect of interaction between the $i$th student and the $m$th level of testing time within combinations of group $i$ and level of achievement $k$, and

12) $\varepsilon_{ijkm}$ is the error term for the $i$th student in group $j$, level of achievement $k$, and level of testing time $m$. 
Since there was only one observation per Student x Time and Group x Achievement level combinations, it was not possible to obtain separate variance estimates for \( \theta_{lm/jk} \) and \( \epsilon_{ijkm} \). In other words, it was impossible to obtain separate variance estimates for the Student x Time interaction within Group x Achievement combinations and population error. They were confounded within a residual source of error which was used to calculate F-values for the within-subjects sources of variability.

**The Analysis.** The 1982 SAS version of the multivariate analysis of variance program was used to simultaneously analyze the achievement and attitude data (SAS, 1982). The multivariate analysis of variance (MANOVA) was selected over three separate, univariate, repeated-measures analyses of variance (ANOVA) because the MANOVA test considers the correlations between the dependent variables. If separate ANOVA tests are performed, it is assumed that either the correlations between the dependent variables are zero or that the correlations were of no interest to the researcher. Even if the major interest was in assessing the effects on only one theoretical construct, it is usually the case that it is more prudent to multi-operationalize a construct rather than mono-operationalize it (Cook and Campbell, 1979; Hazen, 1980; Cole et al., 1981). Therefore, a 2x2x2 factorial, unbalanced MANOVA was selected as an appropriate data analysis procedure. The MANOVA, as well as the ANOVA, test statistics, an appropriate post hoc multiple comparisons procedure, plus a few other pertinent statistics are presented and discussed in Chapter IV.
The Assumptions of MANOVA. As with any inferential statistical procedure, the mathematics of MANOVA is based on a set of assumptions. The statistical requirements for MANOVA are

1) the units of analysis are randomly sampled from the population of interest,
2) the measurements are statistically independent of each other,
3) the dependent variables have a multivariate normal distribution within each group, and
4) the $k$ groups have a common within group population covariance matrix.

Even though these assumptions are statistical requirements for MANOVA, it is rarely the case, for any given experimental study in the social sciences, that all of these assumptions will be precisely met. The present study is no exception.

Based on previous experience with Math 106 students, it seems reasonable to assume that the students in the present study were representative of the population of Math 106 students. In addition, these students were randomly assigned to Math 106 recitation sections, via computer scheduling, and each recitation section was randomly assigned experimental or comparison status.

In repeated measures designs, multiple measures for each subject are collected at different times using the same or parallel forms of the measures. These measures can be viewed as separate variables statistically and, therefore, will not violate the independence of observations assumption (Bray and Maxwell, 1985). Based on a number of Monte Carlo studies (e.g., Ito, 1969; Mardia, 1971; Olson, 1974),
departures from multivariate normality and failing to meet the equality of covariance matrices assumptions seem to have only slight effects on the Type I error rates of the four MANOVA test statistics.

An a priori estimation of power in a MANOVA study is difficult to ascertain because so many unknown parameters must be estimated. As in ANOVA, departures from normality and the magnitude of the within-group intercorrelations definitely effects the power of the four MANOVA test statistics. In most cases, violations of these assumptions will reduce statistical power. This must be considered prior to any interpretation of the results of this study.

Statistical results for both the achievement and attitude data will be presented in the next chapter.
1 For this study, attitude towards mathematics was defined as the student's scores on the Attitude toward Mathematics scale by Suydam and Trueblood (1971). See page 45 for details.

2 For this study, attitude towards microcomputers was defined as the student's scores on the Attitude toward Microcomputers scale by the reseacher. See pages 45 and 46 for details.

3 The content of both the Probability Pretest and Posttest was validated by James E. Schultz, Associate Professor of Mathematics, the Ohio State University.


5 101 subjects were included in the MANOVA analysis because the current SAS version of MANOVA automatically deletes subjects that do not complete all portions of the instruments used in the analysis.

6 Due to the low reliability estimate for the Probability Pretest, a follow-up MANOVA analysis, deleting Time as an independent variable, was conducted. The independent variables were mode of treatment and achievement level. The dependent variables were the Probability Posttest, the Attitude toward Mathematics postscale, and the Attitude toward Microcomputer postscale. The results of this analysis will be presented in Chapter IV.
CHAPTER IV
RESULTS OF THE STUDY
First Level Results

Prior to conducting the major analysis for the present study, a first level investigation of the achievement and attitude data by Groups and Achievement Levels was performed.

Pretest Measure-Achievement. A two-sample t-test was performed on the Probability Pretest (final version) scores to determine the initial statistical status of the two treatment groups. Table 3 presents the results of this analysis. As can be seen from the table, the scores of the two groups were not significantly different on the final version of the Probability Pretest ($p = 0.584$). Therefore, the treatment groups were assumed to be statistically nonsignificantly different on the achievement pretest.

Even though the hypotheses concerning Achievement Level groupings were of secondary importance, two-sample t-tests were employed to determine whether the levels were significantly different from each other at the onset of the study. As can be seen from Table 4, the scores for the students in the Above Average Achievement Level were not significantly different from those in the Average Achievement Level on the final version of the Probability Pretest ($p = 0.323$).
TABLE 3

\(t\)-Test Data for the Probability Pretest (Final Version) by Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>(\bar{x})</th>
<th>SD</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>48</td>
<td>4.15</td>
<td>1.56</td>
<td>0.55†</td>
</tr>
<tr>
<td>Regular</td>
<td>54</td>
<td>3.98</td>
<td>1.46</td>
<td></td>
</tr>
</tbody>
</table>

†\(p=0.584\), groups not significantly different.

TABLE 4

\(t\)-Test Data for the Probability Pretest (Final Version) by Achievement Levels

<table>
<thead>
<tr>
<th>Level</th>
<th>n</th>
<th>(\bar{x})</th>
<th>SD</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Average</td>
<td>62</td>
<td>4.18</td>
<td>1.51</td>
<td>0.99†</td>
</tr>
<tr>
<td>Average</td>
<td>40</td>
<td>3.88</td>
<td>1.49</td>
<td></td>
</tr>
</tbody>
</table>

†\(p=0.323\), levels not significantly different.
Pretest Measure-Attitude. A two-sample t-test was performed on the Attitude toward Mathematics and Attitude toward Microcomputers prescale scores to determine the pre-study statistical status of the two treatment groups on the two attitude scales. Table 5 presents the results of the analysis for the Attitude toward Mathematics data and Table 6 does the same for the Attitude toward Microcomputers scores.

The tables show that the scores for both attitude scales for the two treatment groups were not significantly different from each other ($p = 0.649$ for Mathematics and $p = 0.393$ for Microcomputers). These results imply that the Experimental and Regular groups can be assumed to be statistically nonsignificantly different on both the Attitude toward Mathematics and the Attitude toward Microcomputers scales.

Table 7 presents the results of the analysis of the Attitude toward Mathematics prescale data by Achievement Level groupings. As is readily apparent, student scores in the Above Average Achievement Level differ significantly from those in the Average Achievement Level ($p = 0.003$) in the positive direction. Therefore, any interpretation of the results of the major MANOVA analysis dealing with main and/or interaction effects of Achievement Level must be undertaken carefully and cautiously.

Table 8 presents the results of the two-sample t-test for Achievement Level and Attitude toward Microcomputers. With a $p$-value of 0.711, the Levels were not significantly different.

Correlations. Table 9 presents the overall correlations between the pretest and posttest dependent variable data for the present study. An inspection of this table provides evidence for rejecting the multi-
### TABLE 5

**t-Test Data for the Attitude toward Mathematics scale (pretest) by Groups**

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>( \bar{X} )</th>
<th>SD</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>48</td>
<td>74.10</td>
<td>22.18</td>
<td>-0.46t</td>
</tr>
<tr>
<td>Regular</td>
<td>54</td>
<td>75.91</td>
<td>17.71</td>
<td></td>
</tr>
</tbody>
</table>

\( t_p=0.649, \) groups not significantly different.

### TABLE 6

**t-Test Data for the Attitude toward Microcomputers scale (pretest) by Groups**

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>( \bar{X} )</th>
<th>SD</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>48</td>
<td>41.83</td>
<td>8.11</td>
<td>-0.86t</td>
</tr>
<tr>
<td>Regular</td>
<td>54</td>
<td>43.15</td>
<td>7.37</td>
<td></td>
</tr>
</tbody>
</table>

\( t_p=0.393, \) groups not significantly different.
### TABLE 7

**t-Test Data for the Attitude toward Mathematics scale (pretest) by Achievement Levels**

<table>
<thead>
<tr>
<th>Level</th>
<th>n</th>
<th>$\bar{x}$</th>
<th>SD</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Average</td>
<td>62</td>
<td>79.71</td>
<td>18.65</td>
<td>3.06†</td>
</tr>
<tr>
<td>Average</td>
<td>40</td>
<td>67.85</td>
<td>19.74</td>
<td></td>
</tr>
</tbody>
</table>

$^\dagger p=0.003$, levels significantly different

### TABLE 8

**t-Test Data for the Attitude toward Microcomputers scale (pretest) by Achievement Levels**

<table>
<thead>
<tr>
<th>Level</th>
<th>n</th>
<th>$\bar{x}$</th>
<th>SD</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Average</td>
<td>62</td>
<td>42.76</td>
<td>7.87</td>
<td>0.37†</td>
</tr>
<tr>
<td>Average</td>
<td>40</td>
<td>42.18</td>
<td>7.57</td>
<td></td>
</tr>
</tbody>
</table>

$^\dagger p=0.711$, levels not significantly different
TABLE 9
Overall Correlations between Pretest/Posttest Measures

<table>
<thead>
<tr>
<th>Probability</th>
<th>Attitude toward Mathematics Posttest</th>
<th>Attitude toward Microcomputers Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability Pretest</td>
<td>0.16</td>
<td>0.01</td>
</tr>
<tr>
<td>(0.1161)</td>
<td>(0.9104)</td>
<td>(0.7894)</td>
</tr>
<tr>
<td>Attitude Pretest</td>
<td>0.10</td>
<td>0.92</td>
</tr>
<tr>
<td>(0.3271)</td>
<td>(0.0001)</td>
<td>(0.4456)</td>
</tr>
<tr>
<td>Microcomputers Pretest</td>
<td>-0.02</td>
<td>0.44</td>
</tr>
<tr>
<td>(0.8213)</td>
<td>(0.0001)</td>
<td>(0.0001)</td>
</tr>
</tbody>
</table>
variate analysis of covariance procedure as the appropriate data analysis technique for the achievement and attitude data in the present study.

According to Kennedy, the correlation between each covariate and dependent variable should be strong \((r \geq 0.60)\) and linear (Kennedy, 1978). However, most researchers consider \(r \geq 0.30\) to be a sufficiently strong relationship between covariates and dependent variables (Loadman, 1986).

As can be seen from Table 9, this relationship does not exist for most of the pretest/posttest variables in the present study. Therefore, based on the separate-ANOVA discussion in Chapter III plus the lack of a strong covariate/dependent variable relationship, the MANOVA procedure was determined to be an appropriate data analysis technique for the simultaneous analysis of the achievement and attitude data in this study.

To summarize, the Experimental and Regular groups were not significantly different initially in their achievement in probability, their attitude toward mathematics or their attitude toward microcomputers. The same can be said for Achievement Levels, except in the case of the students' Attitude toward Mathematics prescale scores. In addition, a relatively strong case has been advanced for the use of the MANOVA procedure for the major analysis of this study.
MANOVA Results

The SAS MANOVA procedure yielded output which displayed four multivariate test statistics: the Hotelling-Lawley Trace, Pillai's Trace, Wilks' Criterion, and Roy's Maximum Root Criterion. Because there were two treatment groups (k=2), the four multivariate test statistics provided the same numerical value per main or interaction effect. Table 10 presents the MANOVA results for the present study.

Within-Subjects Results. As can be seen from Table 10, the Achievement x Group x Time and the Achievement x Time interaction effects were nonsignificant at the $\alpha = 0.05$ level of significance. However, the Group x Time interaction and the Time main effect were statistically significant.

Because the Group x Time interaction was statistically significant, a more detailed study of this interaction effect was warranted and necessary for interpretive purposes. The group means (see Table 11) for the Probability test scores (pre and post) were plotted by testing time. Figure 4 presents the graph for the Probability data. Figure 5 presents the graph for the Attitude toward Mathematics data and Figure 6 does the same for the Attitude toward Microcomputers data.

Scheffe's post hoc multiple comparison procedure was used to test for the significance of these means both within and between treatment groups across time. The results of using this procedure on the Probability data were as follows ($\alpha = 0.05$):
TABLE 10

Results for the major 2x2x2 MANOVA Analysis

<table>
<thead>
<tr>
<th>Source</th>
<th>F-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Within Subjects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>64.61</td>
<td>0.0001††</td>
</tr>
<tr>
<td>Group x Time</td>
<td>6.66</td>
<td>0.0005††</td>
</tr>
<tr>
<td>Achievement x Time</td>
<td>2.14</td>
<td>0.0987</td>
</tr>
<tr>
<td>Achievement x Group x Time</td>
<td>0.81</td>
<td>0.4937</td>
</tr>
<tr>
<td><strong>Between Subjects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achievement</td>
<td>6.36</td>
<td>0.0006††</td>
</tr>
<tr>
<td>Group</td>
<td>0.79</td>
<td>0.5040</td>
</tr>
<tr>
<td>Group x Achievement</td>
<td>0.58</td>
<td>0.6355</td>
</tr>
</tbody>
</table>

† Because k=2, the four multivariate test statistics yield the same numerical value.

†† Statistically significant at \( \alpha = 0.05 \)
<table>
<thead>
<tr>
<th>Group</th>
<th>Time</th>
<th>n</th>
<th>Probability</th>
<th>Mathematics Test</th>
<th>Mathematics Attitude</th>
<th>Microcomputers Attitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular</td>
<td>Pre(1)</td>
<td>54</td>
<td>3.98</td>
<td>75.91</td>
<td>43.15</td>
<td></td>
</tr>
<tr>
<td>Experimental</td>
<td>Pre(1)</td>
<td>47</td>
<td>4.15</td>
<td>74.04</td>
<td>41.94</td>
<td></td>
</tr>
<tr>
<td>Regular</td>
<td>Post(2)</td>
<td>54</td>
<td>6.65</td>
<td>77.37</td>
<td>47.35</td>
<td></td>
</tr>
<tr>
<td>Experimental</td>
<td>Post(2)</td>
<td>47</td>
<td>5.98</td>
<td>77.06</td>
<td>51.79</td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 4
Cell Means for Probability Tests
FIGURE 5

Cell Means for Attitude toward Mathematics scales
FIGURE 6
Cell Means for Attitude toward Microcomputers scales
1) Experimental vs. Regular at Time 1 - nonsignificant difference between groups on pretest,
2) Experimental vs. Regular at Time 2 - significant difference between groups on posttest favoring the Regular group,
3) Experimental at Time 1 vs. Experimental at Time 2 - significant difference within group across time favoring Time 2, and
4) Regular at Time 1 vs. Regular at Time 2 - significant difference within group across time favoring Time 2.

The results for the Attitude toward Mathematics data were the following:
1) Experimental vs. Regular at Time 1 - nonsignificant difference between groups on prescale,
2) Experimental vs. Regular at Time 2 - nonsignificant difference between groups on postscale,
3) Experimental at Time 1 vs. Experimental at Time 2 - significant difference within group across time favoring Time 2, and
4) Regular at Time 1 vs. Regular at Time 2 - nonsignificant difference within group across time.

Finally, the results for the Attitude toward Microcomputers data were as follows:
1) Experimental vs. Regular at Time 1 - nonsignificant difference between groups on prescale,
2) Experimental vs. Regular at Time 2 - significant difference between groups on postscale favoring the Experimental group,
3) Experimental at Time 1 vs. Experimental at Time 2 - significant difference within group across time favoring Time 2, and
4) Regular at Time 1 vs. Regular at Time 2 - significant difference within group across time favoring Time 2.

Since the Group x Time interaction was significant and disordinal, the main effect for Time was not formally investigated or interpreted, even though it was significant.

Between-Subjects Results. The between-subjects main effect for Groups and interaction effect for Group x Achievement were nonsignificant and were not investigated further (see Table 10). However, the main effect for Achievement Level was statistically significant ($p = 0.0006$). A significant main effect for Achievement Level means that, when collapsing over Groups and Time, the Achievement Level groupings differ significantly on certain dependent variables. More specifically, the students in the Above Average Achievement Level, on the average, outperformed their counterparts in the Average Achievement Level on the achievement tests and attitude scales across time. Table 12 presents the Achievement Level main effect means.

Included in the SAS MANOVA output was ANOVA data by dependent variables across time.² Table 13 shows that for the Probability tests and the Attitude toward Mathematics scales, the students in the Above Average Achievement Level significantly outperformed those in the Average Achievement Level. However, for the Attitude toward Microcomputers scales the levels did not differ significantly.
### TABLE 12
Main Effect Means for Achievement Level

<table>
<thead>
<tr>
<th>Level</th>
<th>n</th>
<th>Probability</th>
<th>Mathematics Tests</th>
<th>Microcomputer Scales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Average</td>
<td>124</td>
<td>5.46</td>
<td>80.43</td>
<td>45.73</td>
</tr>
<tr>
<td>Average</td>
<td>78</td>
<td>4.78</td>
<td>69.31</td>
<td>46.44</td>
</tr>
</tbody>
</table>

### TABLE 13
ANOVA Results for Achievement Level

<table>
<thead>
<tr>
<th>Source</th>
<th>F-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability</td>
<td>7.66</td>
<td>0.0068†</td>
</tr>
<tr>
<td>Attitude toward Mathematics</td>
<td>8.85</td>
<td>0.0037†</td>
</tr>
<tr>
<td>Attitude toward Microcomputers</td>
<td>0.22</td>
<td>0.6401</td>
</tr>
</tbody>
</table>

† Statistically significant at $\alpha = 0.05$
Further inspection (see Table 14) using Scheffe's post hoc multiple comparisons procedure ($\alpha = 0.05$) showed that the Achievement Levels did not differ significantly on the Probability Pretest, did differ significantly on the Probability Posttest favoring the Above Average Achievement Level, did differ significantly on the Attitude toward Mathematics prescale favoring the Above Average Achievement Level, did differ significantly on the Attitude toward Mathematics postscale favoring the Above Average Achievement Level, did not differ significantly on the Attitude toward Microcomputers prescale, and did not differ significantly on the Attitude toward Microcomputers postscale.

Follow-up Results. Due to the low reliability estimate for the Probability Pretest, a follow-up study was undertaken to determine if this problem would influence the achievement results for the major MANOVA analysis. Therefore, a 2x2 MANOVA, using only the posttest/postscale data, was performed. The results of this analysis were consistent with those of the major MANOVA study. See Table 15 for the follow-up MANOVA statistics.

Measures of Association

In ANOVA, as in MANOVA, a statistically significant result may not necessarily be an important one because small differences may be
TABLE 14
Achievement Level Means by Time

<table>
<thead>
<tr>
<th>Level</th>
<th>Time</th>
<th>n</th>
<th>Probability</th>
<th>Mathematics Test</th>
<th>Mathematics Attitude</th>
<th>Microcomputers Attitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Average</td>
<td>Pre(1)</td>
<td>62</td>
<td>4.18</td>
<td>79.71</td>
<td>42.76</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>Pre(1)</td>
<td>39</td>
<td>3.87</td>
<td>67.62</td>
<td>42.31</td>
<td></td>
</tr>
<tr>
<td>Above Average</td>
<td>Post(2)</td>
<td>62</td>
<td>6.74</td>
<td>81.15</td>
<td>48.69</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>Post(2)</td>
<td>39</td>
<td>5.69</td>
<td>71.00</td>
<td>50.56</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 15
MANOVA Results for the 2x2 Follow-up Study

<table>
<thead>
<tr>
<th>Source</th>
<th>F-value‡</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achievement</td>
<td>6.19</td>
<td>0.0008‡‡</td>
</tr>
<tr>
<td>Group</td>
<td>4.06</td>
<td>0.0093‡‡</td>
</tr>
<tr>
<td>Group x Achievement</td>
<td>0.54</td>
<td>0.6614</td>
</tr>
</tbody>
</table>

† Because k=2, the four multivariate test statistics yield the same numerical value.
‡‡ Statistically significant at \( \alpha = 0.05 \).
statistically significant with large sample sizes. Therefore, measures of association or effect size were developed to appraise the practical significance, not statistical, of a research finding (Kennedy, 1978). A measure of association is used to assess the strength of an effect independent of sample size.

In ANOVA, the most common measure of the strength of association between group membership and a dependent variable is the correlation ratio eta squared. The MANOVA analog is the canonical correlation. Serlin has derived a measure that may be used to estimate the strength of association in the population (Serlin, 1982):

$$
\hat{\eta}^2 = 1 - (1 - \hat{\eta}^2_{\text{mult}}) \left( \frac{N-1}{N-b-1} \right)
$$

where \(N\) is the total sample size,

\(b\) is the larger of \(p\) and \(k-1\), and

\(\hat{\eta}^2_{\text{mult}}\) is the value of the Pillai-Bartlett Trace divided by \(s = \min (k-1, p)\).

\(\hat{\eta}^2_{\text{mult}}\) was calculated for the within and between subjects main and interaction effects. The results were as follows:

1) Time - 66.09% of the variance in the three dependent variables was attributed to the Time variable (67.11%);

2) Group x Time - 14.81% of the variance in the three dependent variables was attributed to Group x Time interaction (17.37%);

3) Achievement x Time - 3.4% of the variance in the three dependent variables was attributed to Achievement x Time interaction (6.33%);
4) Achievement x Group x Time - 0% of the variance in the three dependent variables was attributed to Achievement x Group x Time interaction (2.50%);

5) Achievement - 14.14% of the variance in the three dependent variables was attributed to Achievement (16.72%);

6) Group - 0% of the variance in the three dependent variables was attributed to Group (2.44%);

7) Group x Achievement - 0% of the variance in the three dependent variables was attributed to Group x Achievement interaction (1.79%).

Therefore, it was estimated that in the population 95.04% of the variability in the three dependent variables can be attributed to the statistically significant results of the study, i.e., statistical and practical results were consistent.
NOTES

1 The numbers in parentheses equal the level of significance.

2 With a statistically significant MANOVA main effect, it is permissible to use univariate procedures, such as ANOVA, to determine which treatment group is significantly different on which dependent variables (Kennedy, 1985; Notz, 1986).

3 The sample values are in parentheses.
CHAPTER V
DISCUSSION

This chapter will present an in-depth interpretation of the statistical results of the present study. In addition, a discussion of the limitations of the study will be provided.

Interpretation of the Results

Preliminary Results. Preliminary testing, in the form of two-sample t-tests, was conducted to determine whether the treatment groups were initially statistically nonsignificantly different with respect to the measurements of interest. The same was done for Achievement Level groupings. The findings were as follows:

1) neither the Experimental group nor the Regular group outperformed the other on the Probability Pretest, Attitude toward Mathematics Prescale or the Attitude toward Microcomputers Prescale;

2) students in both the Above Average and Average Achievement Levels performed at the same level of attainment on the Probability Pretest and Attitude toward Microcomputers Prescale; and
3) students in the Above Average Achievement Level exhibited a more positive attitude toward mathematics than their counterparts in the Average Achievement Level at the beginning of the study.

Findings #1 and #2 were anticipated due to the subjects' general lack of experience with the study of probability and the educational uses of microcomputers, plus their general dislike of mathematics. However, based on prior experience with preservice elementary teachers, finding #3 was somewhat surprising. This finding suggests that preservice elementary teachers who performed at the A/B grade level in Math 105 exhibited a more positive reaction to the study of mathematics than their peers who performed at a lower grade level.

It seems reasonable to assume that this result was due in part to the students' mathematics preparation and experiences prior to enrolling in Math 105 and their subsequent mathematics related experience with the Math 105 and 106 content, lecturers, and graduate teaching associates. Regardless of the reasons, this finding was informative and must be seriously considered when interpreting the Achievement Level-related results for the major MANOVA analysis.

Within-Subjects Results. The findings for the within-subjects main and interaction effects were as follows:

1) the Time main effect was significant;
2) the Group x Time interaction effect was significant;
3) there was no significant Achievement x Time interaction effect;
4) there was no significant Group x Time x Achievement interaction effect.

It is customary to interpret interaction effects prior to interpreting main effects and not to pursue a significant main effect when it is involved in a statistically significant interaction effect (Kennedy, 1978). Suffice it to say that, in general, student scores at Time 2 were significantly different, in the positive direction, from those at Time 1.

The significant Group x Time interaction means that in general, treatment groups differed significantly in their responses to the dependent variables over levels of Time 1. For the Probability data, the following were significant findings:

1) the Regular group outperformed the Experimental group on the Probability Posttest;

2) students in the Experimental group improved their Probability test scores from pretest to posttest; and

3) students in the Regular group improved their Probability test scores from pretest to posttest.

Findings #2 and #3 were consistent with the statistical significance of the Time main effect. Regardless of mode of laboratory intervention, students in both the Experimental and Regular groups significantly improved their Probability test scores from pretest to posttest. On an absolute scale, which was researcher-defined as a five-level, equal-interval scale, students in the Regular group went from an average performance ($\bar{X}_{R1} = 3.98$) to a good performance
(\bar{X}_{R_2} = 6.65). Students in the Experimental group went from an average performance (\bar{X}_{E_1} = 4.15) to a good performance (\bar{X}_{E_2} = 5.98). Therefore, students in both treatment groups, in general, increased their knowledge of elementary probability. It seems pedagogically reasonable to assume that these results reflect the commitment of the lecturer and graduate teaching associates in presenting the topic of elementary probability in a clear and understandable manner. In addition, these results might also reflect the students' willingness and desire to work hard to understand this complex and nonintuitive area of mathematics.

Due to the small number of studies in the area of microcomputer-assisted versus activity-based instruction plus the varied results of these studies, it was predicted that the Experimental group would probably outperform the Regular group on the Probability Posttest. Therefore, finding #1 was somewhat surprising.

Even though the students in the Experimental group, in which a semi-abstract approach (i.e., microcomputer-assisted instruction) was used to teach concepts in elementary probability, significantly increased their Probability test scores over Time, the results of the comparison of the two modes of laboratory instruction seem to suggest that a concrete, hands-on, manipulative materials approach is more conducive for the learning of these particular mathematical concepts (finding #1). In other words, when a comparison by treatment groups is
conducted, the students in the present study appear to have the need to physically manipulate the laboratory materials in order to facilitate the learning of concepts in elementary probability.

It may also be the case that this particular experimental microcomputer program in elementary probability is not as effective in promoting the learning of concepts in elementary probability as the use of more traditional manipulative materials, such as dice and colored chips. It is possible that if the program were modified to make it more user-friendly and pedagogically efficient, the results of the achievement portion of this study might be altered.

The low reliability estimates for the Probability Pretest and Posttest are a serious problem and may influence the results and interpretation of the achievement portion of this study. Therefore findings #1, #2, and #3 are presented with caution. A more detailed discussion of this serious reliability problem will be presented in the Limitations section of this chapter.

For the Attitude toward Mathematics data, the only significant finding involved students in the Experimental group. These students significantly improved their attitudes toward mathematics from prescale to postscale. Two explanations may be postulated to account for this result:

1) the Experimental group's exposure to both the LOGO microcomputer laboratory and the microcomputer probability laboratory, and
2) the current teaching and testing philosophy for Math 105 and 106.

Most students, including these preservice elementary teachers, often view mathematics as a dull and boring subject dominated by theorems, postulates, definitions, and formulas. Math 106 offers most of these preservice elementary teachers their first formal exposure to microcomputers in an instructional format and because of this exposure they may see mathematics as current, relevant, dynamic and possibly enjoyable.

Using microcomputers to introduce or reinforce new subject matter, such as elementary probability, may help students to better understand the topic(s) and thereby influence, in a positive direction, their attitude toward mathematics. All of these may be reflected by the scores for the students in the Experimental group on the Attitude toward Mathematics scale (post).

Another reason for this result may be due to the current teaching and testing philosophy for Math 105 and 106. For both courses, solving problems by simply using formulas is no longer the norm. Instead, homework, quiz and examination questions require the students to explain, justify, and, at times, prove their answers. This has a tendency to motivate students to work more diligently and conscientiously and thereby foster an appreciation for the logic, structure and need for the study of mathematics.
Since the students in both the Regular group and Experimental group were exposed to similar conditions, except for the microcomputer probability laboratory, it appears reasonable to assume that there existed a synergistic effect influencing the responses of the Experimental group on the Attitude toward Mathematics scale (post). This would provide a plausible explanation for the difference in the treatment groups' attitudes toward mathematics.

On an absolute scale, which was researcher-defined as a five-level, equal-interval scale, the Regular group's collective attitude toward mathematics remained relatively constant at the neutral level ($\bar{X}_R^1 = 75.91$ to $\bar{X}_R^2 = 77.37$). Even though there was statistical significance across Time for the Experimental group, these students' attitudes, in an absolute sense, did not change dramatically ($\bar{X}_E^1 = 74.04$ to $\bar{X}_E^2 = 77.06$). In other words, their attitude toward mathematics remained constant at the neutral level.

The significant findings for the Attitude toward Microcomputers data were the following:

1) students in the Experimental group exhibited a more positive attitude toward microcomputers at the conclusion of the study than those in the Regular group;

2) students in the Experimental group improved their attitude toward microcomputers from pretest to posttest; and

3) students in the Regular group improved their attitude toward microcomputers from pretest to posttest.
Due to the additional microcomputer experience for the Experimental group, students in this group may have developed a better understanding and appreciation for the impact of microcomputer technology on the teaching and learning of selected topics in mathematics. On a more basic level, these students might simply have enjoyed interacting with the microcomputer, in this nonthreatening learning environment, more than their peers in the Regular group. Both of these reasons may have contributed to the Experimental group's performance on the Attitude toward Microcomputers scale (post).

Findings #2 and #3 were consistent with the statistically significant Time main effect. These findings suggest that any structured laboratory activity dealing with microcomputer-appropriate topics in mathematics will enhance students' attitudes toward the use of microcomputers in an educational setting.

On an absolute scale, which again was researcher-defined as a five-level, equal-interval scale, the Regular group's attitude toward microcomputers went from neutral to good ($\bar{X}_{R1} = 43.15$ to $\bar{X}_{R2} = 47.35$) and the Experimental group's collective attitude went from neutral to good ($\bar{X}_{E1} = 41.94$ to $\bar{X}_{E2} = 51.79$). Therefore, the exposure to microcomputers in an instructional setting had a positive impact on the attitude toward microcomputers for both groups of students. The major reason for this appears to be the ability of microcomputers to replace the stagnant reputation which the study of mathematics seems to possess (at least for these students) with one which fosters excitement and
motivation. The students, in both the Experimental and Regular groups, appeared to enjoy participating in the microcomputer laboratory activities and their responses to the Attitude toward Microcomputers Postscale seem to reflect this enjoyment.

**Between-Subjects Results.** The findings for the between-subjects main and interaction effects were as follows:

1) the Group x Achievement interaction effect was nonsignificant;
2) the Group main effect was nonsignificant; and
3) the main effect for Achievement was significant.

Since the Achievement main effect was statistically significant, a more detailed inspection of this independent variable was warranted. An examination of Tables 13 and 14 provides the following significant findings regarding Achievement Level:

1) the students in the Above Average Achievement Level outperformed their counterparts in the Average Achievement Level on the Probability Posttest; and
2) the students in the Above Average Achievement Level had a more positive attitude toward mathematics than their peers in the Average Achievement Level on the Attitude toward Mathematics scale (pre and post).

Finding #1 may be attributable to the ability of the students in the Above Average Achievement Level to assimilate the lecture and recitation information more efficiently and productively than the students in the Average Achievement Level. Furthermore, because of
their membership in the Above Average Achievement Level, these students may simply work harder, learn more, and perform better on the Probability tests than their counterparts in the Average Achievement Level.

Another consideration which might influence this finding is the low reliability estimates for both the Probability Pretest and Posttest. This problem has the potential to mask the "true" results of the study and thereby alter the interpretation of the significant findings. This problem must be considered when discussing any results and/or findings which involve the Probability tests.

Due to their performance and experiences in Math 105, students in the Above Average Achievement Level may have enjoyed their study of mathematics more than the students in the Average Achievement Level. Their scores on the Attitude toward Mathematics scale (pre) may have reflected this positive feeling. These students may also have had similar positive experiences with their Math 106 lectures, graduate teaching associates, and subject matter which would reinforce their positive attitude toward mathematics and would, in part, explain their continued positive attitude, as measured by the Attitude toward Mathematics scale (post).

Other Considerations

Proposed Model. A search of the literature revealed very little information concerning the magnitude and direction of the relationships...
between mode of laboratory intervention (microcomputers vs. manipulatives) and mathematics achievement and attitude. Therefore, based on the evidence produced by the present study, the proposed model depicting the statistically significant relationships between mode of treatment and the dependent variables of achievement and attitude can be illustrated and described as follows:

![Diagram](image)

Figure 7

1) the students using a traditional activity-based elementary probability laboratory outperformed their peers using a microcomputer-assisted approach; and

2) the students who participated in both microcomputer laboratories (LOGO and probability) had a more positive attitude toward microcomputers than their counterparts who only experienced the LOGO microcomputer laboratory.

Hawthorne Effect. The Hawthorne or novelty effect may have influenced the statistically significant findings mentioned in the previous section. For instance, with regard to the Regular group outperforming the Experimental group on the Probability Posttest, this may have resulted from the possible negative impact of the microcomputers on the Experimental students' ability to focus all their attention on the concepts and relationships emphasized in the laboratory.
activities. These students may have been so involved in and fascinated with the mechanics of interacting with the microcomputer that it diverted much of their concentration away from the important aspects of the probability laboratory, thereby affecting their Probability Posttest scores.

The Experimental group's participation in one more microcomputer laboratory than the Regular group may have had an impact on their attitude toward microcomputers. Due to the additional microcomputer laboratory experience, the students in the Experimental group may have simply enjoyed interacting with the microcomputers and were not necessarily overly cognizant of the actual and/or potential educational use of these machines. In other words, their scores on the Attitude toward Microcomputers scale (post) may have reflected the additional "fun" they had with the microcomputers and not necessarily their feelings concerning the use of the microcomputers in an educational setting.

Aptitude x Treatment Interaction. Cronbach and Snow suggested that a nonsignificant difference between treatment groups is often a sign for a possible significant interaction of the treatments with aptitude measures (Cronbach and Snow, 1977). This implies that treatment differences might be found when students' characteristics, such as their mathematics achievement, are considered. Therefore, Achievement Level was included in the present study as an independent variable.
The findings of this study seem to preclude such an interaction effect. The Treatment Group main effect was nonsignificant, but so was the Group x Achievement interaction effect (see Table 10). Therefore, it seems reasonable to assume that, with the present definition of mathematics achievement, the Aptitude x Treatment Interaction effect was not present in this study.

**Overall Conclusion.** Based on the results of the present study, the inclusion of the experimental microcomputer-based elementary probability laboratory into the official Math 106 syllabus is unwarranted. At least with this group of preservice elementary teachers exposure to the experimental microcomputer laboratory did not enhance the learning of concepts in elementary probability as much as the traditional manipulative materials laboratory. With increased experience with microcomputer-based learning, a replication of this study with similar groups of students could very well result in different conclusions.

**Limitations**

Certain limitations must be explicitly stated in order that the interpretation of the results can be clearly understood.

1) **The low estimate of reliability for the achievement instruments may have affected the results.** The low reliability estimates for the Probability Pretest and Posttest may have influenced the statistical results of the achievement portion of this study. If the reliability
estimates for the Probability tests were substantially higher, the results of the achievement portions of the study might be altered. Therefore, any conclusions drawn from this portion of the study must be viewed with caution and extreme care. In experimental studies using achievement and attitude tests to determine treatment effects, one of the most critical items to remember is to report the reliability of the instruments. Then other researchers can determine for themselves whether they are adequate for any particular purpose.

Due to factors beyond the author's control, a pilot study was not possible. If it had been, probability tests could have been created and modified so as to yield better estimates of reliability and therefore eliminate this serious obstacle to interpretation.

2) The possibility that the basic premise underlying the achievement portion of the study was violated. It is possible that due to the students' familiarity with the use of manipulative materials, students in the Regular group were able to concentrate their efforts on the concepts involved in the conventional probability laboratory while those in the Experimental group had to relearn (based on their LOGO microcomputer laboratory experience) the correct manner in which to react and interact with the microcomputer before focusing on the concepts and relationships being investigated in the laboratory activity. If this were the case, this portion of the study is not comparing the learning of probability (Regular group) to the learning of probability (Experimental group) but instead the learning of probability
(Regular group) to the learning to use the microcomputer and the learning of probability (Experimental Group), thereby, violating the basic premise of the achievement portion of this study.

3) The proposed definition of mathematics achievement may be unwarranted. The final grade in Math 105 may not be the best barometer of the students' mathematics achievement. Unfortunately, no other measures of mathematics achievement were made available to the researcher. In addition, the Department of Mathematics was unable to permit any more than the minimum amount of testing time for this study. Therefore, even if appropriate measures of mathematics and achievement were convenient, sufficient time was not available for administration.

4) The possibility that the assumptions of the multivariate analysis of variance were not satisfied. The MANOVA assumptions are:
   a) subjects are randomly sampled from the population of interest;
   b) observations are statistically independent of each other;
   c) dependent variables have a multivariate normal distribution within each group; and
   d) the two groups have a common within-group population covariance matrix.

For this study it was assumed that the students were randomly sampled from the population of preservice elementary teachers. However, due to scheduling constraints, these students were not randomly assigned to treatment groups.
In repeated measures designs, multiple measures on each subject are collected at different times using the same dependent variable at each time. According to Bray and Maxwell, these dependent variables can be viewed as separate variables statistically and tested using the multivariate analysis of variance procedure without violating the independence of observation assumption (Bray and Maxwell, 1985).

A number of Monte Carlo studies have been conducted to investigate the extent to which MANOVA is robust to violations of multivariate normality and equality of covariance matrices (e.g., Ito, 1969; Mardia, 1971; Olson, 1974). The results of these studies indicate that departures from multivariate normality and equality of covariance matrices have only slight effects on the Type I errors of the MANOVA test statistics.

Since the MANOVA assumptions were not strictly satisfied, it is possible that the MANOVA procedure could yield biased results. Therefore, this potential threat to the integrity of the statistical results must be considered when interpreting the results of the MANOVA procedure.

5) The possibility that the length of the treatment condition may have affected the results of the study. Since each of the treatment conditions was only sixty minutes in duration, it is possible that this was insufficient time to adequately determine a treatment effect. If additional time had been allotted for the laboratory activities, the results of this study might have been altered.
6) The possibility that the sex of the majority of the subjects of the study influenced the results of the study. Ninety-two percent of the subjects of this study were female (see Table 1). If the ratio of males to females had been nearly equal or if the subjects had been predominately male, the results of this study might have been altered.

7) The possibility that errors were introduced through factors which could not be experimentally controlled. It was assumed that the assignment of subjects to intact classrooms was random, when in reality it was subject to the constraints of the University's registration process. In addition, due to logistical reasons, the students could not be randomly assigned to treatment groups.

Another major difficulty was the lack of control for the teacher variable. The researcher had virtually no control over the degree of enthusiasm or the teaching techniques of the graduate teaching associates assigned to the various sections of Math 106. In addition, it is possible that the teaching associates did not ensure that the subjects of the study actively participated in the laboratory activities. If the subjects only reacted passively to the treatment conditions, the results of the study may have been biased.

Other possible sources of error could have arisen from differential mortality, class times and rooms in which the lecture and recitation sections met, the quarter in which the experiment took place, and the dependence on student-supplied data. However, no known bias was introduced due to these factors.
NOTES

1 See Figures 4, 5, and 6 on pages 75, 76, and 77.

2 For the Probability tests, the absolute scales were defined as follows:

<table>
<thead>
<tr>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>very good</td>
<td>very good</td>
</tr>
<tr>
<td>7 ≤ x ≤ 8</td>
<td>7.8 ≤ x ≤ 9.00</td>
</tr>
<tr>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>5 ≤ x &lt; 7</td>
<td>5.6 ≤ x &lt; 7.8</td>
</tr>
<tr>
<td>average</td>
<td>average</td>
</tr>
<tr>
<td>3 ≤ x ≤ 5</td>
<td>3.3 ≤ x ≤ 5.6</td>
</tr>
<tr>
<td>poor</td>
<td>poor</td>
</tr>
<tr>
<td>1 ≤ x ≤ 3</td>
<td>1.1 ≤ x ≤ 3.3</td>
</tr>
<tr>
<td>failing</td>
<td>failing</td>
</tr>
<tr>
<td>0 ≤ x ≤ 1</td>
<td>0.0 ≤ x ≤ 1.1</td>
</tr>
</tbody>
</table>

3 For the Attitude toward Mathematics scales, the absolute scale was defined as follows:

<table>
<thead>
<tr>
<th>Attitude</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>very good</td>
<td>-117 ≤ x ≤ 130</td>
</tr>
<tr>
<td>good</td>
<td>91 ≤ x &lt; 117</td>
</tr>
<tr>
<td>neutral</td>
<td>65 ≤ x &lt; 91</td>
</tr>
<tr>
<td>poor</td>
<td>39 ≤ x &lt; 65</td>
</tr>
<tr>
<td>very poor</td>
<td>26 ≤ x &lt; 39</td>
</tr>
</tbody>
</table>

4 For the Attitude toward Microcomputers scales, the absolute scale was defined as follows:

<table>
<thead>
<tr>
<th>Attitude</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>very good</td>
<td>58.5 ≤ x ≤ 65.0</td>
</tr>
<tr>
<td>good</td>
<td>45.5 ≤ x &lt; 58.5</td>
</tr>
<tr>
<td>neutral</td>
<td>32.5 ≤ x &lt; 45.5</td>
</tr>
<tr>
<td>poor</td>
<td>19.5 ≤ x &lt; 32.5</td>
</tr>
<tr>
<td>very poor</td>
<td>13.0 ≤ x &lt; 19.5</td>
</tr>
</tbody>
</table>

5 The probability test questions were written to reflect the material emphasized in the probability laboratories.

6 The additional laboratory was the experimental microcomputer probability laboratory.

7 For this study, the students' mathematics aptitude was defined to be their achievement in Math 105 which was defined as their final grade in Math 105.

8 As a general rule, estimates of reliability should not be less than 0.80. At this level, correlations are attenuated very little by random measurement error.

9 If more appropriate indicators of mathematics achievement were used, the results of the achievement-related portions of this study might be altered.
Chapter VI presents a concise summary of the results of the present study plus recommendations for further research.

Summary of MANOVA Results

Nonsignificant Results. The following within-subjects effects were statistically nonsignificant at the 0.05 level of significance:

1) the Achievement x Time interaction; and
2) the Achievement x Group x Time interaction.

The following between-subjects effects were statistically nonsignificant at the 0.05 level of significance:

1) the Group main effect; and
2) the Group x Achievement interaction.

Significant Results. The Time main effect and the Group x Time interaction effect were the within-subjects outcomes that were statistically significant (α = 0.05). Since the Group x Time interaction was significant, the Time main effect was not investigated further. The results for the Group x Time interaction effect were as follows (α = 0.05):
I. Probability Data

1) nonsignificant difference between treatment groups on pretest;
2) significant difference between treatment groups on posttest favoring the Regular group;
3) significant difference within the Experimental group across Time favoring the posttest; and
4) significant difference within the Regular group across Time favoring the posttest.

II. Attitude toward Mathematics Data

1) nonsignificant difference between treatment groups on prescale;
2) nonsignificant difference between treatment groups on postscale;
3) significant difference within the Experimental group across Time favoring the postscale; and
4) nonsignificant difference within the Regular group across Time.

III. Attitude toward Microcomputers Data

1) nonsignificant difference between treatment groups on prescale;
2) significant difference between treatment groups on postscale favoring the Experimental group
3) significant difference within the Experimental group across Time favoring the postscale; and
4) significant difference within the Regular group across Time favoring the postscale.
The only statistically significant between-subjects effect was the Achievement Level main effect ($\alpha = 0.05$). The results for this main effect were the following ($\alpha = 0.05$):

1) the levels did not differ significantly on the Probability Pretest;
2) the levels did differ significantly on the Probability Posttest, favoring the Above Average Achievement Level;
3) the levels did differ significantly on the Attitude toward Mathematics prescale, favoring the Above Average Achievement Level;
4) the levels did differ significantly on the Attitude toward Mathematics postscale, favoring the Above Average Achievement Level;
5) the levels did not differ significantly on the Attitude toward Microcomputers prescale; and
6) the levels did not differ significantly on the Attitude toward Microcomputers postscale.

Null Hypotheses Results. With regard to the major null hypotheses (see pages 41 and 42), the results of this study indicate that

1) hypotheses #1 was rejected in favor of the Regular group,
2) hypotheses #2 was retained, and
3) hypotheses #3 was rejected in favor of the Experimental group.

For the secondary null hypotheses dealing with Achievement Level groupings (see page 42),

1) hypotheses #1 was rejected in favor of the students in the Above Average Achievement Level,
2) hypotheses #2 was rejected in favor of the students in the Above Average Achievement Level, and
3) hypotheses #3 was retained.

Recommendations for Further Research

Limitations of this study were discussed in the previous chapter. The most serious of these limitations was the low reliability estimates for the Probability Pretest and Posttest. It would be profitable to consider the present study a pilot study and repeat the experiment with similar subjects (Math 106 students) and with more reliable ($\alpha \geq 0.80$) probability tests. With these considerations in mind, additional recommendations for further research can be made.

1) Redefine mathematics achievement and replicate the study. The mathematics portion of the SAT or ACT test or any other relevant test could be used to determine the students achievement level in mathematics. The students could then be designated as having Average or Above Average mathematics achievement accordingly.

2) Replicate the study using subjects in various grade/age-levels and institutions. Researchers could repeat the experiment with elementary, middle and/or high school students attending the same or different school districts. Replicating the study using incarcerated youths may also be viable. In addition, the study could be replicated with various groups of college students at Ohio State or other universities and colleges.
3) Replicate the study using different mathematical topics which are pedagogically amenable to the utilization of microcomputers and MCAI. Instead of elementary probability, topics in geometry, trigonometry, estimation and statistics could be used as the basis for determining treatment group differences.

4) Increase the amount of computer experience for both treatment groups in order to decrease the novelty of using the machines. As stated previously, the novelty of using the microcomputer to learn the concepts and relationships in the probability laboratory may have contributed to the Experimental group's performance on the Probability Posttest. Therefore, to alleviate this problem due to inexperience, additional computer work, in the form of laboratory activities, should be incorporated into the study.

5) Modify the experimental microcomputer program and replicate the study with a similar group of students and conditions. Add a self-monitoring subroutine to the experimental microcomputer program so that the subjects are forced to complete the laboratory activities without merely pressing the return bar.

In conclusion, the author recognizes that there were cases in which the treatment employed in this study yielded significant differences, but that the interpretation of these findings was based largely on the definition of the variables, the quality of the experimental microcomputer program and the particular instruments used in the study.
APPENDICES
APPENDIX A

Use spaces 1 through 14 to mark your answers to this instrument.

STUDENT INFORMATION SHEET

Department of Mathematics

1) Age:
   a) 18-19   b) 20-21   c) 22-23   d) 24-25   e) 26 and over

2) College:
   a) UVC   b) Education   c) Arts & Sciences   d) Other

3) Year in College:
   a) Freshman   b) Sophomore   c) Junior   d) Senior
       e) Graduate or other

4) Did you transfer to Ohio State from some other college or university?
   a) Yes   b) No

5) How many years of high school mathematics (starting with Algebra I) have you taken?
   a) 1   b) 2   c) 3   d) 4   e) 5 or more

6) What was your average grade in high school mathematics:
   a) A   b) B   c) C   d) D   e) F

7) Which statement best describes the college mathematics courses you have taken at OSU?
   a) have taken only Math 105
   b) have taken both Math 102 and Math 105
   c) have taken math courses in addition to Math 102 and/or Math 105
8) Grade in Math 105 or its equivalent:
   a) A, A-   b) B+, B   c) B-, C+   d) C, C-   e) other

9) Number of times you have taken Math 106:
   a) this is the first time
   b) this is the second time
   c) this is the third or more time

10) Have you taken a high school mathematics or science course which used microcomputers as instructional aids?
    a) Yes   b) No

11) Have you taken a college mathematics or science course which used microcomputers as instructional aids?
    a) Yes   b) No

12) Have you had any experience programming a microcomputer?
    a) Yes   b) No

13) Indicate the extent to which you have studied probability in high school:
    a) not at all
    b) part of a mathematics or science course
    c) entire course in probability

14) Indicate the extent to which you have studied probability in college:
    a) not at all
    b) part of a mathematics or science course
    c) entire course in probability
APPENDIX B

Use spaces 85 through 96 to mark your answers to this instrument.

PROBABILITY PRETEST

Directions: Mark all answers on the separate answer sheet. Mark only one answer for each question. Please use a pencil and completely erase mistakes. Choose the letter which represents the best choice for the answer to the question. Please do the best you can. Be assured that this test will in no way affect your grade in Math 106.

*85) A box contains six white roses and nine red roses. Two roses are drawn simultaneously from the box. What is the probability that both are white?
   a) 15/210  b) 36/225  c) 30/210  d) 81/225  e) 72/210

86) A card is drawn from an ordinary deck of 52 cards. What is the probability that it is red or an ace (or both)?
   a) 4/52  b) 17/52  c) 26/52  d) 28/52  e) 30/52

87) If a fair coin has shown "Heads" in 6 consecutive tosses, the probability that the next toss will be "Heads" is
   a) 1/2  b) greater than 1/2  c) less than 1/2  d) 0  e) none of the above

*88) If a fair coin is flipped 10 times, the probability of 10 "Heads" is closest to which of the following?
   a) 0  b) .001  c) .01  d) 0.1  e) 1

89) If two 12-sided dice (each containing faces numbered 1 to 12) are rolled, the most likely sum is
   a) 7  b) 9  c) 12  d) 24  e) none of the above

Decide whether each of the following is True or False. Mark a) for true  
b) for false

*90) If the probability an event does occur is 0.4, then the probability that the event does not occur is 0.6.
91) If a whole number from 1 to 5 inclusive is selected randomly, the probability it is odd is 1/2.

92) If two 12-sided dice are thrown, the probability of obtaining a pair is 1/12.

*93) If one 12-sided die (singular for dice) is thrown, the probability of obtaining a number greater than 6 equals the probability of obtaining a number less than 6.

94) If you roll one 6-sided die 600 times, you would expect to get a "5" about 100 times.

95) If two 6-sided dice are rolled, the probability of getting a sum of 8 is greater than the probability of getting a sum of 5.

96) If the spinner shown below is spun twice, the probability of obtaining a 4 at least one time is 0.5.

* - Indicates items that were deleted after item-analysis.
APPENDIX C

Use spaces 21 through 46 to mark your answers to this instrument.

ATTITUDE TOWARD MATHEMATICS*

Form B

Marilyn N. Suydam
Cecil R. Trueblood

This is to find out how you feel about mathematics. You are to read each statement carefully and decide how you feel about it. Then indicate your feeling on the answer sheet by marking:

A - if you strongly agree
B - if you agree
C - if your feeling is neutral
D - if you disagree
E - if you strongly disagree

BE ASSURED THAT THIS TEST WILL IN NO WAY EFFECT YOUR GRADE IN MATH 106

21) Mathematics often makes me feel angry.
22) I usually feel happy when doing mathematics problems.
23) I think my mind works well when doing mathematics problems.
24) When I can't figure out a problem, I feel as though I am lost in a mass of word and numbers and can't find my way out.
25) I avoid mathematics because I am not very good with numbers.
26) Mathematics is an interesting subject.
27) My mind goes blank and I am unable to think clearly when working mathematics problems.
28) I feel sure of myself when doing mathematics.
29) I sometimes feel like running away from mathematics problems.
30) When I hear the word mathematics, I have a feeling of dislike.
31) I am afraid of mathematics.
32) Mathematics is fun.
33) I like anything with numbers in it.
34) Mathematics problems often scare me.
35) I usually feel calm when doing mathematics problems.
36) I feel good toward mathematics.
37) Mathematics tests always seem difficult.
38) I think about mathematics problems outside of class and like to work them out.
39) Trying to work mathematics problems makes me nervous.
40) I have always liked mathematics.
41) I would rather do anything else than do mathematics.
42) Mathematics is easy for me.
43) I dread mathematics.
44) I feel especially capable when doing mathematics problems.
45) Mathematics class makes me look for ways of using mathematics to solve problems.
46) Time drags in a mathematics lesson.

* The post attitude scale used NCS answer spaces 121-146.
APPENDIX D

Use spaces 101 and 113 to mark your answers to this instrument.

ATTITUDE TOWARD MICROCOMPUTERS*

Richard M. Krach

This is to find out how you feel about microcomputers. You are to read each statement carefully and decide how you feel about it. Indicate your feeling on the answer sheet by marking:

A - if you strongly agree
B - if you agree
C - if your feeling is neutral
D - if you disagree
E - if you strongly disagree

BE ASSURED THAT THIS TEST WILL IN NO WAY EFFECT YOUR GRADE IN MATH 106

101) Microcomputers are fun.
102) Microcomputers are interesting.
103) Microcomputers often make me feel uneasy.
104) I like microcomputers.
105) When I hear the word microcomputer, I experience a feeling of dislike.
106) I am afraid of microcomputers.
107) I would enjoy taking a class which uses microcomputers.
108) I feel good about microcomputers.
109) I avoid using microcomputers because I am not very good with machines.
110) Microcomputers scare me.
111) Thinking about using microcomputers makes me nervous.
112) I am excited about microcomputers.
113) I would rather use a microcomputer to solve problems than paper and pencil.

* The post attitude scale used NCS answer spaces 151-163.
APPENDIX E

Use space 171 through 182 to mark your answers to this instrument.

PROBABILITY POSTTEST

Directions: Mark all answers on the separate answer sheet. Mark only one answer for each question. Please use a pencil and completely erase mistakes. Choose the letter which represents the best choice for the answer to the question. Please do the best you can. Be assured that this test will in no way affect your grade in Math 106.

171) A box contains six white roses and nine red roses. Two roses are drawn simultaneously from the box. What is the probability that both are white?
   a) 15/210  b) 36/225  c) 30/210  d) 81/225  e) 72/210

*172) A card is drawn from an ordinary deck of 52 cards. What is the probability that it is red or an ace (or both)?
   a) 4/52  b) 17/52  c) 26/52  d) 28/52  e) 30/52

173) If a fair coin has shown "Heads" in 6 consecutive tosses, the probability that the next toss will be "Heads" is
   a) 1/2  b) greater than 1/2  c) less than 1/2  d) 0  e) none of the above

174) If a fair coin is flipped 10 times, the probability of 10 "Heads" is closest to which of the following?
   a) 0  b) .001  c) .01  d) 0.1  e) 1

175) If two 12-sided dice (each containing faces numbered 1 to 12) are rolled, the most likely sum is
   a) 7  b) 9  c) 12  d) 24  e) none of the above

Decide whether each of the following is True or False. Mark
   a) for true
   b) for false

176) If the probability an event does occur is 0.4, then the probability that the event does not occur is 0.6.
177) If a whole number from 1 to 5 inclusive is selected randomly, the probability it is odd is $\frac{1}{2}$.

*178) If two 12-sided dice are thrown, the probability of obtaining a pair is $\frac{1}{12}$.

179) If one 12-sided die (singular for dice) is thrown, the probability of obtaining a number greater than 6 equals the probability of obtaining a number less than 6.

180) If you roll one 6-sided die 600 times, you would expect to get a "5" about 100 times.

181) If two 6-sided dice are rolled, the probability of getting a sum of 8 is greater than the probability of getting a sum of 5.

*182) If the spinner shown below is spun twice, the probability of obtaining a 4 at least one time is 0.5.

* - Indicates items that were deleted after item-analysis.
APPENDIX F

MATH 106
SPRING 1985

PROBABILITY LAB

DIRECTIONS: Though you will be working on the computer you should still fill out a lab sheet like you usually do. This way you will have a record of the lab. The computer program will occasionally indicate you should write on the lab sheet, but you may want to take notes at other times.

A few things to remember...

A. Please do as directed in the program. Don't anticipate!
B. Only type when directed to do so.
C. Always hit <RETURN> when you're finished typing something.
D. Distinguish between numbers and letters.
   Don't use L for 1.
   Don't use 0 for 0.
E. If you have difficulty, ask the Instructor for help.

QUESTIONS

1. When you see something like @@@@ LAB SHEET NUMBER1 @@@@@ it refers to one of the questions on this sheet. This time was just for practice. There's nothing to write.

2. Using a pair of 6-sided dice, what is
   a. the largest possible sum?
   b. the smallest possible sum?

3. a. List all the ways to get a sum of 5 with two ordinary dice.
   (consider 1 + 4 and 4 + 1 to be different.)
   b. How many ways are there?
4. Complete the first two columns of this table:

<table>
<thead>
<tr>
<th>Possible sums</th>
<th>Number of ways sum can occur</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

5. Fill in the third column of the previous table.

6. If in a Monopoly game you want to land on Boardwalk, where do you hope to be in the previous turn?

7. Suppose now that we toss a pair of 12-sided dice.
   a. QUESTION 1: How many ways are there to get a sum of 13.

   b. QUESTION 2: How many possible outcomes are there? (As before, consider 1 + 4 and 4 + 1 to be different.)

   c. QUESTION 3: What is the probability of getting a sum of 13?

8. Make a table for 12-sided dice similar to the one you made for 6-sided dice.
APPENDIX G

MATH 106 Equipment: Apple IIe Computers
Terrapin Logo Language disks

Laboratory 2: Microcomputer Logo

1. Preliminaries

A. To boot Logo

REMEMBER: NEVER INSERT OR REMOVE A DISK WHEN THE RED LIGHT ON
THE DISK DRIVE IS ON !!!!!
HANDLE DISKS ONLY BY THE LABEL. BE ESPECIALLY
CAREFUL NOT TO TOUCH THE OPEN SLOT

IF THE MACHINE IS OFF:

1. If the red light is on, hold down the <CONTROL> key and
press <RESET>. Otherwise go to Step 2.
2. Insert the disk into the disk drive. Close the door.
3. Turn the computer on (around the back, left side).
4. Turn the monitor on.
5. When the red light is off, remove the disk and place it
in the paper sleeve.

IF THE MACHINE IS ON:

1. If the red light is on, hold down the <CONTROL> key and
press <RESET>. Otherwise go to Step 2.
2. Insert the disk into the disk drive. Close the door.
3. Hold down the <CONTROL> and < > with your left hand.
Touch <RESET> with your right hand.
4. When the red light is off, remove the disk and place it
in the paper sleeve.

B. Things to remember when doing Logo.

1. The <CAPS LOCK> key must be down.
2. Be sure you type the numerals 0 and 1 or the letters 0 and I
according to context.
3. Spaces are important. The results of typing FORWARD 100 and
typing FORWARD100 are not the same.
4. Type brackets, parentheses, and quotes as shown. For
example, in typing REPEAT 3 [PRINT "HI", do not substitute
parentheses for brackets, do not add extra quotation marks.
Do not use the shift key when typing brackets.
5. When you are finished typing a line, hit the <RETURN> key.
C. To correct errors

1. Use <leftrightarrow> and <→> (but not <↑> and <↓>) to move the cursor. Use the <ESC> key to erase the character to the left of the cursor.

2. Describe what happens for each set of commands. Do the problems in the order given.

   a) DRAW
      FORWARD 100
      RIGHT 90
      FORWARD 20

   b) DRAW
      FORWARD 100
      RT 90
      FD 20

   c) DRAW
      FD 100
      LT 270
      FD 20

   d) DRAW
      BACK 30
      BK 50

   e) DRAW
      FORWARD 58
      FORWARD 19

   f) DRAW
      FORWARD 58
      BACK 19

   g) DRAW
      FD 1
      HOME
      PENCOLOR 0
      FORWARD 100
      PENCOLOR 1
      FULLSCREEN
      SPLITSCREEN

   i) DRAW
      PENUP
      FORWARD 50
      PENDOWN
      FORWARD 50

3. (Repeat) Tell what happens for each. Remember to use square brackets.

   a) REPEAT 3 [PRINT "HI"]

   b) REPEAT 4 [FD 75 RT 90]

   c) DRAW
      REPEAT 360 [FD 1 RT 1]

   d) DRAW
      REPEAT 180 [FD 1 RT 2]

   e) DRAW
      REPEAT 90 [FD .5 RT 2]

   f) DRAW PU
      LT 90 FD 100 PD
      FD 20 RT 90 FD 58 PU
      BK 98 LT 90 BK 69 PD
      REPEAT 180 [FD 1 RT 2]

   g) Finish what was started in part (f) by making the word LOOT.
4. Use FORWARD and RIGHT to draw
   
   a) a square with side 50.
   b) a rectangle with sides of 20 and 60.
   c) an equilateral triangle with side 100.
   d) a regular hexagon with side 62.
   e) a regular pentagon with side 37.
   f) a regular decagon with side 30.
   g) a "house" like this:

   ![House Diagram]

   h) a shape of your choice.

If time permits...

(Numerical commands) Tell what happens for each:

a) PRINT 84 * 57

   PRINT 2 + 3 * 4 (Does LOGO do the addition or multiplication first?)

   PRINT 21/2
   PRINT QUOTIENT 21 2
   PRINT REMAINDER 21 2
   PRINT ROUND 8.6
   PRINT INTEGER 8.6
   PRINT SQRT 25
MATH 106

Equipment: 6-sided dice (2 dice of different colors for each student); 12-sided dice (for use in groups) brown bags, chips

Laboratory 7: Probability

1. Sums of 2 dice

A. Experiment

Roll 2 dice and record their sum. Perform this experiment 20 times, record your outcomes, put your results together with a partner's, and summarize below what the outcomes were and how often they occurred.

B. Analysis

We can compute the probability of each outcome in this experiment. List below all the possible outcomes and how many ways each can occur. Realizing that the number of ways 2 dice can fall is $6 \times 6 = 36$, give the probability of each outcome.

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<th>Possible sums</th>
<th>Number of ways sum can occur.</th>
<th>Probability</th>
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Are you surprised that your experiment in A turned out like it did? ________________________________
C. Application

If in a Monopoly game you want to land on Boardwalk, where do you hope to be in the previous turn?

D. Experiment

Repeat the experiment in A, this time using 12-sided dice. Summarize your results below.

E. Analysis

Compute the probability of each possible outcome in part D.

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Did the experiment in D have the results you would expect?
2. Brown Bag Experiment

Each of the 3 students should use a brown bag with 20 chips. Do not look inside the bag. Draw a chip and record its color; put the chip back in the bag. Do this 10 times, each time stirring the chips before drawing.

A. How many of each color did you get in 10 draws?

B. What is your best guess about the colors of the chips in the bag after 10 draws? (What colors are there? How many of each?)

C. Repeat the above process 10 more times. How many of each color did you get in 20 draws?

D. What is your best guess about the colors of the chips in the bag after 20 draws?

E. Your instructor will summarize the results for the class. Based on the results for the class, what is your best guess about the colors of the chips in the bag? (All bags have identical contents.)

F. AFTER the class discussion and AFTER you have done part E, examine the contents of your bag. How did your guess in part E compare with the actual contents of the bag?

G. Please replace the chips in the envelopes, stir, and tie them shut.
BIBLIOGRAPHY

Adkins, J.E. An Historical and Analytical Study of the Tally, the Knotted Cord, the Fingers, and the Abacus. Dissertation Abstracts 6, 1956, 2083.


CONDUIT. P.O. Box 388, Iowa City, IOWA. 52244. 1983.


Kleinhaus, R. A Development of Materials to be Used in a Laboratory Approach to a Mathematics Content Course for Pre-Service Elementary Teachers and the Effects of this Approach on Achievement and Attitude. Dissertation Abstracts 37A, 1977, 5758.


Mardia, K.V. "The Effects of Nonnormality on Some Multivariate Tests and Robustness to Nonnormality in the Linear Model." Biometrika 58 (1971) 105-121.

MicroSift Computer Technology Program. Northwest Regional Educational Laboratory, 710 S.W. Second Street, Portland, OR. 98204. 1983.


Schlechty, E.J. Personal Communication. 1984


